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THE NATION'S WATER RESOURCES 1975-2000

Volume 1: Summary

Second National Water Assessment by the U.S. Water Resources Council

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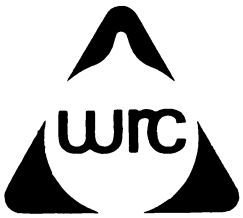

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The Nation's Water Resources—1975-2000

Volume 1: Summary
Volume 2: Water Quantity, Quality, and Related Land Considerations
Volume 3: Analytical Data
Volume 4: Water Resources Regional Reports

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UNITED STATES WATER RESOURCES COUNCIL

SUITE 800 • 2120 L STREET, NW WASHINGTON, DC 20037

JAN 25 1979

Dear Mr. President:

I am pleased to submit the Second National Water Assessment, prepared under the authority of the Water Resources Planning Act of 1965, Public Law 89-80.

This National Assessment presents for the first time nationally consistent current and projected water use and supply information by region and subregion for the entire United States. This information will provide basic data for the Administration and the Congress to decide water policy and program direction.

Information contained in this Assessment provides a basis to initiate those water resources actions needed to help alleviate the Nation's serious water and related land resources problems. Water management problems occur in varying single and multiple forms -- water quality, water quantity, flooding, erosion, loss of wetlands, drainage, dredging, filling, and preservation of fish and wildlife habitat.

The National Assessment has already proven useful in documenting the extent of the serious 1977 western drought; implementing water policy reforms concerning water conservation, ground water supply and instream flow requirements; and directing water research.

Because it is important that sound and consistent data be used to formulate water policy, I recommend that you transmit this report to the Congress for use in its deliberations on this most important resource.

Sincerely yours,

Cecil D. Andrus
Chairman

The President
The White House
Washington, D.C. 20500

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GLOSSARY AND CONVERSION TABLE

Definitions of terms as used in the Second National Water Assessment

"1975"—base year for the Second National Water Assessment data; it represents assumed average conditions and quotation marks are used throughout to indicate that the 1975 data are not actual data.

1985—10-year date from the base year "1975" for which water supply, water use, and other assessment data are projected.

2000—25-year date from the base "1975" year for which water supply, water use, and other assessment data are projected.

aquifer—an underground formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

base year or base conditions data—data based on typical conditions of fresh-water use compared to long-term average fresh-water supply; for the second assessment, the base year is "1975" with projections for 1985 and 2000.

bgd—billion gallons per day.

consumption—portion of water withdrawn for offstream uses and not returned to a surface- or ground-water source.

cropland—land used for agriculture but not in permanent pasture, native hayland, rangeland, or woodland.

evaporation (net)—limited to evaporation from manmade reservoirs that have more than 5,000 acre-feet usable storage capacity and from farm and stock ponds; if rainfall exceeds evaporation, value is zero.

functional water use—category of offstream use of water (e.g. domestic, commercial, manufacturing, agriculture, steam electric generation, minerals industry).

gcd—gallons per capita per day.

ground-water overdraft—that part of the ground-water withdrawals which exceeds recharge; sometimes referred to as ground-water mining.

ground-water mining—*see* ground-water overdraft.

mgd—million gallons per day.

overdraft—*see* ground-water overdraft.

percent streamflow exceedance—a statistical estimate of probability of flow. For example, a 5-percent exceedance flow will be exceeded only in about 5 years of a 100-year period and represents a year with very high streamflows. A 95-percent exceedance flow will be exceeded in about 95 years of a 100-year period and represents a year with very low streamflows.

region—water resources region as designated by the U.S. Water Resources Council; there are 21 regions—18 in the conterminous United States and one each for Alaska, Hawaii, and the Caribbean.

subregion—subdivision of a region; there are 106 subregions used exclusively in the Second National Water Assessment.

withdrawal—water taken from a surface- or ground-water source for offstream use.

CONVERSION TABLE FOR WATER-MEASUREMENT TERMS

QUANTITY	
1 acre-foot	= 325,851 gallons
	= 43,560 cubic feet
1 million gallons	= 3.07 acre-feet
1 cubic foot	= 7.48 gallons
FLOW	
1 million gallons per day (mgd)	= 694.4 gallons per minute
	= 1.55 cubic feet per second
	= 1,120 acre-feet per year
1 billion gallons per day (bgd)	= 1.12 million acre-feet per year
1 cubic foot per second	= 1.98 acre-feet per day

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CONTENTS

Chairman's transmittal letter
U.S. Water Resources Council members
Glossary and conversion table

Highlights ---------- 1
Introduction ---------- 5
Second National Water Assesment in brief ---------- 6
Organization of the assessment report ---------- 6
Water resources regions ---------- 8
Limitations of the assessment data ---------- 8
Water supply ---------- 11
Water budget ---------- 12
Surface water ---------- 14
Ground water ---------- 18
Conservation and augmentation ---------- 21
Overview ---------- 24
Water use ---------- 27
Offstream use ---------- 28
Domestic and commercial ---------- 32
Manufacturing ---------- 34
Agriculture ---------- 36
Energy production ---------- 38
Minerals industry ---------- 40
Instream use ---------- 42
Fish and wildlife ---------- 43
Outdoor recreation ---------- 44
Hydroelectric generation ---------- 46
Navigation ---------- 47
Overview ---------- 48
Identification of critical problems ---------- 51
Analysis of supply and use ---------- 52
Quantity problems:
Inadequate surface-water supply ---------- 56
Overdraft of ground water ---------- 58
Quality problems:
Pollution of surface water ---------- 60
Pollution of ground water ---------- 64
Quality of drinking water ---------- 66
Related land problems:
Flooding ---------- 68
Erosion and sedimentation ---------- 70
Dredging and disposal of dredged material (dredge and fill) ---------- 72
Wet-soils drainage and wetlands ---------- 74
Degradation of bay, estuary, and coastal waters --- 76
Overview ---------- 78
Policy implications ---------- 79
Acknowledgments ---------- inside back cover

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TABLES

Streamflow frequency ---- 15
Ground-water withdrawals and percentage of overdraft ---- 18
Fresh- and saline-water withdrawals ---- 25
Fresh-water withdrawals and consumption by functional use—
- All functional uses ---- 29
- Domestic and commercial ---- 33
- Manufacturing ---- 35
- Irrigation ---- 37
- Steam electric generation ---- 39
- Minerals industry ---- 41

Outdoor recreation activity occasions dependent on or enhanced by water -- 45
Total fresh-water withdrawals and consumption ---- 48
Summary of fresh-water supply and use ---- 54

ILLUSTRATIONS

Map showing—
- Water resources regions ---- 5
- Water resources subregions ---- 9
- Water budget of the conterminous United States ---- 12
- Average annual precipitation ---- 16
- Average annual runoff ---- 16
- Major aquifers ---- 19

by subregion
- Instream-flow approximations for fish and wildlife ---- 43
- Total fresh-water withdrawals and consumption ---- 49
- Water withdrawals by functional use ---- 50
- Dominant functional use ---- 50
- Inadequate surface-water supply and related problems ---- 57
- Ground-water overdraft and related problems ---- 59
- Surface-water pollution problems —
  - Point sources (municipal and industrial waste) ---- 61
  - Nonpoint sources (dispersed) ---- 62
  - Eutrophication ---- 63
- Ground-water pollution problems ---- 65
- Quality of drinking water problems ---- 67
- Flooding problems ---- 69
- Erosion and sedimentation problems ---- 71
- Coastal and inland waterways with dredge and fill problems ---- 73
- Wet-soils drainage and wetlands problems ---- 75
- Bay, estuary, and coastal water problems ---- 77

Figure showing—
- Information flow for the Second National Water Assessment ---- 7
- Total fresh-water withdrawals and consumption, by functional use --- 30
- Water-supply adequacy analysis model ---- 52

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HIGHLIGHTS

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Overview

The Second National Water Assessment shows that in the past decade significant achievements have been made in preserving water and harnessing its power. Although interest in water conservation and environmental protection is growing, still greater efforts are needed. Without intensified dedication to careful management of water resources, pressures from our technological society will continue to deplete and degrade the Nation's water supply.

The many water and related land problems are complex, and any attempt to solve these problems is hampered by competing forces with legitimate interests. No easy answer to the many varied problems exists, and the findings of the second assessment are not free of conflict. The information presented here, much of it available for the first time, will contribute to the planning and decisionmaking that will lead to adequate resolution of the more critical water-management problems.

Specific findings of the second assessment are highlighted below.

Water Supply

Nationally, the United States has an ample supply of water from both surface and underground sources. However, there can be regional or local shortages of water because of the uneven distribution of precipitation. Water shortages, which can occur in any season and in any part of the Nation, generally are associated with the arid West, but many humid eastern localities also have periodic water-supply problems. At times, inadequate water supplies can be caused by poor quality of water or by economic, social, and environmental constraints.

Water supplies can be and are being augmented by better management practices that include conservation efforts, reuse and recycling, desalination, weather modification, and integration of surface- and ground-water sources.

Water Use

The term "water use" in this report means withdrawal use (the amount of water withdrawn from its source). The principal requisite for withdrawal use is that water must be taken from a ground-water or surface-water source and conveyed to the place of use (offstream use). "Water consumed," "consumptive use," or "consumption," refer to that part of the water withdrawn that is evaporated, transpired, incorporated into products and crops, consumed by humans or livestock, or otherwise removed from the immediate water supply.

Nonwithdrawal uses are referred to in this report as "instream use" and encompass all uses taking place within the river channel itself.

• **Offstream Use.** In "1975," the United States withdrew 338 billion gallons per day of fresh water (surface and ground) for such offstream uses as agriculture, manufacturing, minerals production, domestic and commercial use, and steam electric generation. By the year 2000 this amount is projected to decrease to 306 billion gallons per day, a 9-percent reduction from "1975." This decrease will be due to more efficient use of water as a result of conservation efforts and better technology in recycling and similar procedures.

Consumptive use of fresh water was 107 billion gallons per day in "1975." By the year 2000, consumptive use is expected to increase to 135 billion gallons per day, an increase of almost 27 percent. The projected increase is a result of growth in manufacturing and mineral industries, steam electric generation, and

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agriculture, and also as a result of evaporation due to higher water temperatures from increased recycling. Agriculture is, and will continue to be, the major consumptive user of water. In some respects, consumptive use is more critical than the total quantity withdrawn for use because the water consumed is not available for downstream uses.

• **Instream Use.** Fish and wildlife needs, hydroelectric generation, navigation, and recreational activities are considered instream-flow uses. Of these, the largest use is for maintaining fish and wildlife habitat. For the conterminous United States, the estimated ideal flow for fish and wildlife is 1,035 billion gallons per day, which is somewhat below the estimated average daily streamflow of 1,233 billion gallons. The adequacy of streamflow to meet instream-flow needs is similar to that of water supply—it varies from region to region. An example of a rather extreme situation is the Lower Colorado Region which presently has an average flow of 1,550 million gallons per day, well below the 6,864 mgd preferred for ideal fish habitat.

Critical Problems

Intensive use and competition for water to satisfy a wide variety of purposes have created a number of problems. The critical problems that need attention are:

• **Inadequate surface-water supply.** Localized problems of inadequate surface-water supply have been identified in all 21 water resources regions. However, 17 subregions have or will have a serious problem of inadequate surface-water supply by the year 2000.

• **Overdraft of ground water.** The most dramatic instances of ground-water overdraft are found in the High Plains area that extends from Texas to Nebraska. Central Arizona and parts of California also depend heavily on ground water. In some of those areas ground-water levels are declining from 7 to 10 feet per year. Extensive ground-water overdraft is occurring in 8 of the 106 subregions. Moderate ground-water overdraft is occurring in an additional 30 subregions.

• **Pollution of surface water.** Occurrences of surface-water pollution were reported in most of the 21 water resources regions. Dispersed agricultural sources, municipal and industrial wastes, acid mine drainage, and accelerated urban runoff are the significant sources.

• **Pollution of ground water.** Ground-water pollution, whether existing or potential, natural or manmade, poses a significant health threat inasmuch as 40 percent of the population derives drinking water from ground-water sources. Areas of ground-water pollution have been recognized in practically all 21 regions.

• **Quality of drinking water.** Pollution of surface and ground sources of public water supplies has serious potential public-health consequences. For that reason, maintenance of both surface- and ground-water quality for drinking is of concern nationwide. At the community level, most surface water receives extensive monitoring and treatment, and ground water receives at least chlorination. In rural areas, however, where many people obtain drinking water from individual domestic wells, the water receives little or no treatment and the potential health hazard is significant.

• **Flooding.** In 1975, 107 people were killed by flood waters, and potential property damage was estimated to be $3.4 billion. By the year 2000, potential

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flood damage is expected to increase to $4.3 billion annually unless there is expansion of flood-plain management efforts and the regulation of flood plains.

• **Erosion and sedimentation.** The "1975" average cropland soil loss from erosion was nearly 9 tons per acre; in some areas the soil loss exceeded 25 tons per acre. In addition, forest and pasture lands sustain soil losses of about 1 ton per acre per year.

• **Dredging and disposal of dredged material (dredge and fill).** The large volume of sediment deposited each year in navigable stream channels, reservoirs, and harbors requires regular removal and disposal. In order to maintain the national navigation network, continued dredging is necessary. Disposal of the dredged material can disrupt or destroy aquatic life in adjacent wetlands that have important environmental and economic values. Between 1955 and 1975, a total of 6 million acres of wetlands was lost for use by aquatic life, from filling as a result of development, disposition of dredge material, or other causes.

• **Wet-soils drainage and wetlands.** Wet soils comprise an estimated 400 million acres, of which about 104 million acres is used for cropland, and 43 million of those acres need improved drainage. An additional 70 million acres of wet soils in forest, pasture, or other types of wetland could be converted to cropland, but it is estimated that by the year 2000 only 11 million additional acres will have been converted to cropland. This conversion will be offset to some degree by croplands that revert to wetlands and by the creation of new wetlands. Competition between agricultural and wildlife interests is particularly acute in some wetland areas.

• **Degradation of bay, estuary, and coastal water.** Much of the coastal-area water is being degraded by domestic and industrial waste, particularly in the densely populated New England, Mid-Atlantic, and Great Lakes Regions. These coastal waters provide major recreational opportunities for more than 80 percent of the population.

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INTRODUCTION

Water Resources Regions

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The Second National Water Assessment in Brief

The Water Resources Planning Act of 1965 (Public Law 89-80) directs the U.S. Water Resources Council to maintain a continuing study of the Nation's water and related land resources and to prepare periodic assessments to determine the adequacy of these resources to meet present and future water requirements. In 1968, the Water Resources Council reported the results of its initial assessment. The Second National Water Assessment, a decade later, provides a comprehensive nationally consistent data base for the water resources of the United States. This report summarizes the results of the Second National Water Assessment, which was conducted in three phases.

Phase I: Nationwide Analysis.—The Council member agencies researched, analyzed, and prepared estimates of current and projected water requirements and problems and the implications of the estimates for the future.

Phase II: Specific Problem Analysis.—Regional sponsors, one for each of the 21 water resources regions, surveyed and analyzed State and regional viewpoints about (1) current and future water problems, (2) conflicts that may arise in meeting State and regional objectives, and (3) problems and conflicts needing resolution.

Phase III: National Problem Analysis.—The Council conducted this final phase in three steps: (1) An evaluation of phases I and II, (2) an analysis that identified and evaluated the Nation's most serious water resources problems, and (3) the preparation of a final report entitled "The Nation's Water Resources—1975–2000."

Organization of the Assessment Report

The final report of the Second National Water Assessment consists of four separate volumes as described below. These volumes can assist Federal, State, local, and other program managers, the Administration, and the Congress in establishing and implementing water-resources policies and programs.

Volume 1, Summary, gives an overview of the Nation's water supply, water use, and critical water problems for "1975," 1985, and 2000 and summarizes significant concerns.

Volume 2, Water Quantity, Quality, and Related Land Considerations, consists of one publication with five parts:

Part I, Introduction, outlines the origin of the Second National Water Assessment, states its purpose and scope, explains the numerous documents that are part of the assessment, and identifies the individuals and agencies that contributed to the assessment.

Part II, Water-Management Problem Profiles, identifies the 10 general water-problem issues and their implications and potential consequences.

Part III, Water Uses, focuses on the national perspectives regarding existing ("1975") and projected (1985 and 2000) requirements for water to meet offstream, instream, and flow-management needs. State-regional and Federal perspectives are compared.

Part IV, Water Supply and Water Quality Considerations, analyzes the adequacy of freshwater supplies (ground and surface) to meet existing and future requirements. It contains a national water budget; quantifies surface- and ground-water supplies, reservoir storage, and transfers of water within and between subregions; describes regional requirements and compares them to supplies; evaluates water-quality conditions; and discusses the legal and institutional aspects of water allocation.

Part V, Synopses of the Water Resources Regions, covers existing conditions and future requirements for each of the 21 water resources regions. Within each regional synopsis is a discussion of functional and location-specific water-related problems; regional recommenda-

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tions regarding planning, research, data, and institutional aspects of solving regional water-related problems; a problem-issue matrix; and a comparative-analysis table.

Volume 3, Analytical Data, describes the methods and procedures used to collect, analyze, and describe the data used in the assessment. National summary data are included with explanatory notes. Volume 3 is supplemented by five separately published appendixes that contain data for the regions and subregions:

Appendix I, Social, Economic, and Environmental Data, contains the socioeconomic baseline ("1975") and growth projections (1985 and 2000) on which the water-supply and water-use projections are based. This appendix presents two sets of data. One set, the National Future, represents the Federal viewpoint; the other set, the State-Regional Future, represents the regional sponsor and/or State viewpoint.

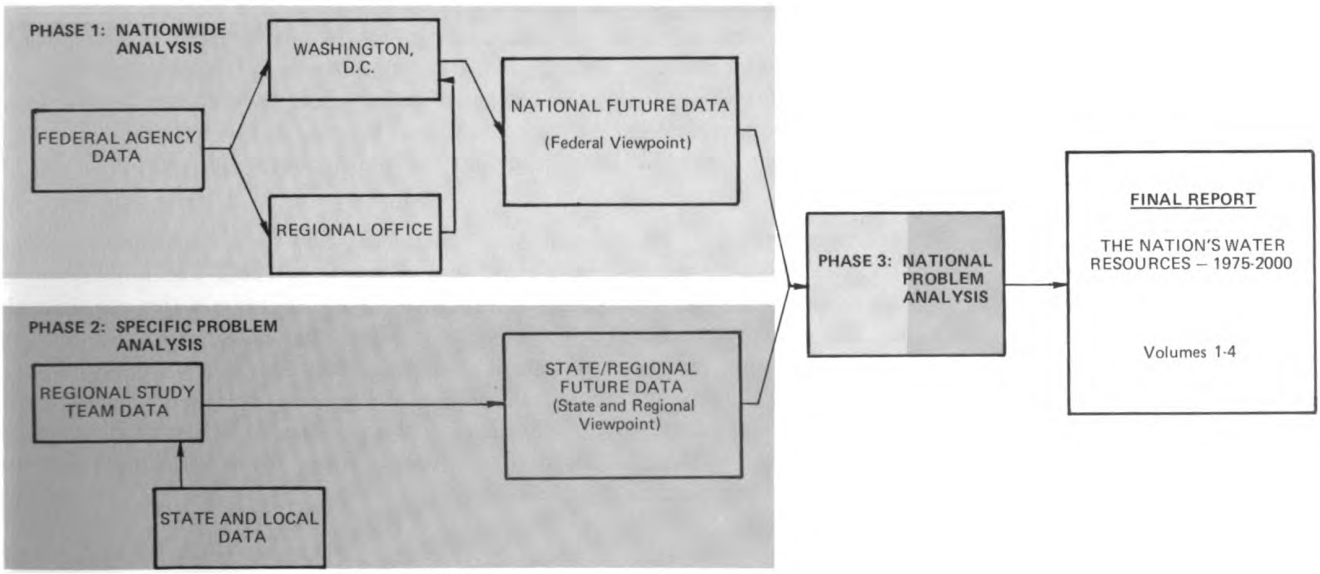
Appendix II, Annual Water Supply and Use Analysis, contains baseline water-supply data and baseline and projected water-withdrawal and water-consumption data used for the assessment. Also included are a water-adequacy analysis, a natural-flow analysis, and a critical-month analysis.

Appendix III, Monthly Water Supply and Use Analysis, contains monthly details of the water-supply, water-withdrawal, and water-consumption data contained in Appendix II and includes an analysis of monthly water adequacy.

Appendix IV, Dry-Year Conditions Water Supply and Use Analysis, contains both annual and monthly baseline and projected water-withdrawal and water-consumption data for dry conditions. Also, a dry-conditions water-adequacy analysis is included.

Appendix V, Streamflow Conditions, contains detailed background information on the derivation of the baseline streamflow information. A description of streamflow gages used, correction factors applied, periods of record, and extreme flows of record are given for each subregion. Also included is the State-Regional Future estimate of average streamflow conditions.

Volume 4, Water Resources Regional Reports, consists of separately published reports for each of the 21 regions. Synopses of these reports are given in Volume 2, Part V.



Information Flow for the Second National Water Assessment

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Water Resources Regions

For compiling and analyzing water-resources data, the Nation has been divided into 21 major water resources regions and further subdivided into 106 subregions. Eighteen of the regions are within the conterminous United States, the other three are Alaska, Hawaii, and the Caribbean area.

The 21 water resources regions are hydrologic areas that have either the drainage area of a major river, such as the Missouri Region; or the combined drainage areas of a series of rivers, such as the South Atlantic-Gulf Region, which includes a number of southeastern States that have rivers draining directly into the Atlantic Ocean and the Gulf of Mexico.

The 106 subregions, which are smaller drainage areas, were used exclusively in the Second National Water Assessment as basic data-collection units. Subregion data point up problems that are primarily basinwide in nature. Data aggregated from the subregions portray both regional and national conditions, and also show the wide contrasts in both regional and national water sources and uses.

Limitations of the Assessment Data

The Second National Water Assessment and its data base constitute a major step in the identification and definition of water-resources problems by the many State, regional, and Federal institutions involved. However, much of the information in this assessment is general and broad in scope; thus, its application should be viewed in that context, particularly in the area of water quality. Further, the information reflects areas of deficiencies in availability and reliability of data. For these reasons, State, regional, and Federal planners should view the information as indicative, and not the only source to be considered. When policy decisions are to be made, the effects at State, regional, and local levels should be carefully considered.

In a national study it is difficult to reflect completely the regional variations within the national aggregation. For example, several regional reviewers did not agree with the national projections made for their regions. These disagreements can be largely attributed either to different assumptions by the regional reviewers or to lack of representation of the national data at the regional level. Therefore, any regional or State resources-management planning effort should consider the State-regional reports developed during phase II and summarized in Volume 4 as well as the nationally consistent data base and the other information presented in this assessment.

Additional years of information and experience show that considerable change has occurred since the first assessment was prepared in 1968. The population has not grown at the rate anticipated, and the projections of future water requirements for this second assessment are considerably lower than those made for the first assessment. Also, greater awareness of environmental values, water quality, groundwater overdraft, limitations of available water supplies, and energy concerns are having a dramatic effect on water-resources management. Conservation, reuse, recycling, and weather modification are considerations toward making better use of, or expanding, available supplies.

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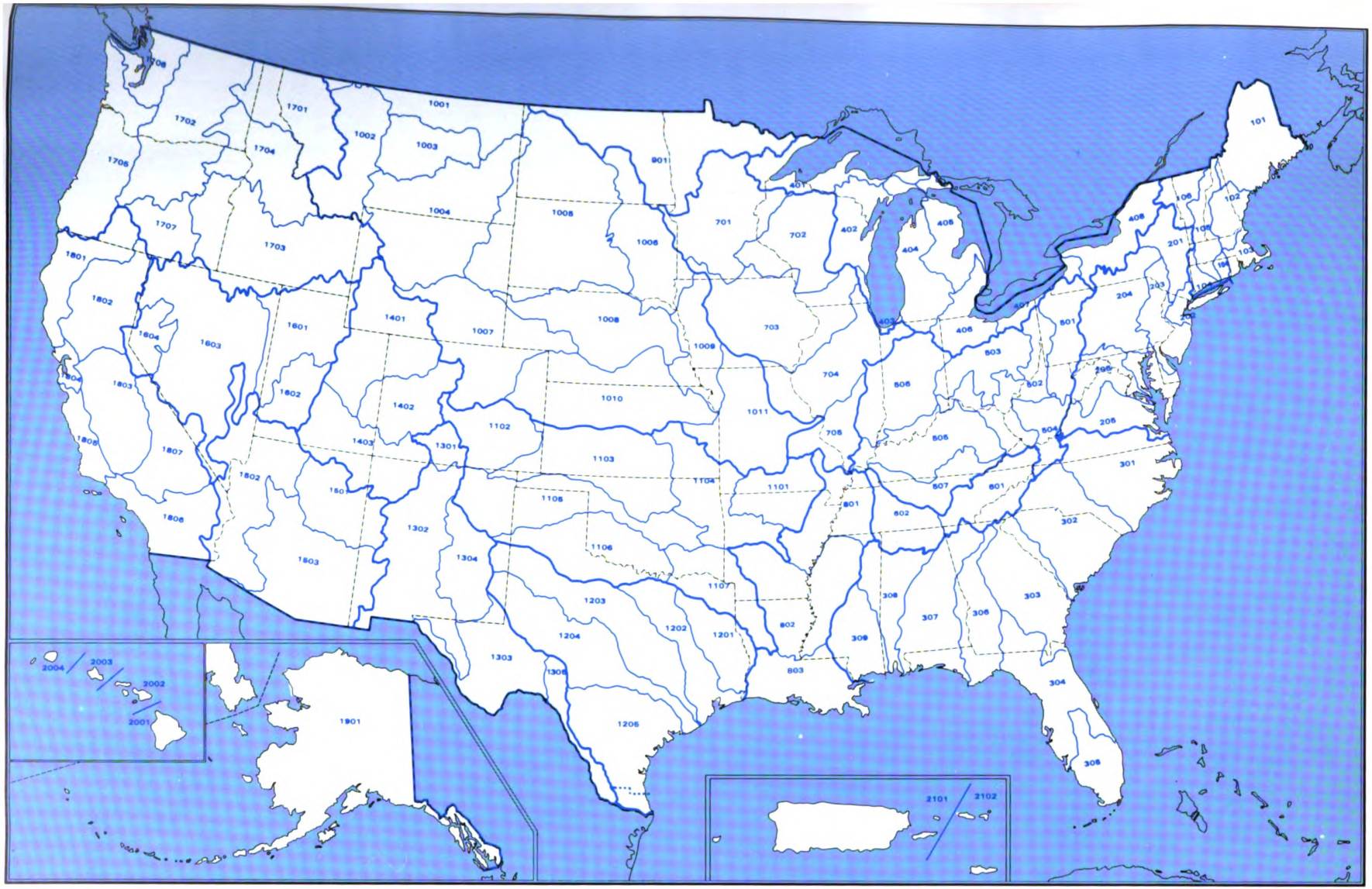

Water resources subregions used in the Second National Water Assessment

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WATER SUPPLY

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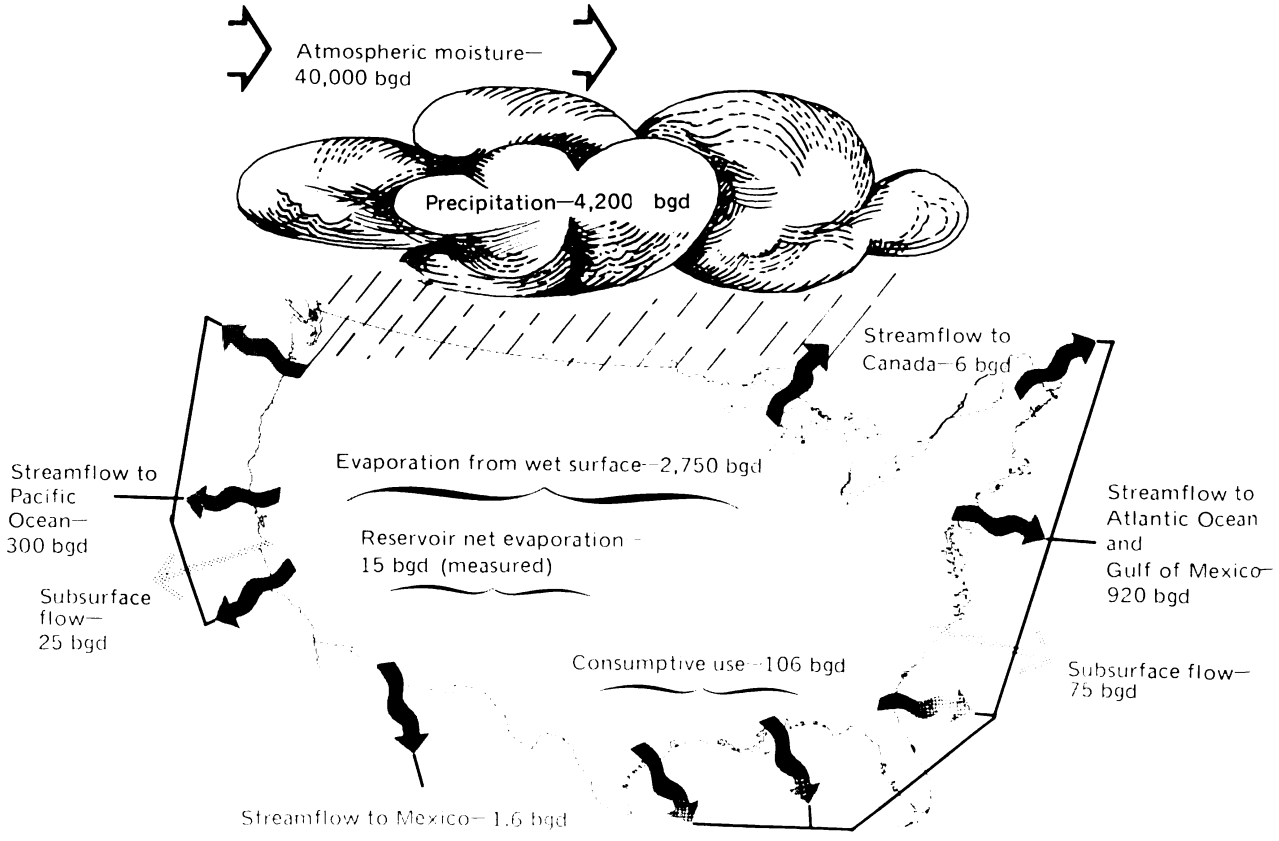
Water Budget

Source

On the average, about 40,000 bgd (billion gallons per day) of water passes over the conterminous United States in the form of water vapor. Of this, approximately 10 percent (about 4,200 bgd) is precipitated as rainfall, snow, sleet, or hail. The remainder continues in atmospheric suspension. Of the 4,200 bgd—equivalent to the average rainfall of 30 inches falling on the conterminous United States—about two-thirds (2,750 bgd) is evaporated immediately from the wet surfaces or transpired by vegetation. The remaining 1,450 bgd accumulates in ground or surface storage; flows to the oceans, the Gulf of Mexico, or across the Nation's boundaries; is consumptively used; or is evaporated from reservoirs.

Only part of the potential 1,450 bgd can be developed for intensive beneficial uses. To date, with existing surface storage and because of the extremes of annual precipitation that cause floods and droughts, only 675 bgd is considered available in 95 out of 100 years.



Water Budget of the conterminous United States

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Availability

Surface water can be available for use as fresh water in the United States from the time it strikes the land surface as precipitation until it is discharged into the ocean; mixes with saline water in estuaries, landlocked seas, or saline lakes; or passes across the border of Canada or Mexico. It is usable only so long as it is not excessively polluted with natural or manmade pollutants.

Average annual runoff for the conterminous United States is highest in the Pacific Northwest and lowest in the Southwest and some of the intermountain valleys. The average annual runoff is sometimes assumed to be the theoretical upper limit of surface supplies. However, the increased storage required to make this quantity of water available for use would be so large that the resulting evaporation from the required reservoirs would substantially decrease the available water. Thus, a mix of increased storage and other alternatives seems to offer the most effective solution. To sustain desired withdrawals 95 percent of the time, considerable additional storage would be needed, but in many areas neither the reservoir sites nor the uncommitted flows are available. Consequently, if projected water requirements are to be satisfied, there is a strong need for water conservation to save water, weather modification to increase precipitation, and improved methods to reduce evaporation.

In "1975," the conterminous United States withdrew a total of 393 bgd from surface and ground sources. Of this total, 254 bgd was from fresh surface-water sources, 58 bgd from saline surface sources, and 81 bgd from aquifers (ground water). Hence, 85 percent (335 bgd) came from fresh surface- and ground-water sources and 15 percent from saline sources.

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Surface Water

Fresh-Water Streamflow

Surface water occurs in rivers, streams, lakes, swamps, marshes, and manmade reservoirs, whereas ground water occurs in the zone of saturation below the land surface. Streamflow varies from region to region, from season to season, and from year to year. For example, within a normal year and for a given region, the ratio of maximum streamflow to minimum streamflow can be more than 500 to 1. Annual variations in flow also are substantial. Even in areas of high precipitation and streamflow, a series of dry years sometimes occurs, resulting in serious droughts such as those in the Northeast in 1961 and 1966, and in the West and other parts of the United States in 1976 and 1977.

Effects of droughts are particularly serious in areas that use a high proportion of the available average annual runoff or where storage and distribution facilities are inadequate to provide sufficient carryover during prolonged periods of low streamflow. In the humid East, streamflow tends to vary less from year to year and from month to month than in the other regions.

Variations in annual streamflow are expressed in terms of flow that is expected to be exceeded in a specific percentage of years. For example, a flow of 5-percent exceedance represents an extremely high flow that will be exceeded in only 5 out of 100 years, on the average. Many flood plains will be inundated when flow is at or above this level. The 50-percent exceedance flow is the median flow; streamflow will exceed the median flow half the time. The 80-percent exceedance flow, on the other hand, represents a low flow, one that will be exceeded 80 years out of 100, on the average. During those years when flows are at 80-percent exceedance, water shortages varying in intensity can occur. The 95-percent exceedance flows represent extreme low flows.

As the following table shows, a few of the 5-percent exceedance (high) flows are twice the mean flow or more, but most are about 1½ times the mean. The 95-percent exceedance (low) flows generally range from 0.4 to 0.7 that of the mean flow.

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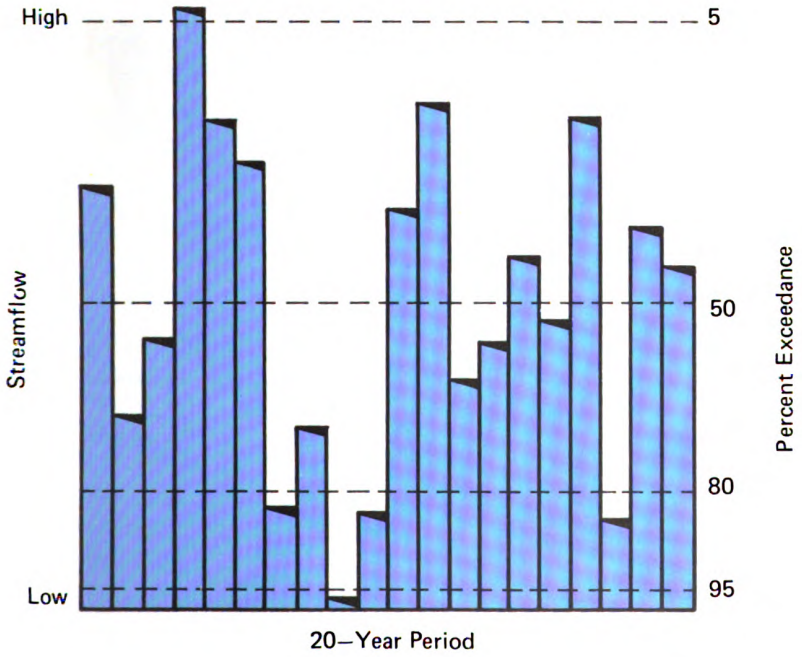
Streamflow frequency—"1975"

[Italic numbers not included in total because these are inflows to another region]

Water resources region and No.	Streamflow, in billion gallons per day				
	Mean	Percent exceedance			
		5	50	80	95
New England (1)	78.2	107.7	77.4	62.7	48.3
Mid-Atlantic (2)	79.2	115.1	77.8	61.2	48.4
South Atlantic-Gulf (3)	228.0	356.6	219.3	164.1	121.8
Great Lakes (4)	72.7	103.9	71.7	57.3	44.9
Ohio (5)	*178.0*	*254.0*	*178.0*	*141.0*	*105.0*
Tennessee (6)	*40.8*	*57.9*	*40.8*	*35.9*	*31.4*
Upper Mississippi (7)	*121.0*	*189.0*	*121.0*	*91.8*	*65.3*
Lower Mississippi (8)	433.0	757.0	433.0	282.0	202.0
Souris-Red-Rainy (9)	6.0	11.4	5.6	3.4	1.8
Missouri (10)	*44.1*	*74.3*	*43.2*	*29.9*	*17.6*
Arkansas-White-Red (11)	*62.6*	*120.7*	*59.1*	*37.4*	*21.6*
Texas-Gulf (12)	28.3	62.4	22.9	12.3	6.3
Rio Grande (13)	1.2	4.4	.6	.3	.2
Upper Colorado (14)	*10.0*	*15.6*	*10.0*	*7.0*	*3.9*
Lower Colorado (15)	1.6	1.7	1.6	1.4	1.2
Great Basin (16)	2.6	4.7	2.4	1.6	1.2
Pacific Northwest (17)	255.3	344.7	254.3	213.3	179.7
California (18)	47.4	87.4	44.3	29.8	19.5
Total, Regions 1–18	1,233.4	1,956.9	1,210.9	889.4	675.3
Alaska (19)	905.0	1,030.0	898.0	795.0	705.0
Hawaii (20)	6.7	10.3	6.3	4.9	3.8
Caribbean (21)	4.9	7.1	4.5	3.3	1.6
Total, Regions 1–21	2,150.0	3,004.3	2,119.7	1,692.6	1,385.7



Hypothetical example of streamflow frequency

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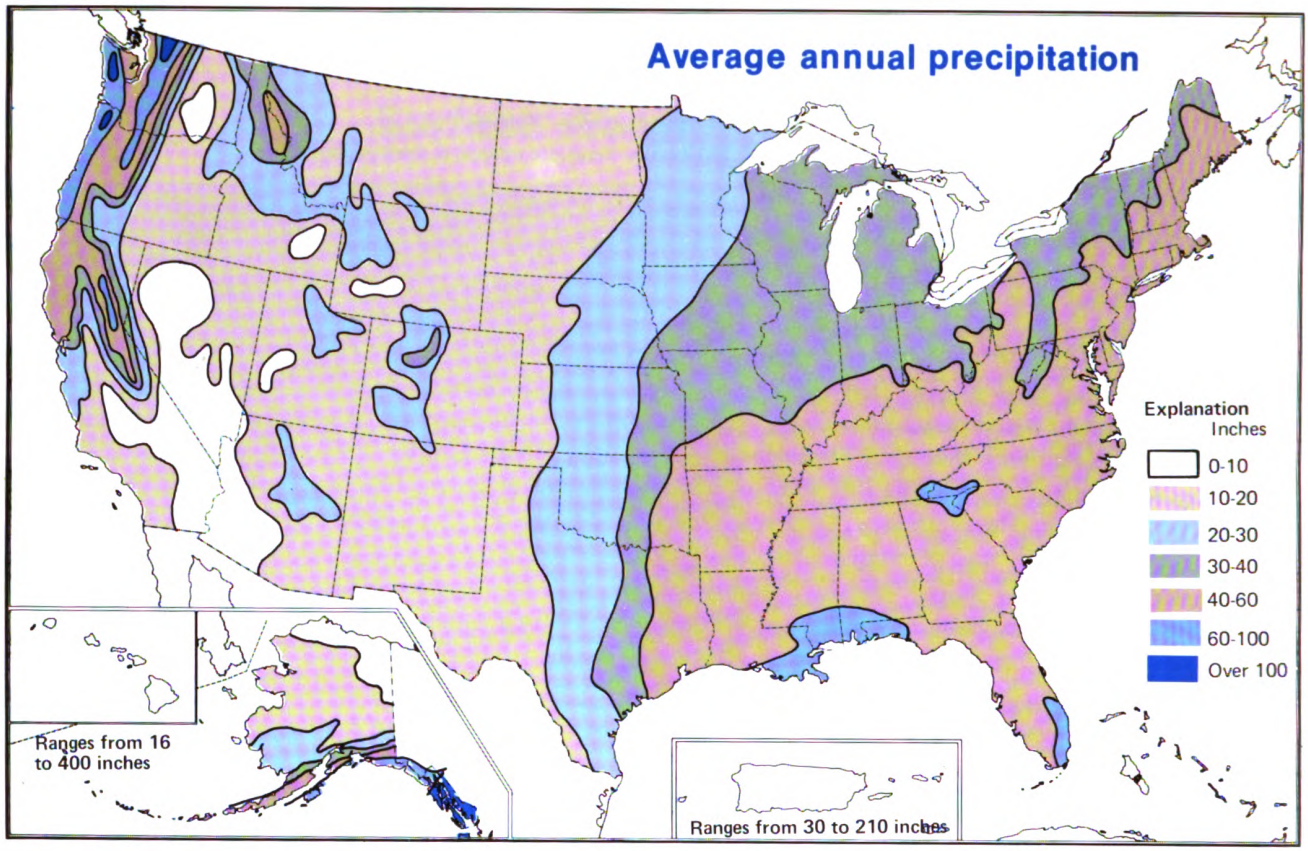

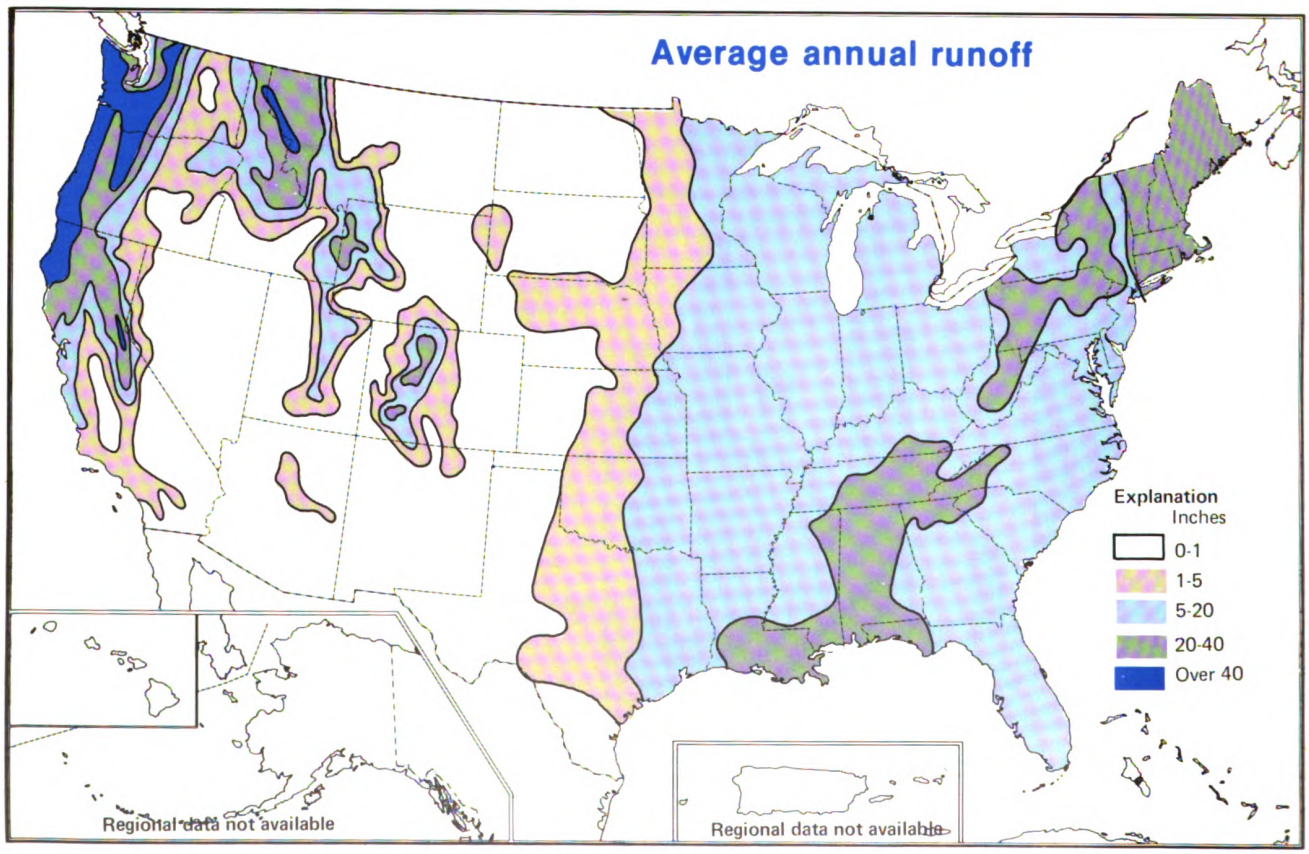

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Reservoir Storage

Large Reservoirs.—Storage of all large reservoirs (50 acre-feet or more) in the Nation is about 450 million acre-feet (about 146,800 billion gallons). Thirty-one of these large reservoirs are over 2 million acre-feet in size, have an aggregated usable storage capacity of 191 million acre-feet, and account for about 41 percent of the Nation's total storage. In addition, 1,600 reservoirs have storage capacities that range from 5,000 to 2 million acre-feet and account for 37 percent of the total storage capacity. Approximately 47,500 reservoirs have storage capacities that range from 50 to 5,000 acre-feet and account for another 20 percent of the storage capacity.

Small Reservoirs.—Over 1.8 million small reservoirs and farm ponds have been developed for water supply, fire protection, and recreation. These smaller water bodies have about 10 million acre-feet of storage capacity or about 2 percent of the total.

Saline Water

The major sources of saline water are the oceans, bays, and estuaries. Sea water is used for cooling in steam electric generating plants and in manufacturing, and as a supply to desalination plants. By definition, water is saline if its dissolved solids concentration is 1,000 milligrams per liter or more, regardless of the kind of constituents in solution.

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Ground Water

Availability

Most of the aquifers, or reservoirs of ground water, are located near (within 2,500 feet of) the land surface. The term "aquifer" describes a body of rock (including unconsolidated material such as sand, gravel, clay, and soil) that is saturated with water and is permeable enough to carry or yield water in useful quantities. Aquifers may be thick or thin, extensive or local, near the land surface or many hundreds of feet below. Aquifers are recharged primarily by downward percolation of rain or snowmelt. In some areas the quantity of recharge is less than the quantity of water withdrawn on a long-term basis, and in these areas water is being taken from storage; that is, the aquifer is being "overdrawn."

About 30 percent of the Nation's streamflow, in an average year, is supplied by ground water that emerges as natural springs and other seepage. In turn, seepage from streams, rivers, canals, and reservoirs is a source of ground-water recharge. Most of the flow in many smaller streams comes from ground water during the low-flow months. In years of below normal precipitation, all the streamflow during low stage may be ground water. Ground water, therefore, is important to the continuity of streamflow.

Ground-water overdraft is substantial in some areas of the Nation—14 million acre-feet or more than 12,500 mgd (million gallons per day) annually in the Texas-Oklahoma High Plains area, an amount about equal to the natural flow of the Colorado River. A balance between withdrawals and recharge is, of course, desirable.

Ground-water withdrawals and percentage of overdraft—"1975"

Water resources region and No.	Total withdrawal (mgd)	Overdraft		Subregions		
		Total (mgd)	Percent	Number in region	Number with overdraft	Range in overdraft (percent)
New England (1)	635	0	0	6	0	---
Mid-Atlantic (2)	2,661	32	1.2	6	3	1- 9
South Atlantic-Gulf (3)	5,449	339	6.2	9	8	2-13
Great Lakes (4)	1,215	27	2.2	8	1	30
Ohio (5)	1,843	0	0	7	0	---
Tennessee (6)	271	0	0	2	0	---
Upper Mississippi (7)	2,366	0	0	5	0	---
Lower Mississippi (8)	4,838	412	8.5	3	3	7-13
Souris-Red-Rainy (9)	86	0	0	1	0	---
Missouri (10)	10,407	2,557	24.6	11	10	4-36
Arkansas-White-Red (11)	8,846	5,457	61.7	7	7	2-76
Texas-Gulf (12)	7,222	5,578	77.2	5	5	24-95
Rio Grande (13)	2,335	657	28.1	5	4	22-43
Upper Colorado (14)	126	0	0	3	0	---
Lower Colorado (15)	5,008	2,415	48.2	3	3	7-53
Great Basin (16)	1,424	591	41.5	4	4	7-75
Pacific Northwest (17)	7,348	627	8.5	7	6	4-45
California (18)	19,160	2,197	11.5	7	5	7-31
Regions 1-18	81,240	20,889	25.7	99	59	1-95
Alaska (19)	44	0	0	1	0	---
Hawaii (20)	790	0	0	4	0	---
Caribbean (21)	254	13	5.1	2	1	5
Regions 1-21	82,328	20,902	25.4	106	60	1-95

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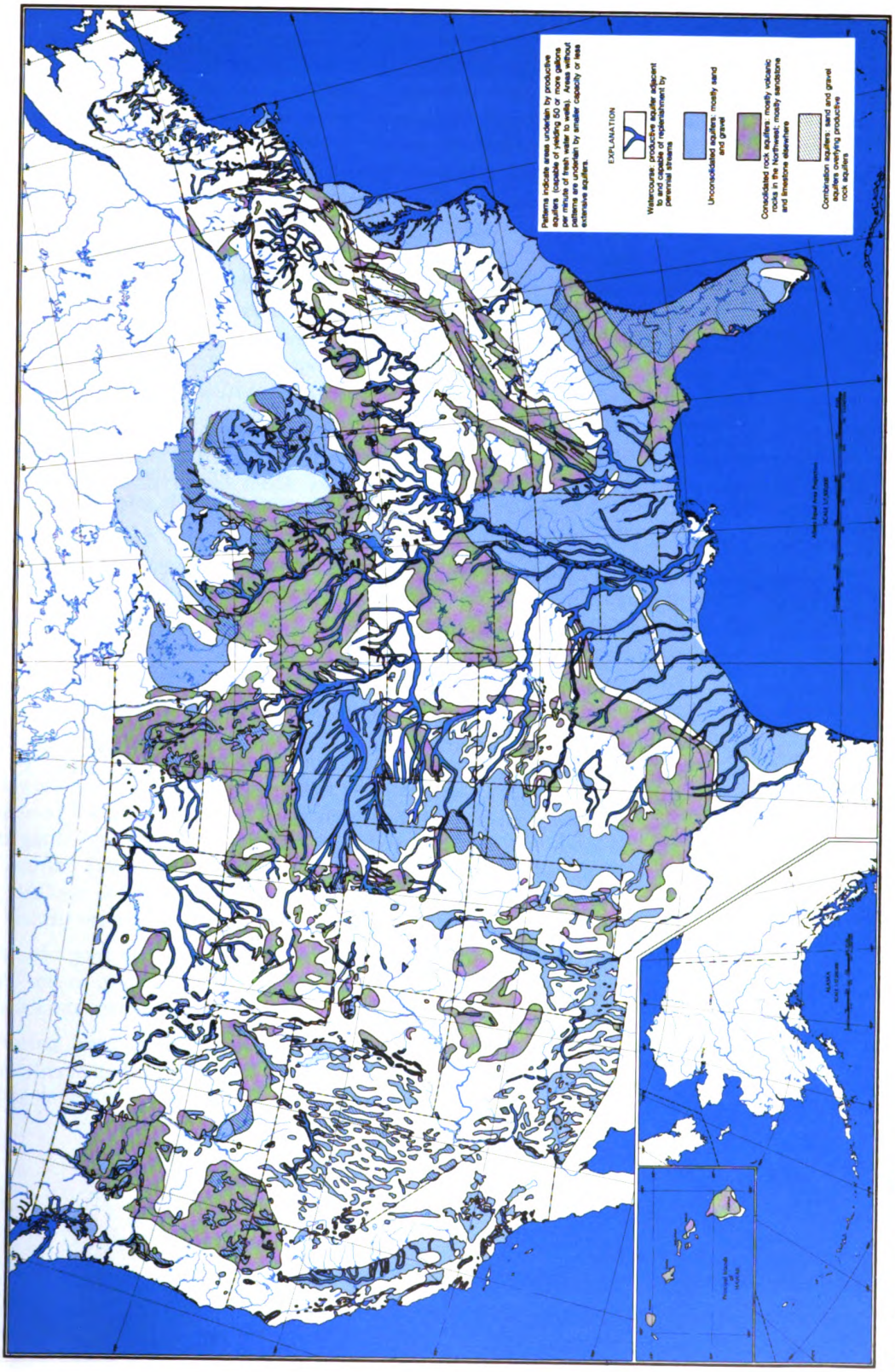

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Major aquifers

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Quantity

The quantity of ground water in storage is much greater than the quantity of available surface water in streams and lakes. Within the conterminous United States, estimates of total ground water within 2,500 feet of the land surface range from 33,000 trillion to 59,000 trillion gallons (100 billion to 180 billion acre-feet). To gain some perspective, compare the 59,000 trillion gallons of ground water with the 1,290 trillion gallons of water in Lake Michigan or with the 33,000 trillion gallons of water that the Mississippi River discharged into the Gulf of Mexico during the last 200 years. Because of environmental considerations and the cost of extraction, however, much less than the total quantity of ground water is regarded as available supply.

Patterns of Present Use

In the United States, use of ground water for fresh-water supplies has been increasing gradually. During the last 25 years total fresh-water withdrawals increased at an annual rate of 2 percent, whereas fresh ground-water withdrawals increased 3.8 percent each year, on the average.

In "1975," ground water provided more than 40 percent of the total fresh water withdrawn in 23 of the 106 subregions. California extracted more ground water than all of the eastern regions combined. For example, 48 percent of the total fresh water used in California in "1975" was obtained from wells; this accounted for 23 percent of the total national ground-water withdrawal.

The principal use of ground water is for irrigation. In "1975," 82 bgd of fresh ground water was withdrawn for use. Of this quantity, 56 bgd was used for irrigation, about 68 percent of all ground water withdrawn and about 35 percent of all the water used for irrigation.

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Conservation and Augmentation

Water Conservation

The goal of water conservation is to avert critical water shortages and to get the greatest use from existing supplies. If better management and technology can reduce water withdrawals while producing the same services, the efficiency of water use (output produced for each unit of water) can be increased. Although improvements in water management and technology will be constrained by costs and other considerations, conservation efforts can focus on technologies to reduce water requirements. For example:

- Irrigation is a prime candidate for water conservation because of the large quantities of water used and its concentration in the relatively water-short Western States. Irrigation accounts for 47 percent of total national withdrawals and 81 percent of consumptive use. Recent reports indicate that the potential for saving in irrigation withdrawals is from 20 to 30 percent, or a 30 to 45 bgd savings.

  Improvements to off-farm delivery systems, such as lined and covered canals, computer monitoring and scheduling of releases, and automated weirs and gates, can reduce withdrawals by as much as 10 percent. Better on-farm water-management practices, such as closer scheduling of water applications to meet crop needs without over irrigating, irrigating at night instead of during the day, improved irrigation systems such as sprinkler and drip systems and well-designed surface systems, and better land preparation, can reduce withdrawals an additional 10 to 40 percent.

- Water provided by central domestic-use systems is only 6 percent of total national withdrawals. This use seems an unlikely candidate for conservation, but ways to reduce water use substantially at little cost do exist. Substantial reductions in water use can be achieved within the home. Bathing and toilet flushing, for instance, represent over half of all household water use. Retrofitting showers and toilets with more efficient fixtures can reduce by one-third the water used for these purposes. Reductions in outside uses of water (largely lawn and garden watering, car washing, and swimming pools), which account for over one-third of all water used by urban systems, also can be obtained. In addition, leakage in some central systems results in considerable losses of valuable treated water.

- Steam electric generation water withdrawals could be reduced by 25 to 30 percent by means of dry cooling towers that use no water but do require more energy to operate and are expensive.

- Manufacturing water withdrawals already are being reduced significantly by in-plant treatment and recycling and by the use of processes and equipment that require less water.

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Neither "availability" nor "requirements" should be treated as unalterable in water conservation. Technology and management can bring supply and demand into balance in the best public interest. The challenge for water conservation is to ensure the best allocation of available supplies among users. Findings of the Second National Water Assessment can be used to target priority problem areas that need new or accelerated conservation programs.

Improved Surface-Water Management

Water supplies can be improved by better management of water storage and distribution facilities and by the construction of additional reservoirs to store free-flowing surface water. A more unified operation of existing facilities would result in additional water supplies. An important part of surface-water management is the allocation of water for artificially recharging the ground-water body where a temporary surplus of surface water exists and where ground-water levels are far enough below the land surface that artificial recharge is feasible.

Weather Modification

Efforts to induce or modify precipitation by seeding clouds with silver iodide, frozen carbon monoxide, and other nuclei have been the subject of considerable applied research and development over the past three decades. Seeding of winter storms in local areas of the West has increased total precipitation from 5 to 25 percent. Cloud seeding that increases snowpack on the western slopes of the western mountain ranges also adds to spring runoff and snowmelt in downstream storage reservoirs.

Seeding of summer cumulus clouds to produce additional rainfall is considerably more complex than seeding of winter clouds. Experiments on single cumulus clouds have had mixed results. Some experiments have decreased rainfall; the causes for this are not fully understood. However, seeding of multi-cloud formations has had positive results. For example, experiments in the Dakotas increased total seasonal rainfall by 10 to 20 percent. In Florida, results ranged from a plus 18 percent to minus 6 percent. Whether the same results can be obtained in other parts of the country is not yet known.

Desalination

Water desalination, or desalting, is the process by which potable water is produced from saline or brackish waters. It is one method that can be developed to meet threatening water shortages and pressures caused by increasing requirements in water-short areas.

Since 1955, the number of desalination plants has increased from about a dozen, that produced 2 mgd, to more than 330, that are producing almost 100 mgd—about 0.1 percent of the Nation's total fresh-water withdrawals for domestic and manufacturing use. Although most desalination is for industrial purposes, its use for domestic purposes has increased in recent years—in "1975" it was over 30 mgd.

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Most of the desalination plants (54 percent) are in California, Texas, and Florida. However, about 61 percent of the installed capacity is east of the Mississippi River, and a significant number of the plants are in the industrialized Northeast.

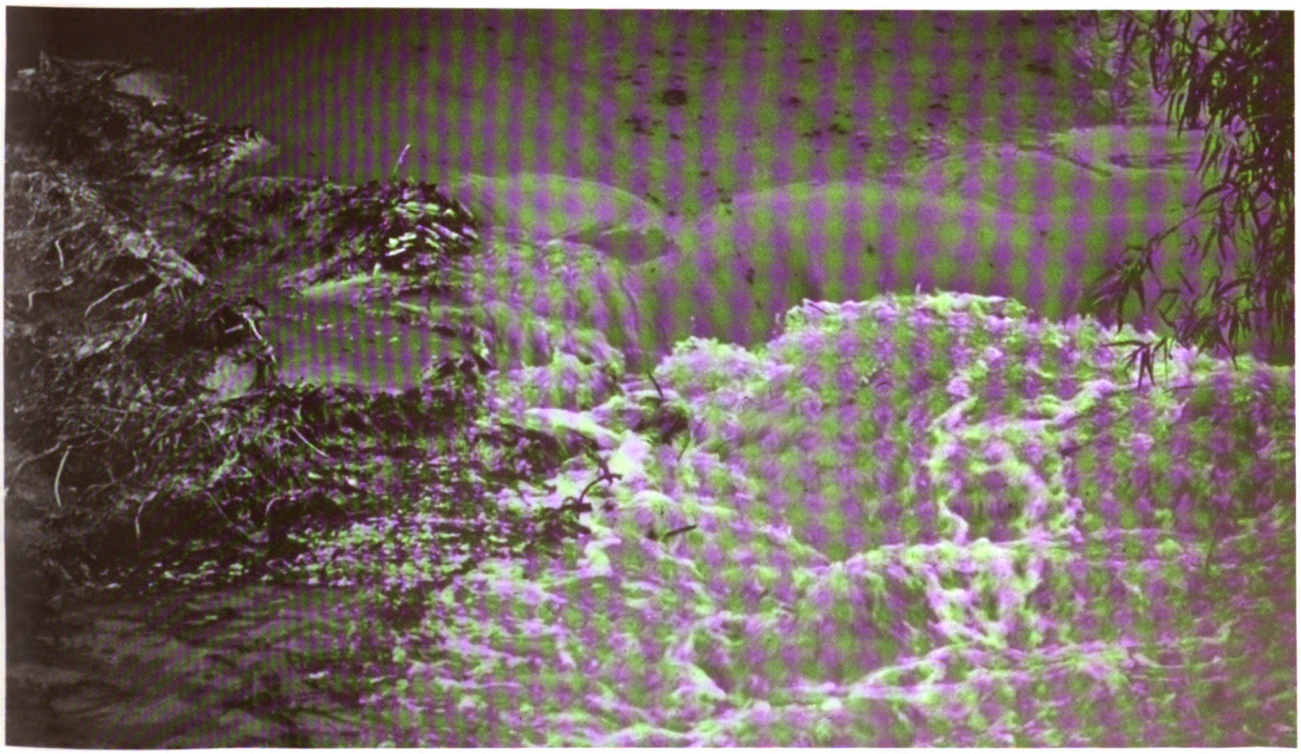
Desalination operations are still expensive and they also use significant quantities of energy; therefore, desalination facilities are constructed only if alternative sources of water are unavailable or more costly.

Water Reuse

Limitation of supply, increased delivery costs, and water pollution control laws for higher quality waste-water discharges have increased the national interest in water reuse and waste-water reclamation. Some ways of reusing water are:

- Use of treated waste water for manufacturing, steam-powered electric generation, and irrigation.
- Routing storm water to recharge basins to augment aquifer recharge.
- Use of treated waste water to augment water supply either by aquifer recharge or blending in surface-water reservoirs.
- Use of treated waste water to create a pressure barrier to protect fresh-water aquifers from salt-water intrusion.

Obviously, the feasibility of reusing waste water depends on the ease with which the quality can be improved to meet the requirements of the intended use. Further research—including development and operation of prototype facilities to determine acceptable practices—is needed.



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Water Supply—Overview

"1975" and 2000

The Nation's water resources have been extensively developed to satisfy a wide variety of beneficial uses. However, these developments have not always made the best use of the resource. Water projects generally supported a dominant single purpose such as urban water supply, irrigation, flood control, or navigation. Additional purposes were sometimes incorporated to more fully justify the project. When possible, hydroelectric generation was incorporated to provide additional revenue to reduce the cost of water for the dominant project purpose. As a result of this limited-purpose approach, adverse environmental effects sometimes occurred and water was not available for some purposes that could have been incorporated into the project.

In some areas ground-water overdraft has been underway for a number of years. This overdraft is complicated by inadequate planning for long-term consequences of the loss of ground-water supplies. Moreover, the discharge of poor-quality water to stream systems and the resulting percolation to ground water has lowered the quality of the ground water.

Because of public concern for environmental values and because of the limitations on the water supplies remaining for development in some areas of intensive water use, there has been a substantial shift towards better and more comprehensive water-resources management to provide a balanced program for all beneficial purposes. Adverse water-quality conditions now receive additional attention. ground-water overdraft conditions are being better defined, and flood-plain management procedures are being further developed. As a result, much of the future increase in water needs will be satisfied by better management and more balanced procedures to manage the resource for all.

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Total fresh- and saline-water withdrawals—"1975"

Water resources region and No.	Withdrawals, in millon gallons per day				
	Fresh water			Saline water	Total
	Surface	Ground	Total		
New England (1)	4,463	635	5,098	5,216	10,314
Mid-Atlantic (2)	15,639	2,661	18,300	19,625	37,925
South Atlantic-Gulf (3)	19,061	5,449	24,510	7,460	31,970
Great Lakes (4)	41,598	1,215	42,813	0	42,813
Ohio (5)	33,091	1,843	34,934	0	34,934
Tennessee (6)	7,141	271	7,412	0	7,412
Upper Mississippi (7)	10,035	2,366	12,401	0	12,401
Lower Mississippi (8)	9,729	4,838	14,567	1,253	15,820
Souris-Red-Rainy (9)	250	86	336	0	336
Missouri (10)	27,609	10,407	38,016	0	38,016
Arkansas-White-Red (11)	4,022	8,846	12,868	0	12,868
Texas-Gulf (12)	9,703	7,222	16,925	9,163	26,088
Rio Grande (13)	3,986	2,335	6,321	0	6,321
Upper Colorado (14)	6,743	126	6,869	0	6,869
Lower Colorado (15)	3,909	5,008	8,917	0	8,917
Great Basin (16)	6,567	1,424	7,991	0	7,991
Pacific Northwest (17)	30,147	7,348	37,495	131	37,626
California (18)	20,476	19,160	39,636	14,569	54,205
Total, Regions 1–18	254,169	81,240	335,409	57,417	392,826
Alaska (19)	261	44	305	57	362
Hawaii (20)	1,089	790	1,879	1,139	3,018
Caribbean (21)	653	254	907	1,124	2,031
Total, Regions 1–21	256,172	82,328	338,500	59,737	398,237

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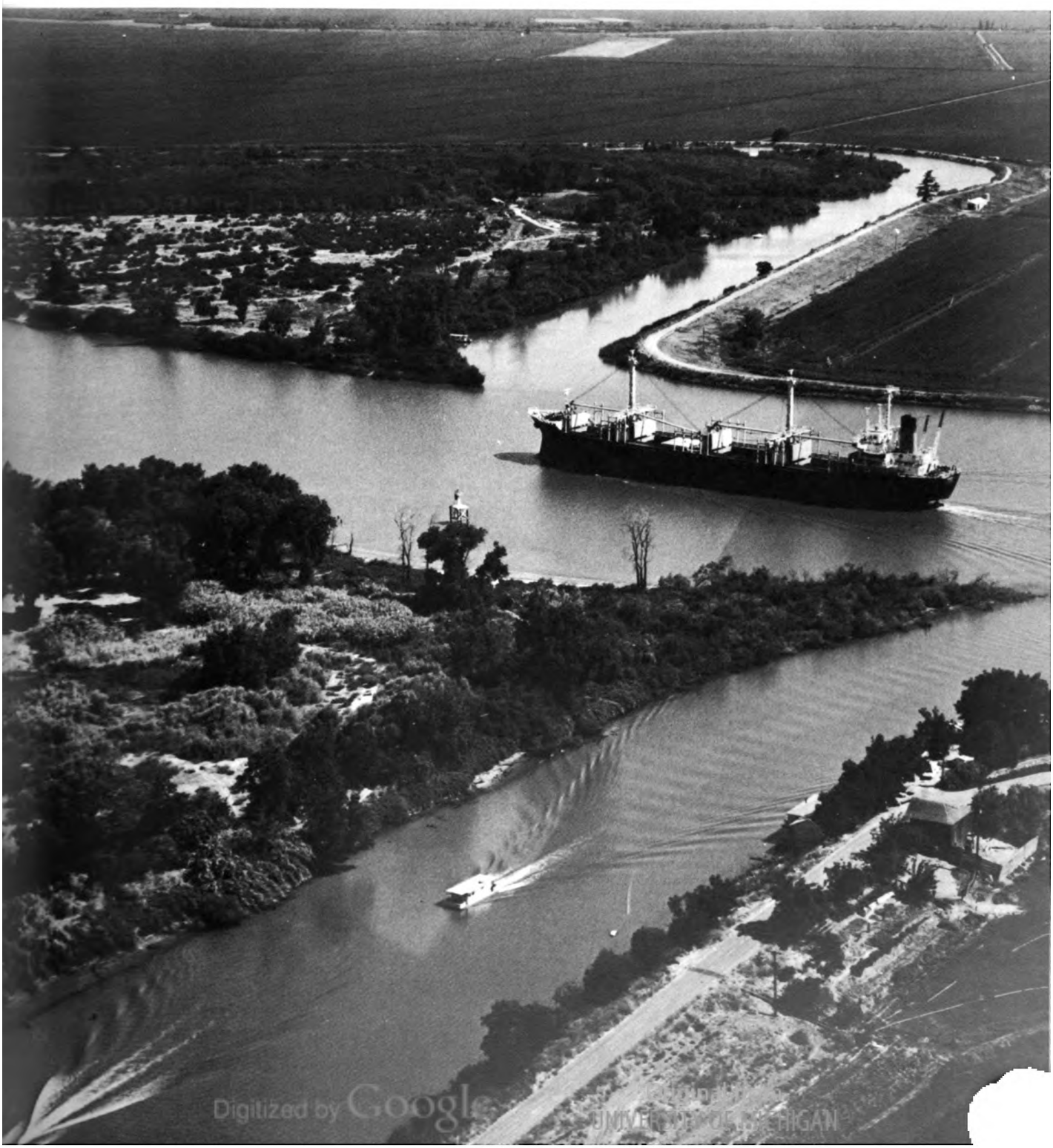
WATER USE



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Offstream Use

Water withdrawn for offstream use consists of two variables: (1) the part returned to the surface-water or ground-water source after being used, and (2) the part consumed or not returned to the source after use. A typical example of consumption is vegetation transpiration. Much of the water used for irrigation, particularly sprinkler irrigation, either is transpired by the plants or is evaporated from the soil. Withdrawals may include saline water, but the major concern of this assessment is with fresh-water withdrawals and consumption in the various regions and for each category of use. Water uses and available water supplies (streamflow, ground water, imports, and exports) were analyzed to identify where critical water imbalances now exist or may develop in the future.

Withdrawals

Total fresh-water withdrawals for all offstream uses—agriculture, domestic and commercial uses, manufacturing, minerals production, steam electric generation, public lands, and other uses—for "1975" were 338.5 bgd. By the year 2000, fresh-water withdrawals are projected to decrease to 306.4 bgd, a 9-percent reduction from "1975." This expected decline is based on certain assumptions about water-use efficiency and recycling that result from technology and conservation. The most significant contribution to this reduction in offstream use will be made in the manufacturing sector where fresh-water withdrawals are projected to decline from 51.2 bgd to 19.7 bgd, or 62 percent. Although the quantity of withdrawals for irrigation and steam electric generation will decrease slightly between "1975" and 2000, the percentage of total withdrawals for these two uses will remain essentially unchanged, at about one-half for irrigation and one-fourth for steam electric generation. All other offstream uses will increase both in amount and percentage in their share of the Nation's total withdrawals.

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Consumption

Consumption of water in some respects is more critical than the total quantity withdrawn for use because consumed water is not available for downstream uses or for ground-water recharge. Consumptive use is not equally proportionate to withdrawals among the functional use categories. Offstream consumption was 106.6 bgd in "1975" and is projected to increase by 27 percent to 135.1 bgd by the year 2000. Agriculture (irrigation and livestock watering) has the highest consumptive use of water. Agriculture was responsible for 83 percent of the total water consumed in "1975"; this percentage will decrease to about 70 percent in 2000 because of higher consumption expected in steam electric generation and manufacturing.

Total withdrawals and consumption, by functional use, for the 21 water resources regions—"1975," 1985, 2000

[million gallons per day]

Functional use	Total withdrawals			Total consumption		
	"1975"	1985	2000	"1975"	1985	2000
Fresh water:						
Domestic:						
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699
Agriculture:						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609
Public lands and others[1]	1,866	2,162	2,461	1,236	1,461	1,731
Total fresh water	338,500	330,375	306,397	106,590	120,545	135,080
Saline water,[2] total	59,737	91,236	118,815			
Total withdrawals	398,237	421,611	425,212			

[1] Includes water for fish hatcheries and miscellaneous uses.
[2] Saline water is used mainly in manufacturing and steam electric generation.

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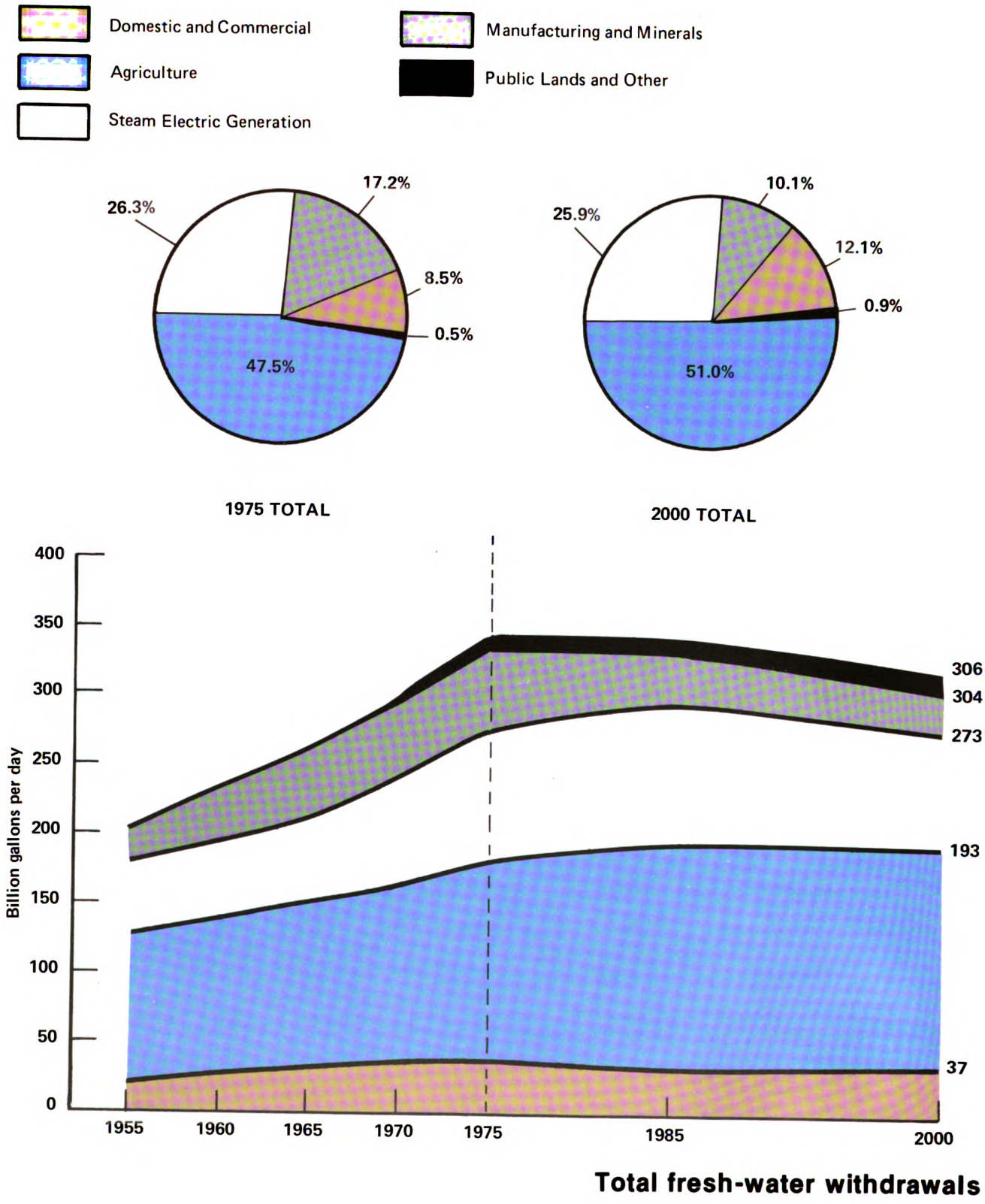
WITHDRAWALS



Total fresh-water withdrawals

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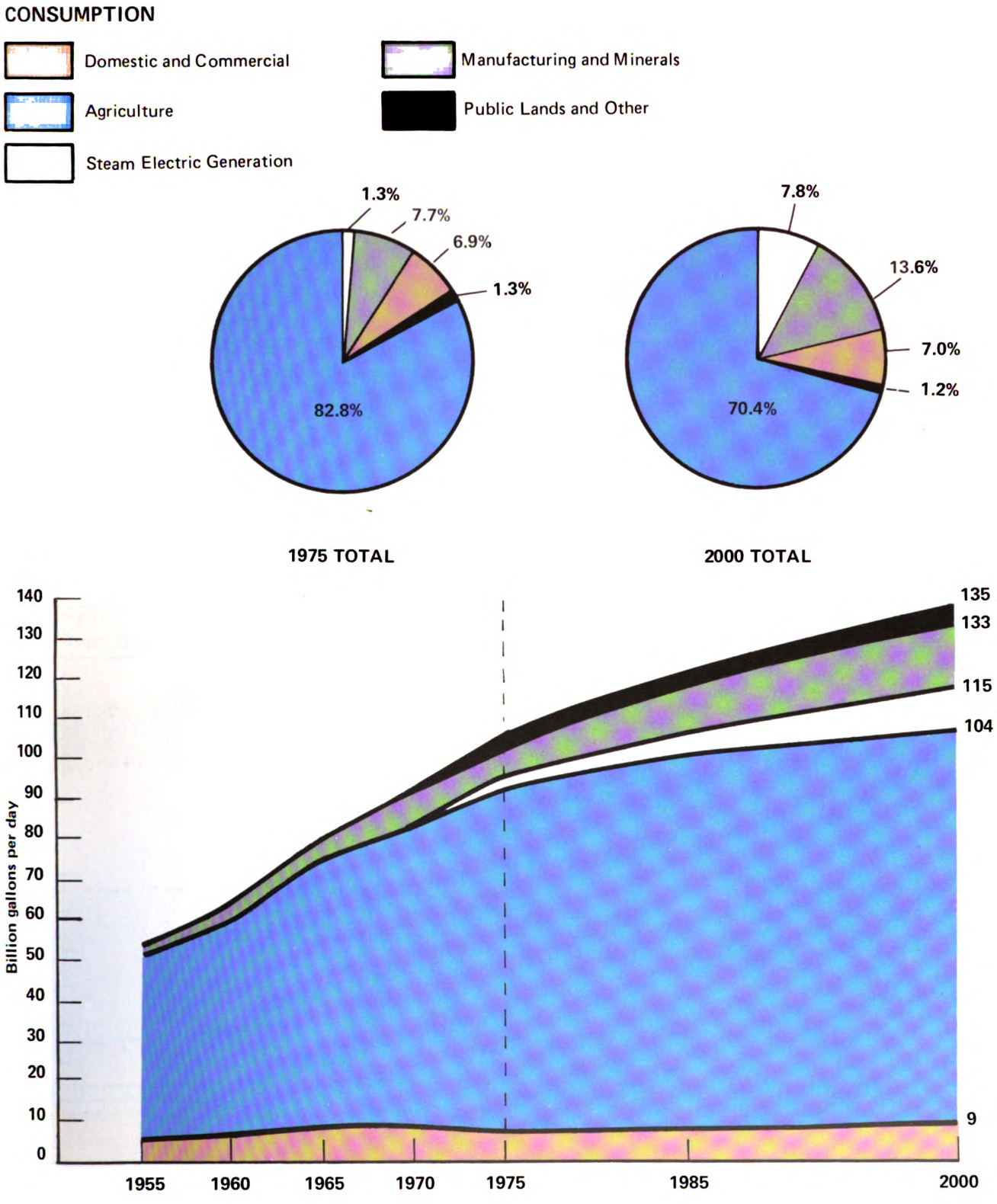

and consumption, by functional use

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Domestic and Commercial

For domestic and commercial purposes, central water-supply systems in "1975" provided water to approximately 179 million people (83 percent of the total population) in municipal areas. Of the population that lived outside the service areas of the central-supply systems, 33 million had their own domestic systems, usually wells, and about 4 million people had no piped water supply. Projections indicate that by the year 2000, central-supply systems will serve 242 million or 90 percent of the population; 26 million will depend on individual domestic water systems.

The percentage breakdown of total water used for domestic and commercial purposes varies slightly from region to region, mostly as a result of lawn care and swimming pools. Little change is projected; the total domestic use in "1975" was 28.8 bgd, and the projected increase to 37.0 bgd by the year 2000 is based largely on population increases.

Average daily domestic (central) withdrawal in "1975" was 118 gallons per capita per day (gcd). However, a typical family of four used about 87 gcd for drinking, culinary, washing, and sanitary needs. The 31-gcd difference is accounted for by delivery losses, fire protection, street washing, city and park maintenance, and other similar items. Most central systems have the capacity to deliver 150 gcd, but this amount includes some water for manufacturing which is accounted for in manufacturing water use. In a typical rural household (noncentral), domestic use averaged about 66 gallons per person—22 gallons outside the home and 44 gallons inside.

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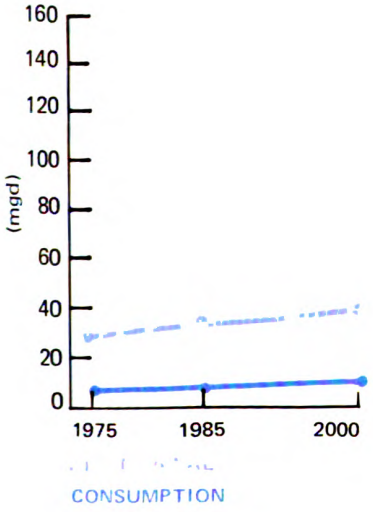
Domestic and commercial fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	1,483	1,616	1,798	212	231	254
Mid-Atlantic (2)	4,604	5,193	5,994	796	891	1,010
South Atlantic-Gulf (3)	2,841	3,433	4,254	998	1,217	1,506
Great Lakes (4)	4,277	4,705	5,283	589	642	703
Ohio (5)	2,337	2,597	2,914	411	456	498
Tennessee (6)	353	421	499	70	81	90
Upper Mississippi (7)	1,965	2,161	2,411	345	369	398
Lower Mississippi (8)	805	880	960	343	370	398
Souris-Red-Rainy (9)	68	71	70	31	31	31
Missouri (10)	1,246	1,351	1,497	331	352	380
Arkansas-White-Red (11)	945	1,028	1,132	348	377	409
Texas-Gulf (12)	1,490	1,697	1,921	507	570	659
Rio Grande (13)	327	352	380	168	181	195
Upper Colorado (14)	80	86	94	28	31	33
Lower Colorado (15)	498	612	772	234	288	364
Great Basin (16)	378	444	530	147	170	200
Pacific Northwest (17)	1,078	1,145	1,264	265	276	298
California (18)	3,388	3,809	4,360	1,434	1,610	1,839
Total, Regions 1–18	28,163	31,601	36,134	7,257	8,143	9,265
Alaska (19)	91	114	147	7	10	12
Hawaii (20)	177	208	255	55	64	78
Caribbean (21)	355	428	514	58	72	88
Total, Regions 1–21	28,786	32,351	37,050	7,377	8,289	9,443



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Manufacturing

In the United States, approximately 20 million people (almost 25 percent of the work force) are employed in 300,000 manufacturing plants that provide 27 percent of the total United States earnings. These plants are concentrated largely in areas of high population density. The concentration is so great that about 80 percent of the manufacturing earnings come from urban areas that represent about 2 percent of the Nation's total land area.

In 1954, manufacturing industries withdrew about 32.4 bgd of fresh and saline water from surface- and ground-water sources and recycled this water within the plant about 1.8 times before returning 93.2 percent to a water source. By "1975" the combined amount of water withdrawn increased to 60.9 bgd, which was recycled about 2.2 times before 90.5 percent was returned to surface-water sources.

By the year 2000, total in-plant manufacturing water requirements are projected to increase to 312 bgd. However, because of pollution control limitations on waste discharge, the technology of water management within plants is expected to change, and the result will be a tenfold in-plant recycling increase. Combined fresh- and saline-water withdrawals are thus projected to decline from the present 60.9 bgd to about 29.1 bgd in the year 2000. Fresh-water withdrawals, which amounted to 51.2 bgd in "1975," are expected to decline to 19.7 bgd by the year 2000. This projected decrease in withdrawals for manufacturing might be considered overly optimistic by some; however, experts from both Europe and the United States have indicated that the projection is within reason.

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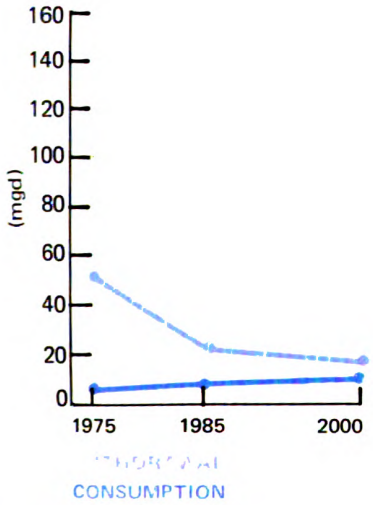
Manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	2,170	1,022	781	192	332	567
Mid-Atlantic (2)	5,416	2,526	1,942	607	934	1,361
South Atlantic-Gulf (3)	4,103	3,377	3,318	611	1,203	2,532
Great Lakes (4)	13,220	4,106	2,821	1,474	1,719	2,059
Ohio (5)	10,881	3,323	2,341	817	1,095	1,757
Tennessee (6)	2,093	765	671	147	266	514
Upper Mississippi (7)	2,030	886	728	240	309	506
Lower Mississippi (8)	4,163	1,634	1,365	314	552	1,067
Souris-Red-Rainy (9)	102	44	31	13	19	23
Missouri (10)	669	315	292	136	122	202
Arkansas-White-Red (11)	713	476	480	165	232	360
Texas-Gulf (12)	1,932	2,559	2,444	571	1,003	1,917
Rio Grande (13)	19	42	32	5	15	24
Upper Colorado (14)	4	2	2	2	1	2
Lower Colorado (15)	89	92	138	55	54	104
Great Basin (16)	112	93	98	24	42	77
Pacific Northwest (17)	2,324	1,321	1,132	329	501	880
California (18)	796	830	828	257	375	567
Total, Regions 1–18	50,836	23,413	19,444	5,959	8,774	14,519
Alaska (19)	134	93	86	26	41	68
Hawaii (20)	252	181	139	74	88	112
Caribbean (21)	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1–20	51,222	23,687	19,669	6,059	8,903	14,699

N/A = data not available.



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Agriculture

Water in agriculture is used for irrigation and livestock. Livestock watering is only 1 percent of the total water withdrawal for agricultural use. Of all functional water uses, irrigation is the largest use of water—there are about 45 million acres of irrigated farmland—and offers the greatest opportunity for conservation of water that could be diverted to additional agricultural production or other uses.

In "1975," irrigation water withdrawals were 158.7 bgd, and consumptive use was 86.4 bgd. Withdrawals are projected to decline somewhat as a result of ground-water overdraft in the Southwest and some increase in irrigation efficiency elsewhere. Consumption, however, is projected to increase slightly. In "1975," irrigation accounted for 81 percent of the total water consumed by the Nation, and the California Region used almost one-third of the total water consumed by irrigation. It should be pointed out that since the data were compiled for this report there has been a significant increase in irrigated cropland in the South Atlantic–Gulf Region.

Currently, the United States has about 2 billion acres used in agriculture and forestry of which about 422 million acres is in cropland. Since 1950, the Nation's agricultural crop production has increased 50 percent. This increase resulted from significant improvements in productivity—not from major increases in the total cropland harvested. The most significant improvements were more productive varieties of crops; increased use of chemical fertilizers, pesticides, and herbicides; larger and more efficient machinery; and improved management. Productivity is expected to continue to increase, but at a slower rate. Projections indicate that by the year 2000 domestic consumption of agricultural products will have increased by about 25 percent.

Irrigated agriculture is important to total agricultural production, particularly in specialty crops. Overall, national agricultural production has responded to domestic needs as well as to the international exports. Recently, the $20 billion to $25 billion annual export of agricultural products helped improve the Nation's balance of trade.

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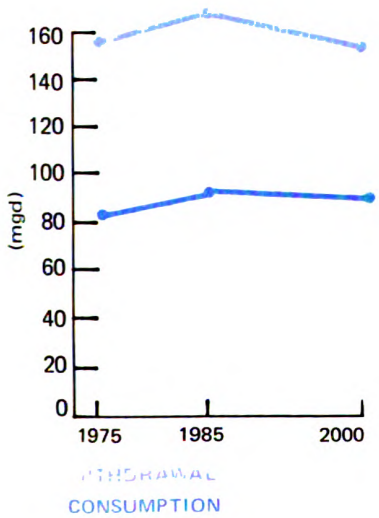
Irrigation fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	35	41	46	25	29	33
Mid-Atlantic (2)	265	366	481	196	269	354
South Atlantic-Gulf (3)	3,464	4,008	4,509	2,752	3,184	3,597
Great Lakes (4)	145	211	282	114	169	232
Ohio (5)	47	68	91	37	53	74
Tennessee (6)	14	18	21	11	14	17
Upper Mississippi (7)	192	283	387	153	230	323
Lower Mississippi (8)	4,580	4,559	4,444	3,065	3,204	3,272
Souris-Red-Rainy (9)	46	144	434	37	116	350
Missouri (10)	31,636	39,376	36,236	14,214	17,597	17,607
Arkansas-White-Red (11)	9,980	10,483	9,776	7,048	7,468	7,125
Texas-Gulf (12)	11,538	9,333	7,427	9,347	7,597	6,100
Rio Grande (13)	5,684	5,498	4,873	3,886	3,920	3,570
Upper Colorado (14)	6,400	7,223	6,672	2,194	2,657	2,741
Lower Colorado (15)	7,989	7,299	6,343	4,026	3,962	3,720
Great Basin (16)	6,969	6,120	5,825	3,225	3,082	3,196
Pacific Northwest (17)	33,181	34,639	29,961	11,026	13,362	13,213
California (18)	34,611	34,863	34,764	24,282	25,134	26,311
Total, Regions 1–18	156,776	164,532	152,572	85,638	92,047	91,835
Alaska (19)	4	4	4	3	3	3
Hawaii (20)	1,447	1,226	951	474	481	473
Caribbean (21)	516	490	319	276	289	195
Total, Regions 1–21	158,743	166,252	153,846	86,391	92,820	92,506



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Energy Production

Steam-powered generation of electricity accounted for 95 percent (88.9 bgd) of the fresh-water withdrawals for all energy production in "1975." As a result of advances in cooling technology, by the year 2000 fresh-water withdrawals for steam electric generation are projected to decrease by 11 percent (79.5 bgd) but will still constitute 94 percent of the fresh-water withdrawals for energy production. Although steam electric generation requires large amounts of water, its consumptive use of water was only 2 percent of the fresh-water withdrawals for steam electric generation in "1975." However, along with the projected decrease in withdrawals by the year 2000 due to cooling technology, consumption is projected to increase to 13 percent of the fresh-water withdrawals for steam electric generation. This significant increase is due largely to greater evaporation resulting from higher temperatures in the recycling process.

Other types of energy production (mining and processing of coal and oil shale, and extracting and refining of oil and natural gas) account for the remaining 5 percent of the total fresh-water withdrawals for energy production. This percentage is accounted for in manufacturing and minerals industry water use. As coal-produced energy becomes more significant, so will water used in its production. The problems of water for energy production will emerge first in the Missouri, Ohio, and Upper Colorado Regions where there are large coal and oil-shale deposits.

In addition to the fresh-water withdrawals described above, large amounts of saline water also are used in energy production.

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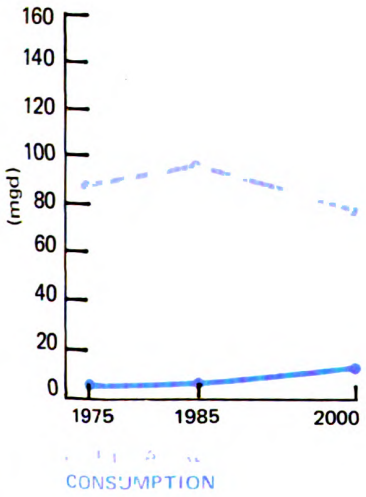
Steam electric generation fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	1,263	1,069	375	21	18	167
Mid-Atlantic (2)	7,463	7,130	4,657	103	224	644
South Atlantic-Gulf (3)	12,768	12,912	13,952	153	722	1,857
Great Lakes (4)	24,362	22,689	16,061	175	497	1,384
Ohio (5)	21,022	21,008	10,574	324	656	1,692
Tennessee (6)	4,799	5,738	4,581	42	231	417
Upper Mississippi (7)	7,644	6,347	3,537	129	352	1,079
Lower Mississippi (8)	4,175	9,313	16,687	54	118	291
Souris-Red-Rainy (9)	82	23	0	1	0	0
Missouri (10)	3,540	5,834	4,938	68	239	637
Arkansas-White-Red (11)	498	1,026	1,012	89	237	457
Texas-Gulf (12)	724	1,000	1,713	99	270	991
Rio Grande (13)	34	16	10	18	9	5
Upper Colorado (14)	103	157	201	39	106	151
Lower Colorado (15)	68	150	154	63	134	126
Great Basin (16)	33	65	82	3	42	52
Pacific Northwest (17)	260	203	580	13	104	344
California (18)	42	158	367	25	101	242
Total, Regions 1–18	88,880	94,838	79,481	1,419	4,060	10,536
Alaska (19)	36	20	11	0	2	5
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1–21	88,916	94,858	79,492	1,419	4,062	10,541



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Minerals Industry

In the minerals industry, water is used for mining metals, nonmetals, and fuels. Metals include lead, zinc, manganese, gold, silver, copper, and molybdenum. Nonmetals are lime, clay, barite, phosphate, rock salt, pumice, cement, sand and gravel, and stone. Fuels include coal, oil shale, petroleum, natural gas, and natural gas liquids.

The minerals industry withdrew an average of 7.1 bgd or 2.1 percent of the Nation's fresh-water withdrawals in "1975." Water withdrawals for the minerals industry are projected to increase 61 percent by the year 2000 to an average of 11.3 bgd, or 3.7 percent of the Nation's fresh-water withdrawals. Water withdrawals for the minerals industry will grow concurrently with increased use of minerals unless there are improvements in water-use efficiency or recycling. This projected increase of 61 percent is in contrast to other water uses inasmuch as the Nation's total fresh-water withdrawals are projected to decline 9 percent between "1975" and 2000. Consumption of water for the minerals industry is expected to increase 64 percent by the year 2000; however, it is expected to remain fairly constant at 2 to 3 percent of the Nation's consumption of water.

Water withdrawals for nonmetals mining in "1975" accounted for more than half the industry's total. However, fuels mining and processing, which accounted for about 36 percent of the industry's total withdrawals, was responsible for 62 percent of the industry's total consumption. Water used in fuels mining is important in the Missouri and Upper Colorado Regions where coal and oil-shale mining and processing are developing.

Water withdrawals and consumption for metals mining is stable at about 12 to 14 percent of the industry's total.

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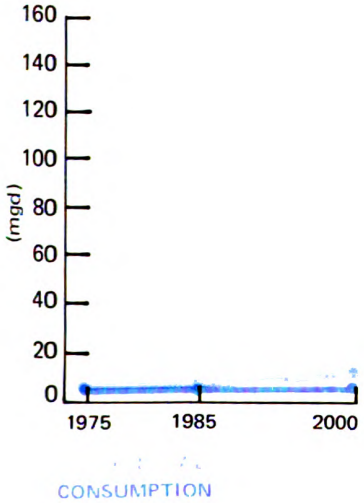
Minerals industry fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	90	115	153	11	16	20
Mid-Atlantic (2)	459	548	700	70	82	102
South Atlantic-Gulf (3)	1,178	1,538	2,077	214	274	349
Great Lakes (4)	696	831	1,044	155	175	211
Ohio (5)	493	662	808	91	132	160
Tennessee (6)	110	140	186	15	21	27
Upper Mississippi (7)	333	417	533	46	58	74
Lower Mississippi (8)	799	1,010	1,318	206	253	416
Souris-Red-Rainy (9)	8	9	10	3	3	3
Missouri (10)	269	356	424	111	139	163
Arkansas-White-Red (11)	448	469	571	173	184	218
Texas-Gulf (12)	1,044	1,133	1,245	555	588	632
Rio Grande (13)	190	221	255	103	129	150
Upper Colorado (14)	132	195	355	47	72	144
Lower Colorado (15)	184	252	311	151	217	280
Great Basin (16)	145	206	273	28	44	64
Pacific Northwest (17)	118	141	167	18	19	27
California (18)	297	359	375	183	225	213
Total, Regions 1–18	6,993	8,602	10,805	2,180	2,631	3,253
Alaska (19)	30	192	476	12	141	350
Hawaii (20)	1	1	1	0	0	0
Caribbean (21)	31	37	46	4	5	6
Total, Regions 1–21	7,055	8,832	11,328	2,196	2,777	3,609



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Instream Use

The First National Water Assessment did not address instream-flow uses due to lack of data, but stated that "in future assessments, a more complete analysis of the adequacy of flow for instream uses will be undertaken."

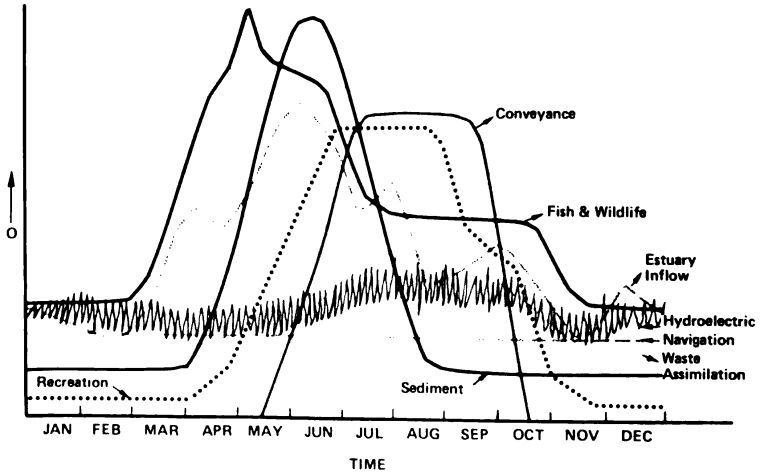
In fulfilling that promise, this second assessment provides the first nationwide examination of instream-flow conditions—and the implications of accelerated offstream uses of water—through a volumetric analysis of the consumptive and nonconsumptive water uses in relation to water supply.

Instream-flow use, often referred to as instream-flow need, is that amount of water flowing through a natural stream channel needed to sustain the instream values at an acceptable level. Values of instream flows relate to uses made of water in the stream channel that include fish and wildlife population maintenance, outdoor recreation activities, navigation, hydroelectric generation, waste assimilation (sometimes termed water quality), conveyance to downstream points of diversion, and ecosystem maintenance that includes fresh-water recruitment to the estuaries and riparian vegetation and flood-plain wetlands. Streamflow sufficient to maintain all these uses establishes the acceptable level for the "instream-flow uses." Understandably, at a given location in a given stream system, only certain uses may be applicable. The actual instream-flow needs are based on the dominant of those instream-flow uses, or alternatively, on the resulting best mix after tradeoffs within the instream-use sector have been made.

The second assessment has quantified minimum streamflow levels for fish and wildlife population maintenance and for navigation. In all subregions, the fish and wildlife use is the dominant instream-flow use.

Also, in this assessment, streamflows for treaties and compacts were cited for those subregions where a compact or treaty affected the flows to be discharged from the subregion.

Approximately 50 interstate compacts and international treaties affecting water resources have been approved by the Congress; still others are in negotiation. The purpose of most of these compacts and treaties is to allocate the amounts of water among political subdivisions for existing or potential uses downstream.



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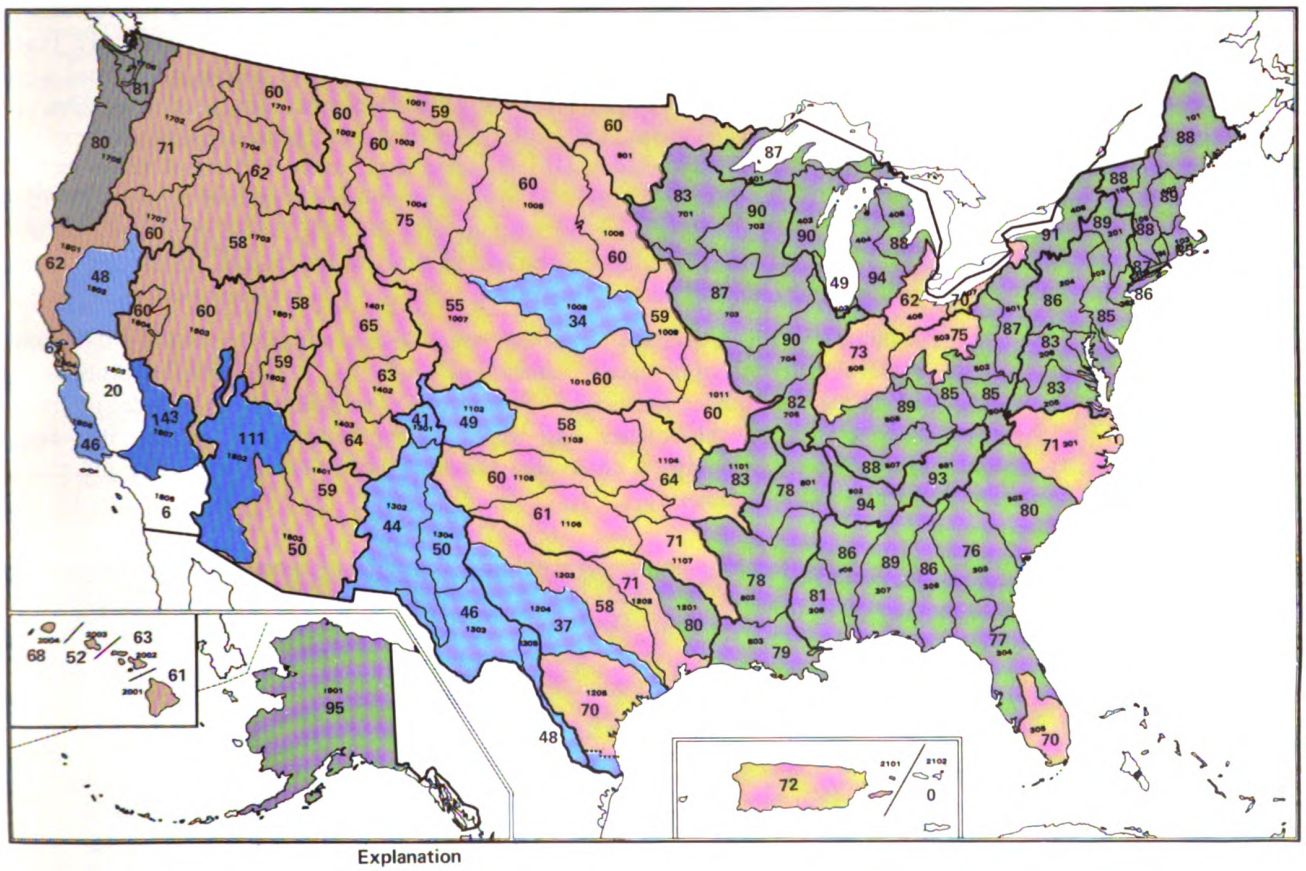
Fish and Wildlife

In order to reflect the relative severity of problems in management and use of the Nation's water supplies, instream-flow approximations (IFA's) for fish and wildlife were developed. However, an analysis of the instream-flow approximation for a group of streams comprising a major river basin cannot be made without sacrifice in precision.

Instream-flow approximations were prepared solely for use in the water-data analysis of the Second National Water Assessment. These estimates are for the outflow point(s) of each subregion. They represent judgmental estimates of monthly flow regimes sufficient to support habitat of aquatic life and outdoor recreation. These estimates are useful for guiding decisions, but better or more definitive methods are available and should be applied in site-specific studies.

The percentage of total streamflow represented by the instream-flow approximations is shown in the map below. The variability of the percentages reflects the different methods used and the relative recognition of water-resources development.



Instream flow approximations for fish and wildlife, as a percentage of total streamflow

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Outdoor Recreation

Water-related outdoor recreation activities are divided into two types—water-dependent and water-enhanced—that require a substantial supply of accessible water and supporting lands and facilities. These recreation activities are measured in "activity occasions," which is defined as participation by a person 12 years or older in a specific activity without regard to the duration of the activity. In "1975," there were 2 billion activity occasions; by the year 2000, activity occasions are projected to increase by 34 percent to 2.7 billion.

Water-dependent activities consist of beach swimming (43 percent), sport fishing (28 percent), boating (20 percent), water skiing (5 percent), and sailing and canoeing (about 2 percent each). In "1975," activity occasions for water-dependent recreation were estimated to number 1,379 million.

Water-enhanced activities are divided between picnicking (83 percent) and camping (17 percent). In "1975," activity occasions for water-enhanced recreation were in excess of 600 million.

About 20.3 million acres of surface water are accessible and usable for recreation in the conterminous United States, or about 122 acres per 1,000 people (12 years of age or older). However, this recreational surface-water area is only about one-fourth of the nearly 84.6 million acres of surface-water area available. The remaining 64.3 million acres of potential recreation water area are now inaccessible, polluted, or otherwise restricted from recreational uses. Additional water-surface needs for recreation were estimated to be a cumulative 8 million acres in "1975," 10 million acres in 1985, and 13 million acres in 2000. These needs may be met by removing restrictions on access to existing water bodies, improving water quality, and reducing competitive uses.

A number of major recreation problem issues were evaluated in all 106 subregions. Preserving free-flowing stream values was ranked as a high priority problem in 73 subregions. Ranked in descending order, other recreation issues include: retaining flood plains, coastal beaches, and wetlands; improving water quality; increasing recreation opportunities at reservoirs; providing public access to water; and maintaining instream flows.

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Outdoor recreation activity occasions—"1975," 1985, 2000

[million activity occasions]

Water resources region and No.	Water-dependent			Water-enhanced		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	69.8	77.9	91.0	35.7	40.9	48.4
Mid-Atlantic (2)	217.9	246.6	289.3	115.0	131.0	155.9
South Atlantic-Gulf (3)	160.5	192.0	235.1	57.9	68.4	85.3
Great Lakes (4)	220.4	247.1	295.0	106.6	119.1	138.7
Ohio (5)	142.1	158.3	182.8	58.9	65.5	75.5
Tennessee (6)	22.5	26.4	31.9	8.0	9.4	11.3
Upper Mississippi (7)	97.3	112.0	126.4	47.6	53.0	61.4
Lower Mississippi (8)	40.7	44.3	49.4	14.5	15.8	17.5
Souris-Red-Rainy (9)	4.7	4.7	4.8	2.3	2.3	2.3
Missouri (10)	61.9	67.5	77.2	32.8	35.7	40.8
Arkansas-White-Red (11)	44.5	48.6	55.8	18.0	19.7	22.2
Texas-Gulf (12)	62.6	73.1	89.2	22.3	26.0	31.7
Rio Grande (13)	10.7	11.7	13.1	5.9	6.5	7.3
Upper Colorado (14)	2.2	2.3	2.6	1.4	1.5	1.7
Lower Colorado (15)	15.4	19.2	25.4	9.8	12.3	16.3
Great Basin (16)	8.0	9.7	12.2	5.2	6.2	7.8
Pacific Northwest (17)	42.7	46.1	53.1	27.4	29.6	34.0
California (18)	134.8	156.6	189.5	86.4	100.4	121.3
Total, Regions 1–18	1,358.7	1,544.0	1,823.7	655.7	743.3	879.4
Alaska (19)	2.0	2.4	3.1	1.3	1.5	2.0
Hawaii (20)	18.2	20.8	25.6	5.9	6.6	8.0
Caribbean (21)	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1–20	1,378.9	1,567.2	1,852.4	662.9	751.5	889.4

N/A = data not available.

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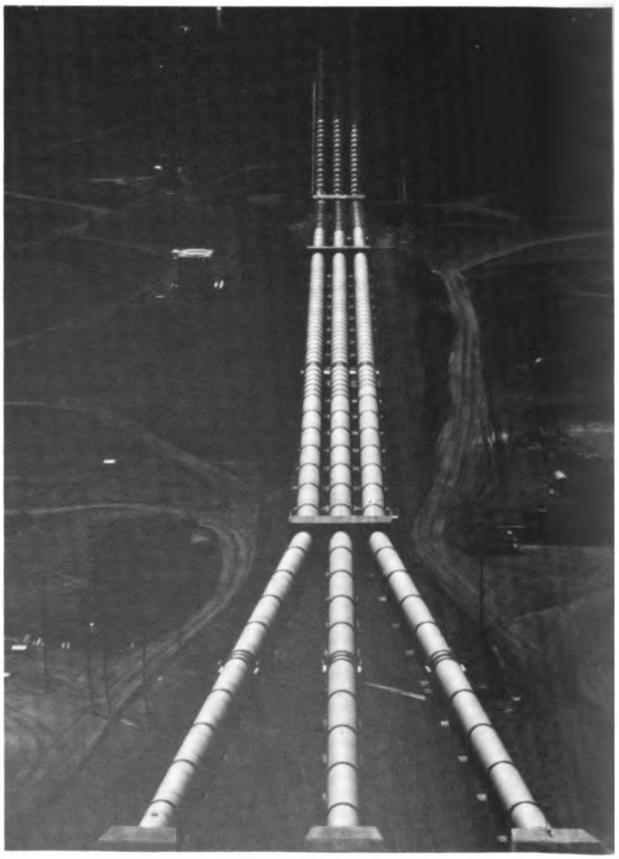
Hydroelectric Generation

In "1975," hydroelectric generation supplied about 15 percent of the total national electricity requirement. Conventional hydroelectric plants are projected to generate only about 6 percent more electricity in the year 2000 than they did in "1975."

Throughout the Nation hydroelectric powerplants commonly are used to meet peak daily electric loads. However, in the Pacific Northwest, where runoff is high and reservoir capacity large, base loads generally are met by hydroelectric generation; auxiliary steam electric generation is used to meet daily peak loads only when the hydroelectric generation capacity is inadequate or when reservoir levels must be protected to avoid base-load interruption. Peak-load plants usually operate for only a limited number of hours and a limited number of days of the week except for that part of the plant through which a discharge is made to maintain continuous downstream flow for fish, wildlife, navigation, and other purposes.

Hydroelectric powerplants have the advantage of producing power without consuming fuel and without polluting water or air. These plants have long lives, low operating costs, and low outage rates. New advances in low-head flow generation and rewinding generators to increase production offer renewed interest in the potential of hydroelectric generation, particularly as fuel costs increase.



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Navigation

The Nation's rivers and lakes have served as avenues for public and commodity transportation from the time of the earliest inhabitants. Since about 1770, the extent and capacity of inland and intracoastal waterway systems have continually increased to the point where they now consist of more than 25,000 miles of navigable channels and canals. Between "1975" and the year 2000 the inland waterway network is expected to have few major changes in either total length or channel dimensions. The major components of the network are:

- *The Mississippi River and Tributaries*—about 9,000 miles of commercial waterways, of which 65 percent has an authorized channel depth of 9 feet.
- *The Gulf Intracoastal Waterway and Other Gulf Coastal Waterways*—about 5,400 miles of navigable channels, of which 50 percent has a depth of at least 9 feet.
- *The Atlantic Intercoastal, New York, and New England Waterways*—about 7,000 miles of which 60 percent has an authorized channel depth of 9 feet.
- *The Central California and Columbia-Snake Waterways*—about 3,600 miles, of which 65 percent has a channel 9 feet deep.

The Great Lakes Waterway System and the St. Lawrence Seaway, which connects the Great Lakes with the Atlantic Ocean, add an additional 1,700 miles of navigable waters to the total.

In 1965, total domestic waterborne traffic was 829 million tons; by 1974 the traffic increased to about 1,000 million tons. By the year 2000, 1,500 million tons is expected. In 1974, domestic waterborne commerce was about 25 percent of the total intercity freight measured in ton-miles, but only about 16 percent of the net tons carried. These percentages represent only a slight decline from 1965 figures.

The instream flow required for navigation's nonconsumptive use depends largely on the degree to which the waterways are channeled, the depth being maintained, the number of locks, the degree to which lockage water is pumped back to upper pools, and other factors. In 1985 and 2000, water supplies, without consideration of needs for other purposes, are expected to be adequate for navigation in most water resources regions except for perhaps the Missouri Region.

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Water Use—Overview

"1975" and 2000

Relative per capita withdrawal and consumption rates in each of the 21 regions reflect the population density, as well as the mix of water-intensive industries in each region. In "1975," the Nation had a water withdrawal rate of 1,564 gcd (gallons per capita per day) and a consumption rate of 493 gcd. By the year 2000, the withdrawal rate is projected to decline by 27 percent to 1,143 gcd, but the consumption rate will remain almost unchanged at 504 gcd. The highest per capita withdrawal in "1975" was in the Upper Colorado Region—about 20,000 gcd, a rate nearly 50 times greater than the combined withdrawals for the New England and Mid-Atlantic Regions. By the year 2000, the Upper Colorado Region per capita daily withdrawal rate is expected to be nearly 100 times that of the Northeast.

In most western regions consumption is projected to be around 2,000 gcd, about 4 times the national average and about 50 times that of the Northeast. These higher consumption rates will result largely from the relative concentration of irrigated agriculture, minerals mining, and steam electric generation in areas of low population density.

In summary, most of the withdrawals and consumption of water in the Nation supports agricultural and energy production. Great opportunities for effecting more efficient allocation and use for water exist in these offstream functional use areas.

Total fresh-water withdrawals and consumption—"1975," 1985, 2000

[million gallons per day]

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	5,098	3,939	3,230	481	647	1,063
Mid-Atlantic (2)	18,300	15,857	13,873	1,843	2,472	3,548
South Atlantic-Gulf (3)	24,510	25,457	28,340	4,867	6,772	10,053
Great Lakes (4)	42,813	32,666	25,623	2,598	3,300	4,693
Ohio (5)	34,934	27,838	16,925	1,798	2,527	4,332
Tennessee (6)	7,412	7,131	6,013	313	647	1,105
Upper Mississippi (7)	12,401	10,386	7,910	1,145	1,604	2,688
Lower Mississippi (8)	14,567	17,453	24,841	4,027	4,554	5,511
Souris-Red-Rainy (9)	336	329	587	112	204	446
Missouri (10)	38,016	48,037	44,359	15,469	19,206	19,913
Arkansas-White-Red (11)	12,868	13,799	13,337	8,064	8,769	8,887
Texas-Gulf (12)	16,925	15,932	14,991	11,259	10,227	10,529
Rio Grande (13)	6,321	6,204	5,633	4,240	4,320	4,016
Upper Colorado (14)	6,869	7,841	7,519	2,440	3,018	3,232
Lower Colorado (15)	8,917	8,528	7,857	4,595	4,754	4,708
Great Basin (16)	7,991	7,316	7,258	3,779	3,765	4,036
Pacific Northwest (17)	37,495	38,098	33,852	11,913	14,610	15,196
California (18)	39,636	40,549	41,265	26,641	27,932	29,699
Total, Regions 1–18	335,409	327,360	303,413	105,584	119,328	133,655
Alaska (19)	305	433	745	58	207	459
Hawaii (20)	1,879	1,619	1,349	605	636	666
Caribbean (21)	907	963	890	343	374	300
Total, Regions 1–21	338,500	330,375	306,397	106,590	120,545	135,080

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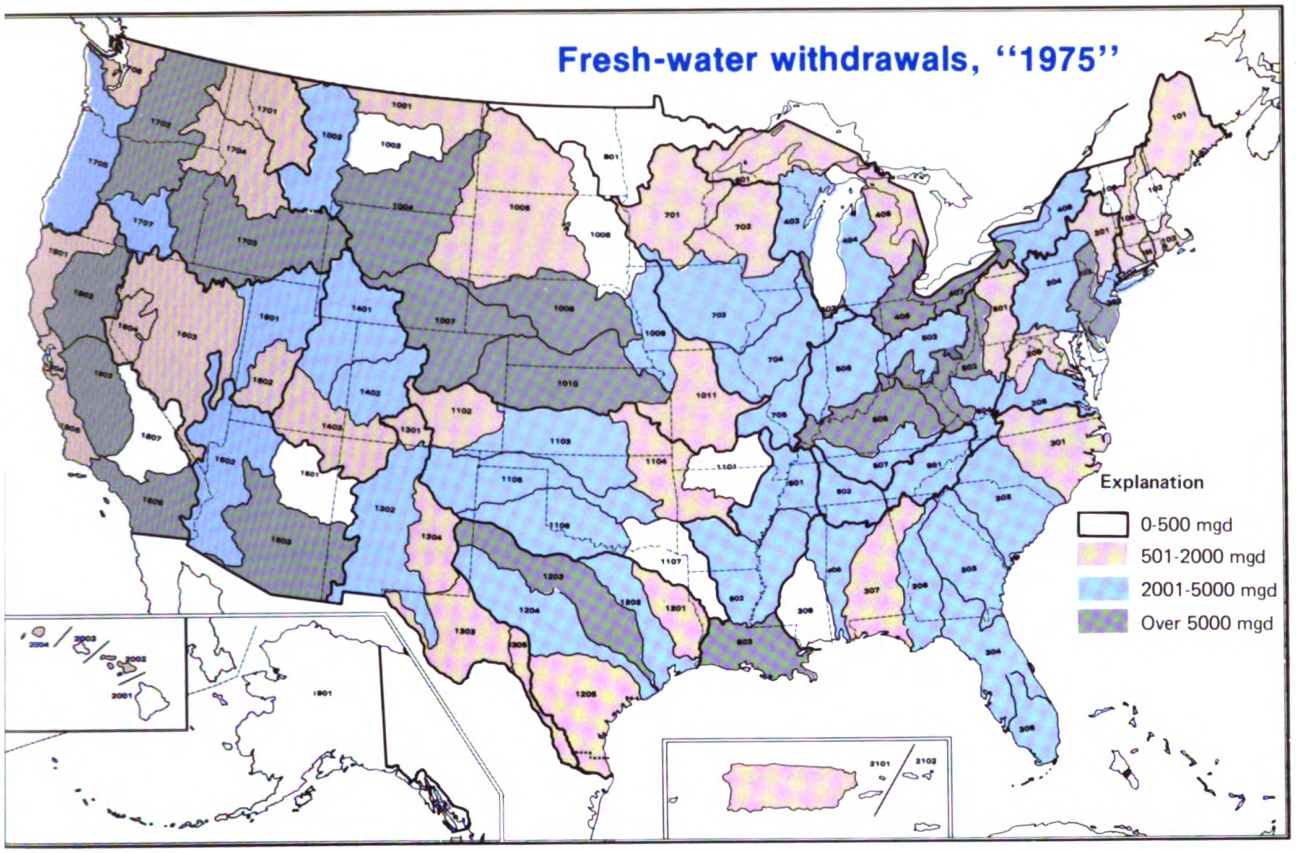

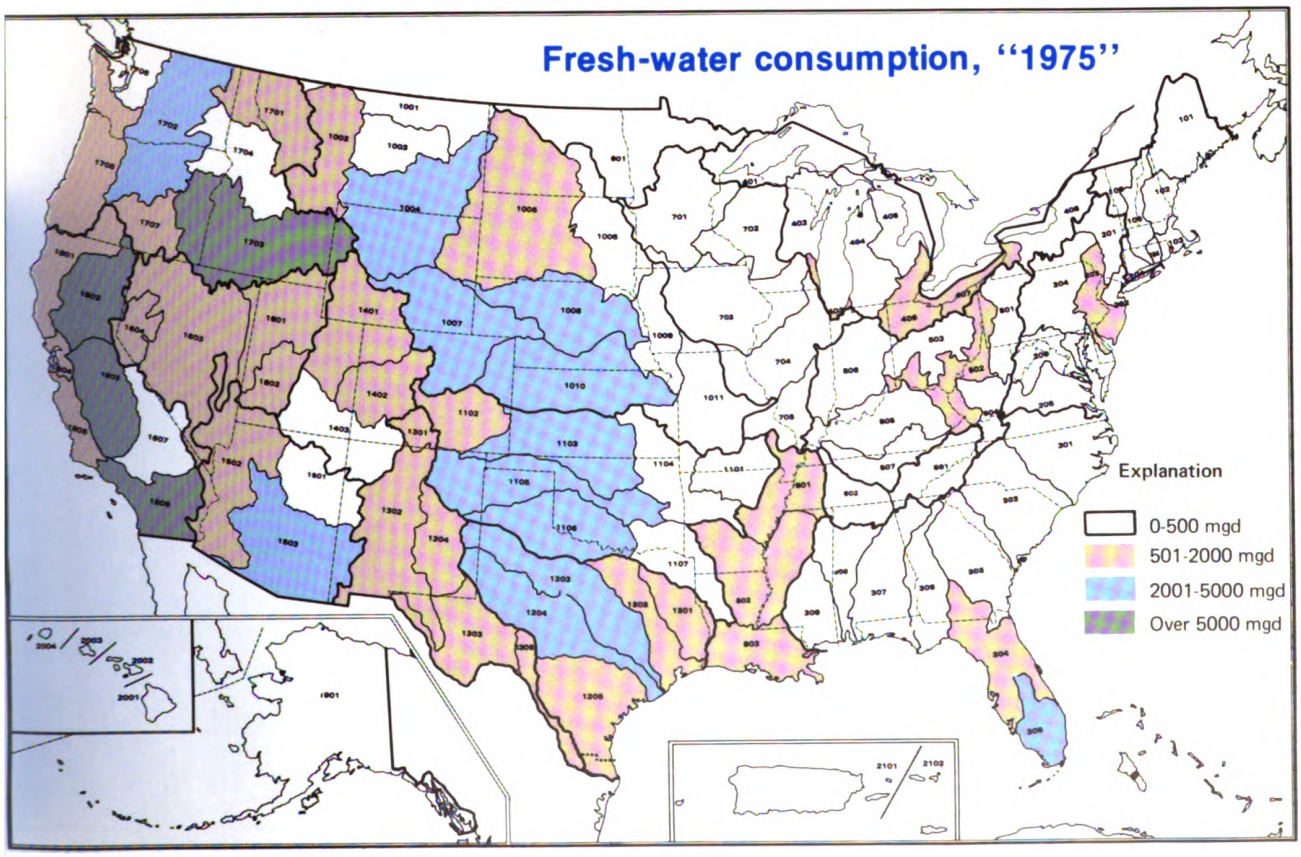

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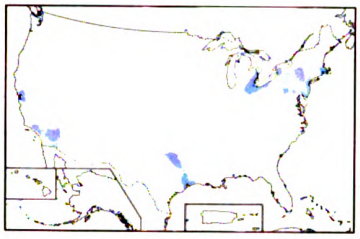
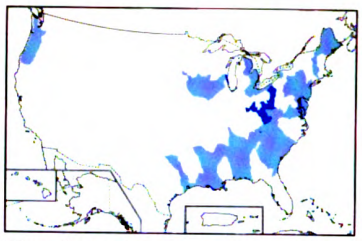
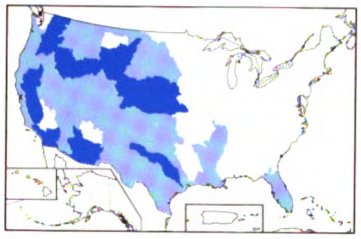


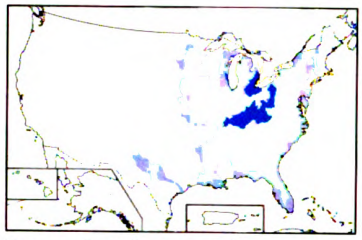
Domestic and Commercial



Manufacturing



Agriculture



Steam electric generation

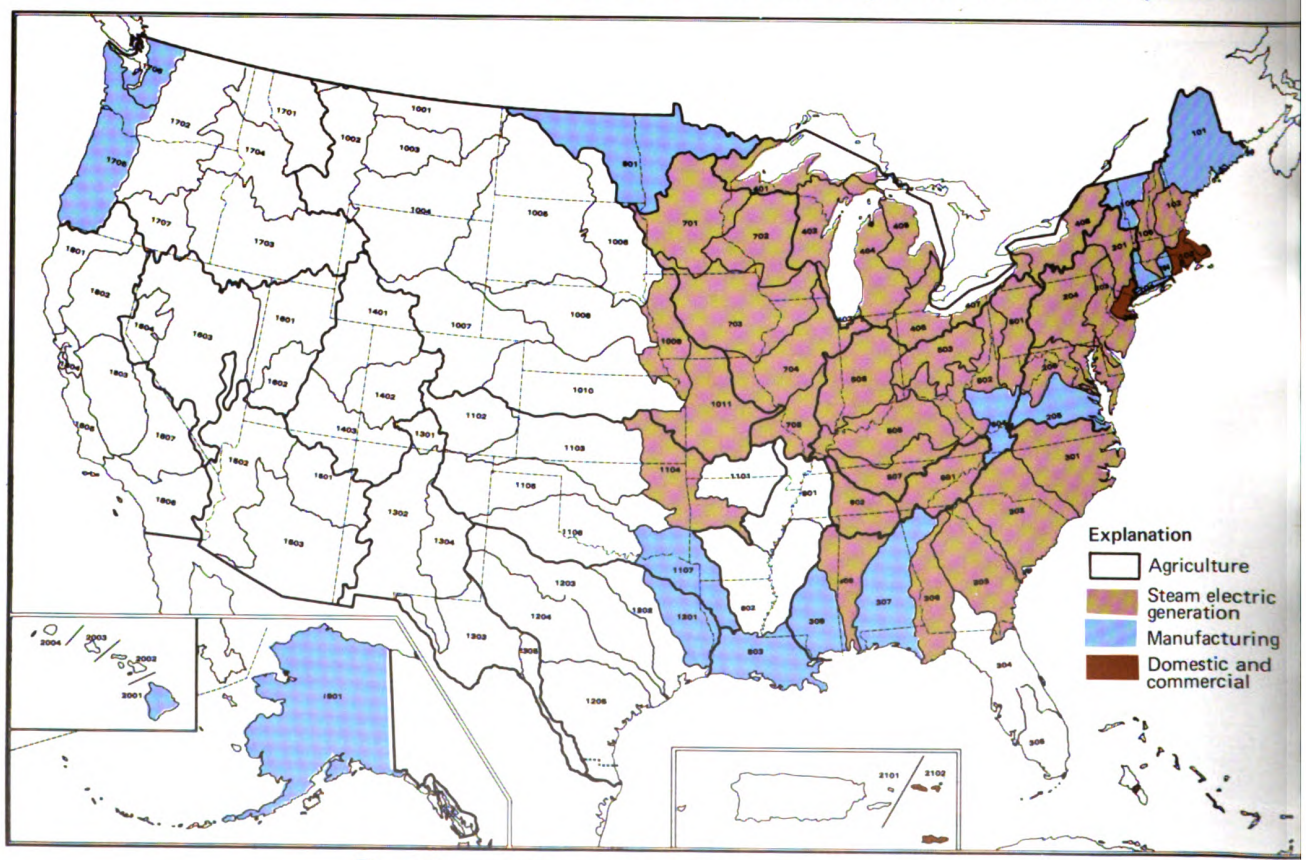
Minerals

Explanation

Million gallons per day

- 0-500
- 500-5000
- Over 5000

Water withdrawals by functional use, "1975"



Dominant functional water use, by subregion, "1975"

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IDENTIFICATION OF CRITICAL PROBLEMS

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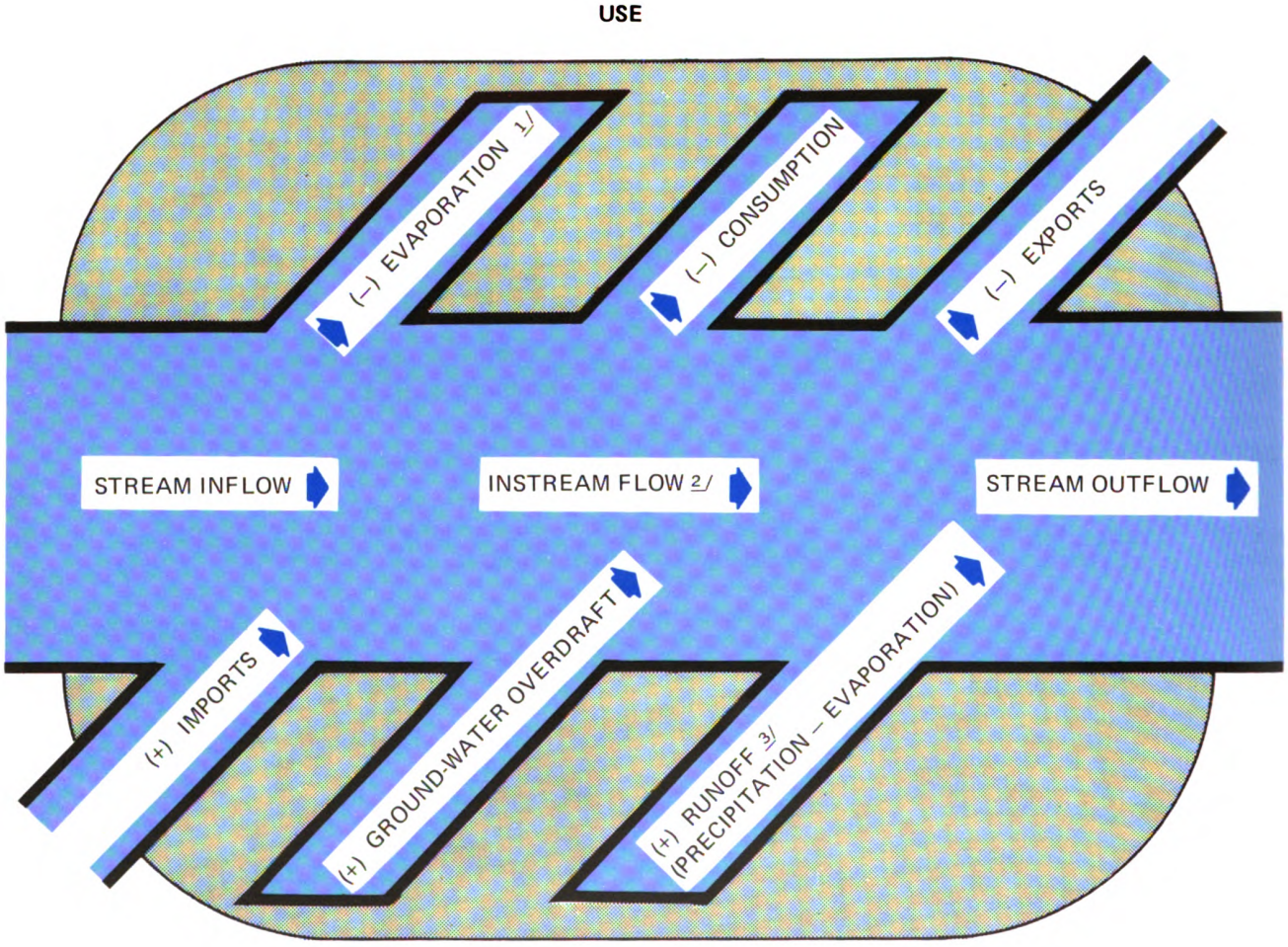
Analysis of Supply and Use

Water-Supply Adequacy Analysis Model

To identify the Nation's critical water problems, a water-supply adequacy analysis model was developed. It was based on the concept of a balance between water use and water supply, and took into consideration both ground water and fresh surface water. This model, which is shown graphically below, provided a subregional analysis for each of the 106 water resources subregions.



1/ Includes only evaporation from manmade reservoirs.

2/ Includes flow requirements for navigation, hydroelectric, conveyance to meet downstream treaty and compact commitments, fish and wildlife habitat maintenance, waste assimilation, recreation, sediment transport and fresh-water inflow to estuaries.

3/ Includes precipitation minus natural evaporation from the land surfaces and plant transpiration, and drainage to ground water.

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Subregions have water inflow or supply from upstream subregions, interbasin imports, precipitation runoff, and ground water. Water uses include interbasin exports, consumption, and evaporation, which are deducted from the potential supply. Ground-water recharge is accounted for in the model and is not considered a loss.

Quantities listed in the following table of water supply and uses were obtained by means of the adequacy analysis model. The analysis for "1975" includes conditions both with and without ground-water overdraft. The analysis for future conditions, 1985 and 2000, excludes ground-water overdraft on the basis that excessive pumping becomes uneconomical as water levels continue to decline.

Comparison of Water Supply and Water Use

Comparison of water-supply and water-use data shows that overall the Nation's water supplies generally are sufficient to meet water needs for all beneficial purposes. However, there are major water problems in most of the 21 water resources regions, and more particularly there are local problems of varying intensity in nearly all of the 106 subregions. These problems include shortages resulting from poor distribution of supplies, instream-offstream conflicts, competition among various offstream users, ground-water overdraft, quality degradation of both surface water and ground water, and institutional conflicts that prevent a unified approach to water management.

Ten critical problems are identified in the following pages. Each problem is delineated on a map of the United States. These problems overlap, and solutions to one problem should not be considered in isolation of the other problems.

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Summary of fresh-water supply and use—"1975," 1985, 2000

[Data are in million gallons per day. Shaded areas reflect conditions without ground-water overdraft]

Water resources region and No.	Year[1]	Supply			Use			Remaining stream outflow	Instream flow approximation[5]
		Stream inflow[2]	Natural outflow[3]	Net imports	Ground-water overdraft	Total consumption	Net evaporation[4]	Net exports		
New England (1)	"1975"	0	78,661	0	0	481	0	0	78,180	
	"1975"	0	78,661	0	0	481	0	0	78,180	69,001
	1985	0	78,661	0	0	647	0	0	78,014	
	2000	0	78,661	0	0	1,063	0	0	77,598	
Mid-Atlantic (2)	"1975"	0	80,522	479	32	1,843	0	0	79,190	
	"1975"	0	80,522	479	0	1,843	0	0	79,158	68,840
	1985	0	80,522	479	0	2,472	0	0	78,529	
	2000	0	80,522	479	0	3,548	0	0	77,453	
South Atlantic-Gulf (3)	"1975"	0	232,544	0	339	4,867	0	6	228,010	
	"1975"	0	232,544	0	0	4,867	0	6	227,671	188,655
	1985	0	232,544	0	0	6,772	0	6	225,766	
	2000	0	232,544	0	0	10,053	0	6	222,485	
Great Lakes (4)	"1975"	0	75,262	19	27	2,598	0	0	72,710	
	"1975"	0	75,262	19	0	2,598	0	0	72,683	63,951
	1985	0	75,262	19	0	3,300	0	0	71,981	
	2000	0	75,262	19	0	4,693	0	0	70,588	
Ohio (5)	"1975"	40,800	138,998	0	0	1,798	0	0	178,000	
	"1975"	40,800	138,998	0	0	1,798	0	0	178,000	160,520
	1985	40,466	138,998	0	0	2,527	0	0	176,937	
	2000	40,008	138,998	0	0	4,332	0	0	174,674	
Tennessee (6)	"1975"	0	41,113	0	0	313	0	0	40,800	
	"1975"	0	41,113	0	0	313	0	0	40,800	38,480
	1985	0	41,113	0	0	647	0	0	40,466	
	2000	0	41,113	0	0	1,105	0	0	40,008	
Upper Mississippi (7)	"1975"	44,100	76,024	2,064	0	1,145	43	0	121,000	
	"1975"	41,543	76,024	2,064	0	1,145	43	0	118,443	110,750
	1985	37,428	76,024	2,064	0	1,604	45	0	113,867	
	2000	35,880	76,024	2,064	0	2,688	46	0	111,234	
Lower Mississippi (8)	"1975"	361,600	75,015	0	412	4,027	0	0	433,000	
	"1975"	353,586	75,015	0	0	4,027	0	0	424,574	359,033
	1985	346,966	75,015	0	0	4,554	0	0	417,457	
	2000	341,804	75,015	0	0	5,511	0	0	411,308	
Souris-Red-Rainy (9)	"1975"	0	6,138	0	0	112	16	0	6,010	
	"1975"	0	6,138	0	0	112	16	0	6,010	3,673
	1985	0	6,138	58	0	204	18	0	5,974	
	2000	0	6,138	641	0	446	19	0	6,314	
Missouri (10)	"1975"	0	61,525	411	2,557	15,469	4,924	0	44,100	
	"1975"	0	61,525	411	0	15,469	4,924	0	41,543	33,958
	1985	0	61,525	433	0	19,206	5,324	0	37,428	
	2000	0	61,525	0	0	19,913	5,595	137	35,880	
Arkansas-White-Red (11)	"1975"	0	67,694	128	5,457	8,064	2,615	0	62,600	
	"1975"	0	67,694	128	0	8,064	2,615	0	57,143	46,169
	1985	0	67,694	177	0	8,769	2,910	0	56,192	
	2000	0	67,694	200	0	8,887	3,111	0	55,896	
Texas-Gulf (12)	"1975"	0	35,626	30	5,578	11,259	1,705	0	28,270	
	"1975"	0	35,626	30	0	11,259	1,705	0	22,692	22,917
	1985	0	35,626	30	0	10,227	1,875	0	23,554	
	2000	0	35,626	30	0	10,529	1,992	0	23,135	
Rio Grande (13)	"1975"	0	5,309	234	657	4,240	730	0	1,230	
	"1975"	0	5,309	234	0	4,240	730	0	573	2,287
	1985	0	5,309	199	0	4,320	764	0	424	
	2000	0	5,309	199	0	4,016	785	0	707	

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Summary of fresh-water supply and use—"1975," 1985, 2000—continued

[Data are in million gallons per day. Shaded areas reflect conditions without ground-water overdraft]

Water resources region and No.	Year[1]	Supply: Stream inflow[2]	Supply: Natural outflow[3]	Supply: Net imports	Supply: Ground-water overdraft	Use: Total consumption	Use: Net evaporation[4]	Use: Net exports	Remaining stream outflow	Instream flow approximation[6]
Upper Colorado (14)	"1975"	0	13,956	0	0	2,440	711	805	10,000	
	"1975"	0	13,956	0	0	2,440	711	805	10,000	7,947
	1985	0	13,956	0	0	3,018	721	985	9,232	
	2000	0	13,956	0	0	3,232	728	1,095	8,901	
Lower Colorado (15)	"1975"	10,000	-605	0	2,415	4,595	1,202	4,463	1,550	
	"1975"	10,000	-605	0	0	4,595	1,202	4,463	[5]-865	6,864
	1985	9,232	-605	0	0	4,754	1,222	4,084	[5]-1,433	
	2000	8,901	-605	0	0	4,708	1,236	3,896	[5]-1,544	
Great Basin (16)	"1975"	0	5,976	101	591	3,779	327	0	2,562	
	"1975"	0	5,976	101	0	3,779	327	0	1,971	3,389
	1985	0	5,976	177	0	3,765	331	0	2,057	
	2000	0	5,976	251	0	4,036	333	0	1,858	
Pacific Northwest (17)	"1975"	0	268,523	47	627	11,913	2,014	0	255,270	
	"1975"	0	268,523	47	0	11,913	2,014	0	254,643	214,004
	1985	0	268,523	47	0	14,610	2,055	0	251,905	
	2000	0	268,523	47	0	15,196	2,083	0	251,291	
California (18)	"1975"	0	68,050	4,438	2,197	26,641	669	0	47,375	
	"1975"	0	68,050	4,438	0	26,641	669	0	45,178	32,607
	1985	0	68,050	4,069	0	27,932	679	0	43,508	
	2000	0	68,050	3,881	0	29,699	686	0	41,546	
Regions 1-18	"1975"	0	1,330,331	2,677	20,889	105,584	14,956	0	1,233,357	
	"1975"	0	1,330,331	2,677	0	105,584	14,956	0	1,212,468	1,035,221
	1985	0	1,330,331	2,677	0	119,328	15,944	0	1,197,736	
	2000	0	1,330,331	2,677	0	133,655	16,614	0	1,182,739	
Alaska (19)	"1975"	0	905,058	0	0	58	0	0	905,000	
	"1975"	0	905,058	0	0	58	0	0	905,000	859,000
	1985	0	905,058	0	0	207	0	0	904,851	
	2000	0	905,058	0	0	459	0	0	904,599	
Hawaii (20)	"1975"	0	7,353	0	0	605	1	0	6,747	
	"1975"	0	7,353	0	0	605	1	0	6,747	4,590
	1985	0	7,353	0	0	636	1	0	6,716	
	2000	0	7,353	0	0	666	1	0	6,686	
Caribbean (21)	"1975"	0	5,181	0	13	343	0	0	4,851	
	"1975"	0	5,181	0	0	343	0	0	4,838	3,706
	1985	0	5,181	0	0	374	0	0	4,807	
	2000	0	5,181	0	0	300	0	0	4,881	
Regions 1-21	"1975"	0	2,247,923	2,677	20,902	106,590	14,957	0	2,149,955	
	"1975"	0	2,247,923	2,677	0	106,590	14,957	0	2,129,053	1,902,517
	1985	0	2,247,923	2,677	0	120,545	15,945	0	2,114,110	
	2000	0	2,247,923	2,677	0	135,080	16,615	0	2,098,905	

[1] The second "1975" shows "1975" data without ground-water overdraft for a more direct comparison with the conditions for 1985 and 2000.

[2] Flow across international boundaries is not shown.

[3] Estimated water supply generated within each region. Negative values indicate that evaporation and plant transpiration are greater than rainfall in the region.

[4] From manmade reservoirs with storage capacities larger than 5,000 acre-feet and from farm ponds and lagoons. If precipitation exceeds evaporation value is zero.

[5] Negative values show the amount of excess water use without ground-water overdraft. Streamflow will be maintained to meet commitments to Mexico.

[6] U.S. Fish and Wildlife Service estimates for optimal fish and wildlife habitat conditions.

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Inadequate Surface-Water Supply

Competing offstream uses of water for energy, agricultural, domestic, and industrial needs coupled with associated environmental and instream-flow uses have resulted in basinwide and local problems throughout the United States. The Second National Water Assessment projects that by the year 2000 the national increase in annual fresh-water consumption will further compound problems. The problem of inadequate surface-water supply is or will be severe by the year 2000 in 17 subregions located mainly in the Midwest and Southwest. However, an analysis of monthly water data shows that during low-flow months there will be an increase in the number of subregions, including some in the East, with inadequate supply.

This assessment addressed the issue of instream flows for fish and wildlife. To estimate these flows, a stream-depletion analysis was made on fish and wildlife habitat to determine the effect of different streamflow levels.

The following criteria (indicated by depletion ratios) are one way in which the effect can be described.

Sixty percent of average flow (40-percent depletion).—A base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreation uses.

Thirty percent of average flow (70-percent depletion).—A base flow that sustains good survival habitat for most aquatic life forms.

Ten percent of average flow (90-percent depletion).—A flow that can sustain only short-term survival habitat for most aquatic life forms.

The depletion analysis indicates the relative flexibility of riverine ecosystems to cope with fluctuating streamflows. Offstream uses (especially extensive development of irrigated agriculture) often strain the riverine ecosystems and, when protection for aquatic ecosystems is lacking, can severely threaten fish and wildlife dependent on the river flow.

The results of the analysis show that instream flows generally are considered inadequate in the West, and they also indicate that instream flows are of concern in the East. Nationally, ideal flow levels total 1,035 bgd. With an average daily instream flow of 1,233 bgd, the flows seem to be adequate for fish and wildlife. However, several regions do not reflect such favorable conditions. For example, the Lower Colorado Region has an average flow of 1,550 mgd, well below the 6,864 mgd preferred for ideal fish habitats.

With ever increasing offstream and instream demands being placed on the Nation's water resources, it must be recognized that competition for water is a fact. To arrive at solutions, tradeoffs must be made that may result in some restrictions on use (and, therefore, development).

Although competition for water refers primarily to surface water, in most locations throughout the Nation ground- and surface-water supplies are interrelated. The hydrologic connections often are not obvious; however, surface and ground waters represent a single resource with different characteristics.

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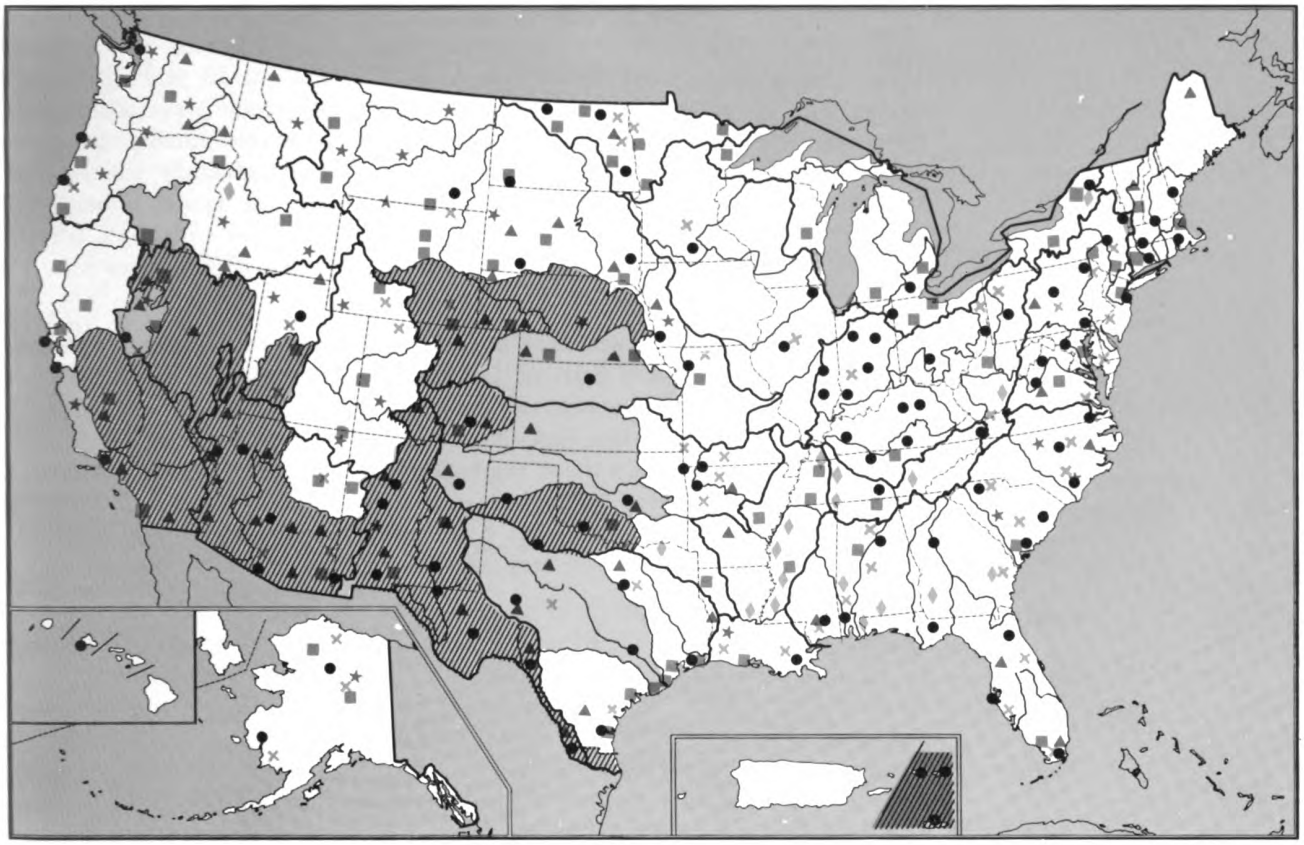

Explanation

Subregion with inadequate streamflow ("1975"-2000)

- 70 percent depleted in average year
- 70 percent depleted in dry year
- Less than 70 percent depleted

Specific problems *(as identified by Federal and State/Regional study teams)*

★ Conflict between offstream and instream uses

Inadequate supply of fresh surface water to support–

Offstream use

- ● Central (municipal) and noncentral (rural) domestic use
- × Industry or energy resource development
- ▲ Crop irrigation

Instream use

- ■ Fish and wildlife habitat or outdoor recreation
- ^ Hydroelectric generation or navigation

Boundaries

- Water resources region
- Subregion

Inadequate surface-water supply and related problems

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Overdraft of Ground Water

Generally, the volume of ground water in the United States is estimated to be far greater than the total capacity of all the Nation's lakes and reservoirs (including the Great Lakes). Ground-water volume is equivalent to about 50 years of surface runoff. Yet increased demands upon this resource in certain areas are causing mounting stress on the supply. Diminished artesian pressure, declining springflow and streamflow, land subsidence, and salt-water intrusion generally indicate that ground water is being withdrawn at a rate greater than an aquifer is being replenished. An aquifer is said to be overdrawn when water is withdrawn from it at a rate greater than the long-term rate of recharge (this is sometimes referred to as ground-water mining).

Ground-water overdraft is occurring in the High Plains from Nebraska to Texas, south-central Arizona, and parts of California. Land subsidence resulting from ground-water overdraft has been a long-term problem in California's Central Valley where the land surface has subsided several feet over a fairly large area. The map on the facing page shows the nature of the problems caused by ground-water overdraft and where the problems occur. Analysis of the assessment data shows that 8 of the 106 subregions have critical overdraft problems, 30 have moderate overdraft, and 22 have only minor overdraft.

Before the ground-water levels in an area decline enough to make pumping uneconomical, several things need to be done: (1) Alternative sources of water must be found; (2) artificial recharge must be developed; (3) water-using activities must be relocated, or (4) water use must be reduced through improved water management. In the absence of appropriate water-conserving measures, the increasing energy costs related to the greater pumping lifts could force abandonment of irrigated cropping if no other source of water at reasonable cost is available. Irrigation is used as an example because it represents a form of ground-water demand much greater than other uses.

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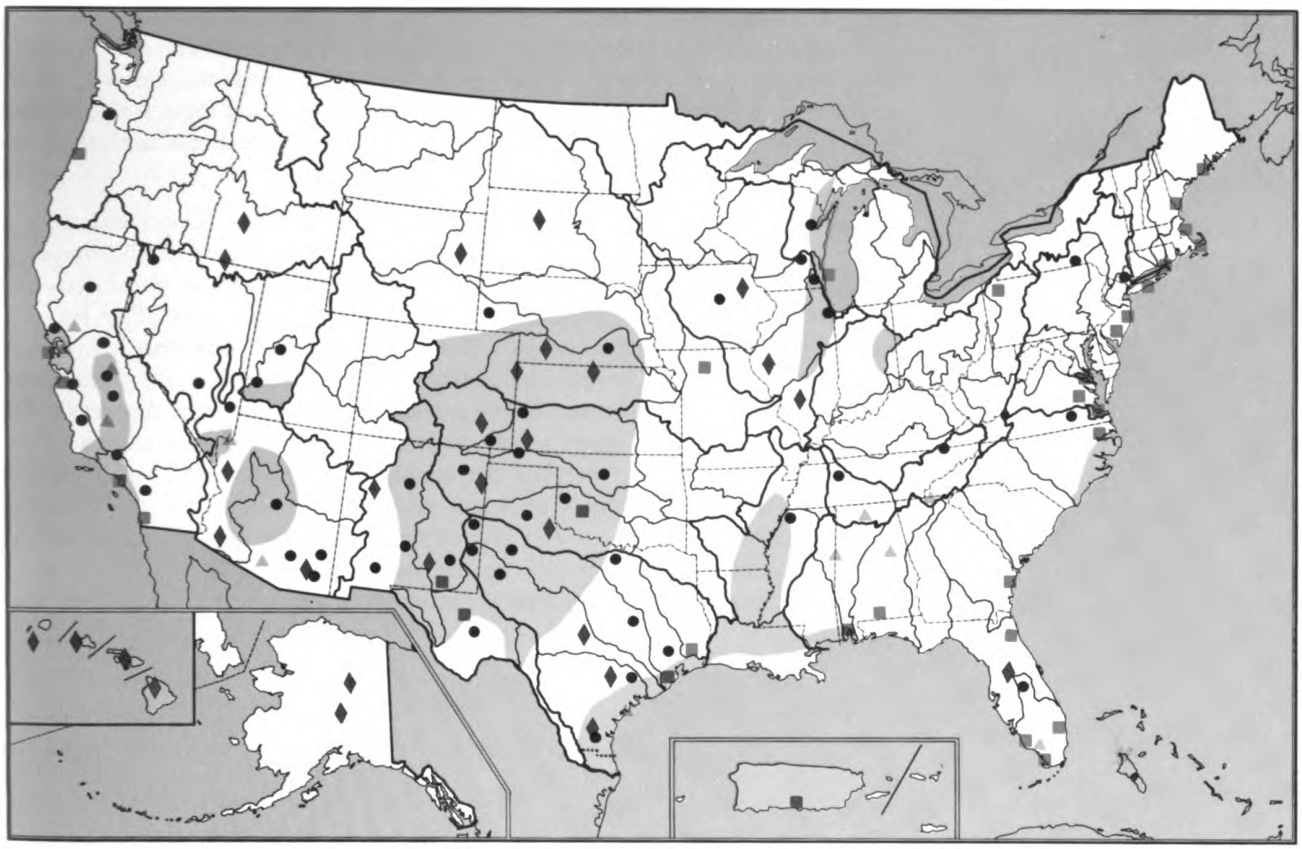

Explanation

Area problem

Area in which significant ground-water overdraft is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific problems *(as identified by Federal and State/Regional study teams)*

- Declining ground-water levels
- Diminished springflow and streamflow
- Formation of fissures and subsidence
- Saline-water intrusion into fresh-water aquifers

Boundaries

- Water resources region
- Subregion

Ground-water overdraft and related problems

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Pollution of Surface Water

Point and Nonpoint Sources

Historically, the Nation's streams, rivers, and lakes have been convenient, and seemingly inexpensive and inexhaustible, dumping areas for human and animal wastes and residuals from industrial production. In contrast, the majority of the population also has always depended, directly or indirectly, on these same streams, rivers, and lakes for some of its fresh-water supplies, recreational activities, and esthetic beauty.

Surface-water pollution results from both point and nonpoint (dispersed) sources. Point-source pollution is caused largely by the direct and indirect discharges of municipal and industrial wastes. Nonpoint- or dispersed-source pollution stems from runoff from urban, agricultural, forested, and mining areas. The Environmental Protection Agency's National Residuals Discharge Inventory shows that about 33 percent of the oxygen-demanding loads, 66 percent of the phosphorus, and 75 percent of the nitrogen discharged to streams come from dispersed agricultural sources. Where storm runoff from urbanized areas drains into nearby surface-water bodies it can degrade the quality of the water. Because of the impervious surface characteristics of urban areas, storm runoff can transport significant quantities of sediment and also of trace elements, nutrients, and organic material, ultimately to deposit them in the receiving surface-water body. With increasing urbanization, the problems of accelerated storm-water runoff and associated nonpoint pollution can be expected to become more and more difficult to solve.

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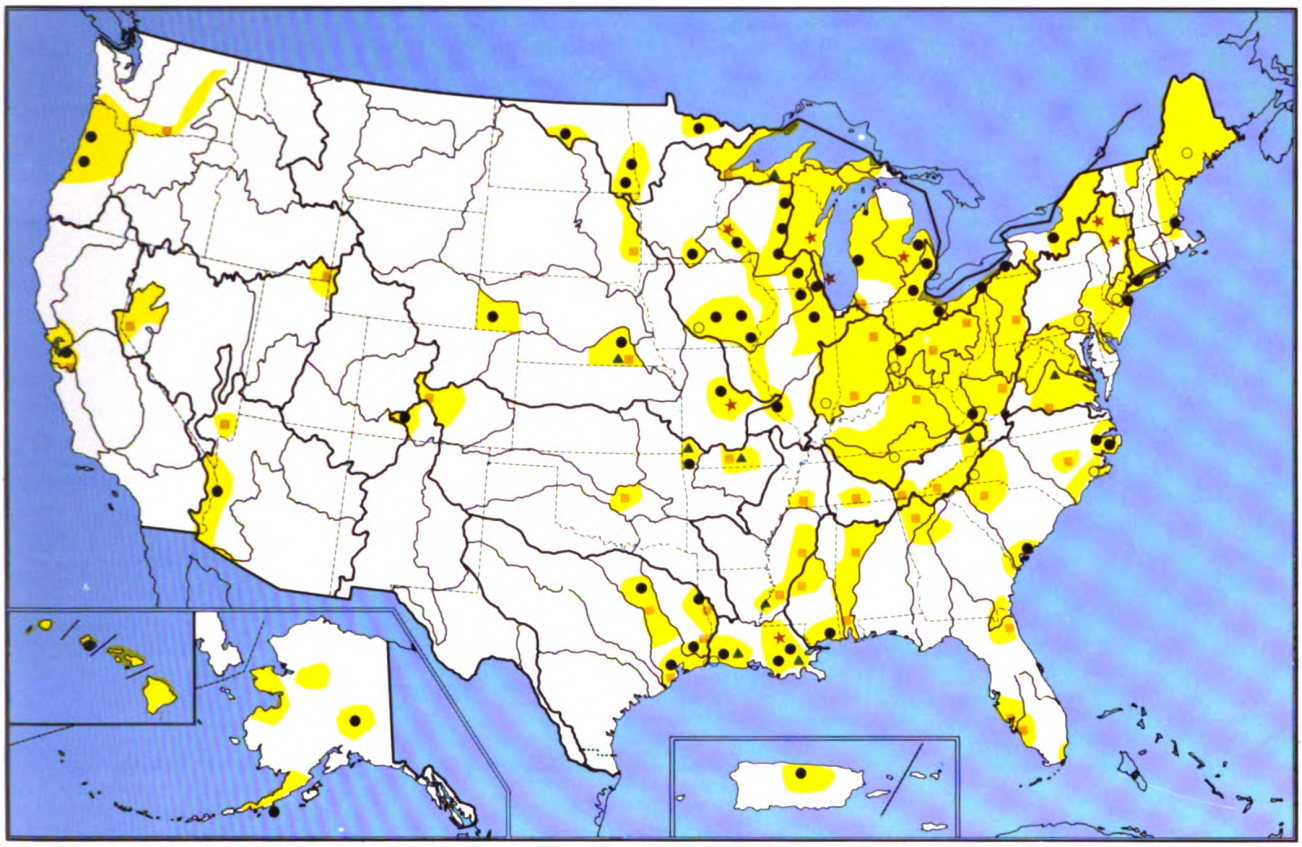

Explanation

Area problem

Area in which significant surface-water pollution from point sources is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific types of point-source pollutants

- ● Coliform bacteria from municipal waste or feedlot drainage
- ★ PCB (polychlorinated biphenyls), PBB (polybromated biphenyls), PVC (polyvinyl chloride), and related industrial chemicals
- ▲ Heavy metals (e.g., mercury, zinc, copper, cadmium, lead)
- ■ Nutrients from municipal and industrial discharges
- ○ Heat from manufacturing and power generation

Boundaries

- Water resources region
- Subregion

Surface-water pollution problems from point sources (municipal and industrial waste)

(As identified by Federal and State/Regional study teams)

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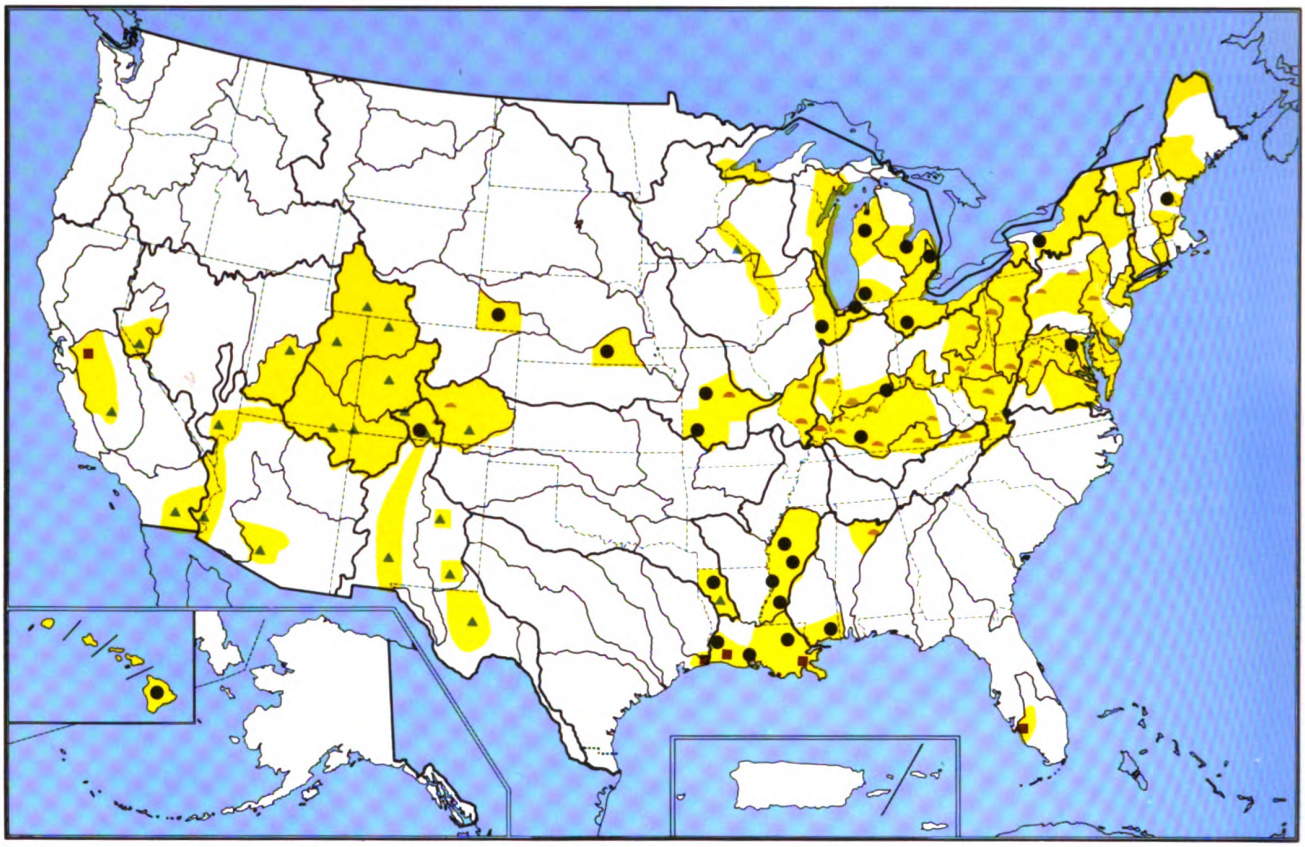

Explanation

Area problem

Area in which significant surface-water pollution from nonpoint sources is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific types of nonpoint-source pollutants

- Herbicides, pesticides, and other agricultural chemicals
- Irrigation return flows with high concentration of dissolved solids
- Sea-water intrusion
- Mine drainage

Boundaries

- Water resources region
- Subregion

Surface-water pollution problems from nonpoint sources (dispersed)

(As identified by Federal and State/Regional study teams)

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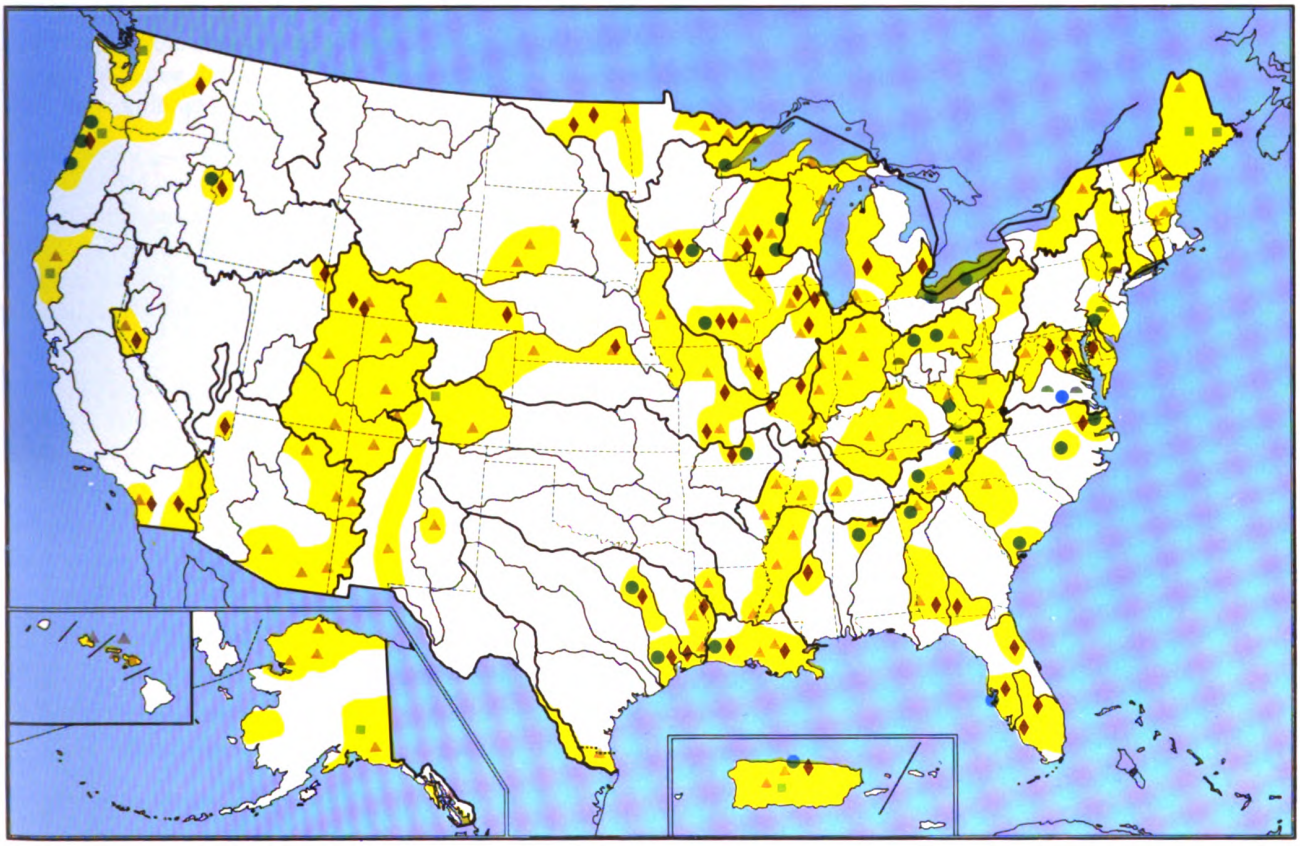
Eutrophication

Eutrophication is a term that generally pertains to waters in which the growth of algae is high as a consequence of a large supply of nutrients. Most eutrophic bodies of water are characterized by excessive growths of algae, dense stands of shoreline vegetation, foul odors from decaying vegetation, and, in some cases, fish kills resulting from the decomposition of large amounts of organic materials. All these limit the usefulness of the water.

Inasmuch as eutrophication is a natural process, all water bodies are eutrophic to some degree. The natural eutrophic process, which takes many years, can be altered or accelerated by the addition of nutrients from pollutional sources. This is called cultural eutrophication. Cultural eutrophication has occurred to some extent in nearly every subregion.



Explanation

Area problem

Area in which significant eutrophication of manmade and natural water bodies is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific causes of eutrophication

Low levels of dissolved oxygen

High levels of nutrients

Natural sedimentation from streambank, cropland, and other natural erosion

Man-induced sedimentation from urban, industrial, and construction/earth moving activities

Heat from manufacturing and power generation

Boundaries

Water resources region

Subregion

Surface-water pollution problems—eutrophication
(As identified by Federal and State/Regional study teams)

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Pollution of Ground Water

Ground water generally is much less subject to pollution from biological sources than is surface water. However, ground-water pollution by fecal coliform bacteria from septic tank drainfields has long been recognized. In addition, an increasing number of occurrences of pollution caused by infiltration of wastes from livestock yards, animal feedlots, seepage from community solid-waste landfills, and discharges of toxic and hazardous material is being reported.

In some areas and under natural conditions, both fresh and saline ground water can be found—the fresh water in one aquifer, the saline in another. In such instances, the saline water is a potential pollutant; withdrawal of significant quantities of fresh water can decrease artesian pressure in the fresh-water aquifers to the extent that the saline water can migrate into the fresh-water zone. Continued withdrawal of the fresh water at high rates could cause the fresh water to become so saline that it is no longer potable without desalination or blending with fresh water from some other source.

Inasmuch as 40 percent of the population derives drinking water from ground-water sources, pollution, whether real or potential, is of significant concern, not only from a public-health standpoint but also from an economic standpoint. The cost of treating water to attain an acceptable level of quality continues to increase, both because of the larger quantities of material needed to treat the water and the increasing cost of the material.

Once an aquifer becomes polluted, recovery from that pollution usually is slow because of the generally slow rate of ground-water movement through the aquifer. Hence, ground-water pollution may be considered a semipermanent condition, perhaps lasting for years after the source of the pollution has been located and the pollution stopped.

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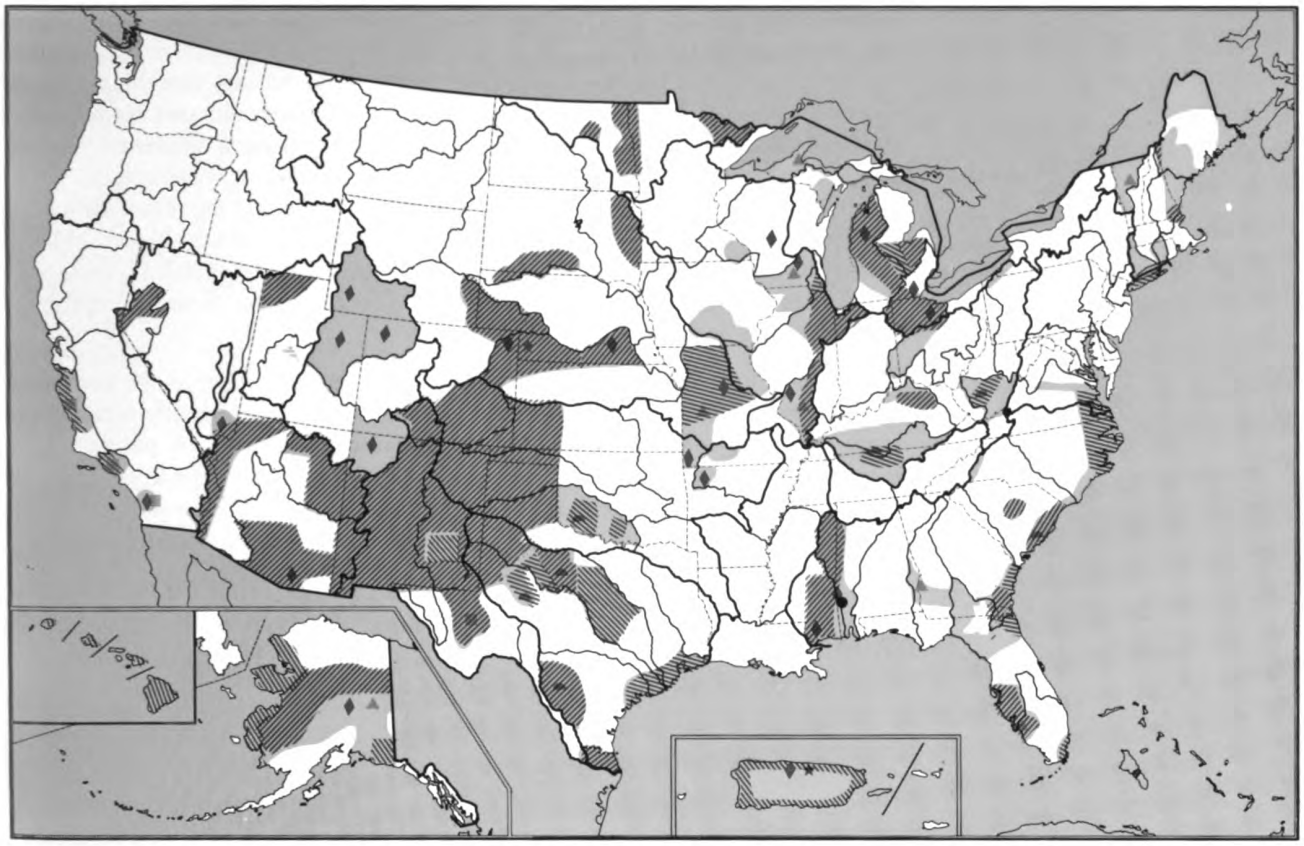

Explanation

Area problems

- Significant ground-water pollution is occurring
- Salt-water intrusion or ground water is naturally salty
- High level of minerals or other dissolved solids in ground water
- Unshaded area may not be problem-free, but problem was not considered major

Specific sources of pollution

- Municipal and industrial wastes including wastes from oil and gas fields
- Toxic industrial wastes
- Landfill leachate
- Irrigation return waters
- Wastes from well drilling, harbor dredging, and excavation for drainage systems
- Well injection of industrial waste liquids

Boundaries

- Water resources region
- Subregion

Ground-water pollution problems

(As identified by Federal and State/Regional study teams)

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Quality of Drinking Water

A safe drinking-water supply is essential for good health. Over the last 50 years, strides in improving the quality of drinking water have been so effective that much of the public has lost its awareness of the potential for serious waterborne disease. Nevertheless, since about 1970 the incidence of waterborne illnesses seems to have been increasing, or at least methods of detecting them have improved. At least 4,000 cases of waterborne illness, primarily of bacterial or viral origin, are reported each year. The actual number of cases, including the more-difficult-to-identify chemical poisonings, could be as much as 10 times higher. Medical science has only begun to address the nature of the effects of chemical carcinogens, whose effects involve latency periods of 20 years or more before symptoms of damage can be identified.

Most surface water receives extensive monitoring and treatment at the community level before distribution. Ground water, on the other hand, normally receives little or no treatment other than disinfection. Because more than 40 percent of the population drinks ground water, the need for full-treatment technology and effective monitoring is particularly appropriate for ground water. However, steps must be taken to prevent the increase in pollution of surface and ground sources of public water supplies.

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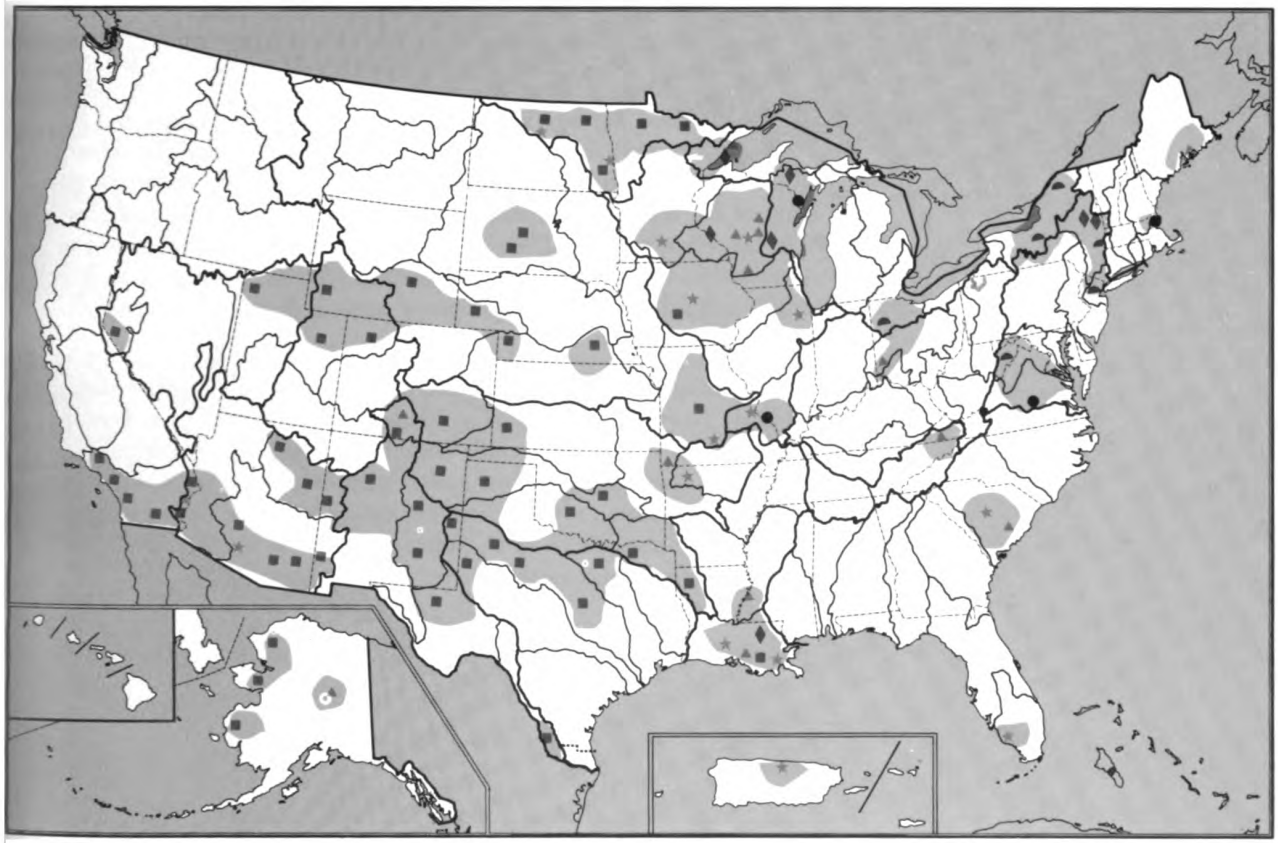

Explanation

Area problem

- Area in which existing or potential pollution of domestic water supply was reported
- Unshaded area may not be problem-free, but the problem was not considered major

Specific sources of pollution

- Industrial chemicals other than chlorinated hydrocarbons
- Chlorinated hydrocarbons from treatment processes and energy development
- Heavy metals (e.g., mercury, zinc, copper, cadmium, lead)
- Coliform and other bacteria
- Saline water
- General municipal and industrial wastes

Boundaries

- Water resources region
- Subregion

Quality of drinking water problems

As identified by Federal and State/Regional study teams)

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Flooding

Flooding affects many parts of the United States—arid as well as humid areas. In 1975, 107 people were killed by flood waters and potential property damage for the year was estimated to be $3.4 billion.

Almost half of all flood damage is suffered by agriculture as crops and livestock are destroyed and productive land is covered or washed away. In urban areas, residential and business property is damaged or destroyed, adversely affecting the economy of the area. The impact of flooding on wildlife, fish, and ecosystems is mixed. In upstream areas, wildlife food and habitat are often removed or covered by flood waters that severely damage natural systems. Positive aspects include transporting beneficial nutrients that improve natural downstream systems.

By the year 2000, potential annual flood damage is expected to increase to $4.3 billion on the average, even with moderate application of flood-plain management and regulations. To reduce flood damage, better management of the flood plain is required; management practices include combining traditional structural measures, such as dams and levees, with nonstructural measures, such as flood forecasting, advance-warning evacuation systems, and relocating high-risk properties out of the flood plain. The participation of local, State, and Federal agencies is necessary for successful flood-plain management.

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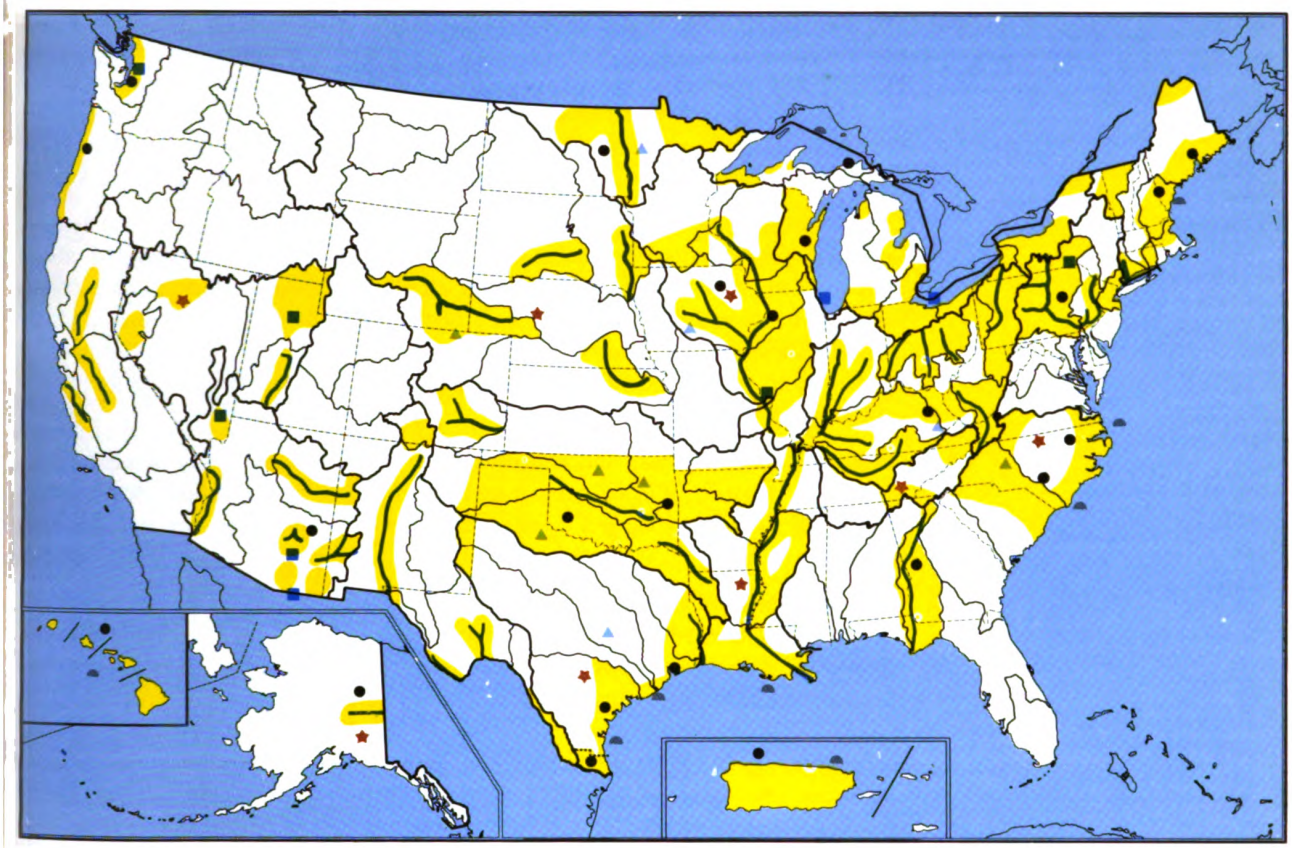

Explanation

Area problem

- Area in which flooding causes major damage to agricultural, urban, and other developments
- Unshaded area may not be problem-free, but problem was not considered major
- Major streams and tributaries with periodic overbank flooding

Reasons for intensified flood damage

- Urban, suburban, and industrial development on flood plains
- Accelerated runoff from urban areas
- Inadequate upstream watershed management
- Loss of flood control from inadequate structural systems
- Tidal effects along coasts during storms and hurricanes

Boundaries

- Water resources region
- Subregion

Flooding problems

(As identified by Federal and State/Regional study teams)

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Erosion and Sedimentation

Erosion and the resulting sedimentation are natural processes, but when they are accelerated by the acts of man, they are the most pervasive water-related problem in the United States. The "1975" average cropland soil loss from sheet and rill erosion was 8.6 tons per acre or approximately 1/16 inch of soil; in some areas the loss was 25 tons or more, approximately 3/16 inch per acre. In addition, forests and pasture lands sustain soil losses of about 1 ton per acre per year.

Overgrazing of pasture lands reduces vegetative cover, fosters erosion, and decreases long-term productivity. On forest lands some types of timber harvest and off-road recreation vehicles can increase erosion significantly. As surface mining expands to support national energy needs, the potential for erosion of the mined lands will increase; however, legislation such as the 1977 Surface Mining Control and Reclamation Act is intended to minimize the potential for destructive erosion caused by surface mining.

Channel banks, beaches, and shorelines can be damaged by the scouring action of flowing waters. Wakes from barges and ships, construction activities, and changes in river flows caused by reservoir impoundments also can damage shorelines.

Sediment from the various types of erosion (sheet and rill, gully and streambank, and wind) is carried into streams, suspended in the water, and deposited when streamflow diminishes or when velocities are slowed. In urban areas, storm runoff from residential and industrial development and highway construction carries sediment into streams and reservoirs. In streams the deposits of sediment cause a further reduction in velocity and spread the water beyond the streambanks. In reservoirs, the deposits can significantly decrease storage capacity and shorten the life of the reservoir. Also, sediment is a carrier of pollutants such as phosphates and pesticides, and it adversely affects the environmental quality of water bodies by covering fish and wildlife habitats, damaging spawning and nesting areas, and impairing fisheries.

In some instances sediment deposits can be beneficial by adding rich soil to certain low-lying areas, but mostly the deposits damage crops, orchards, residential improvements, roadways, and other structures, and clog navigable channels.

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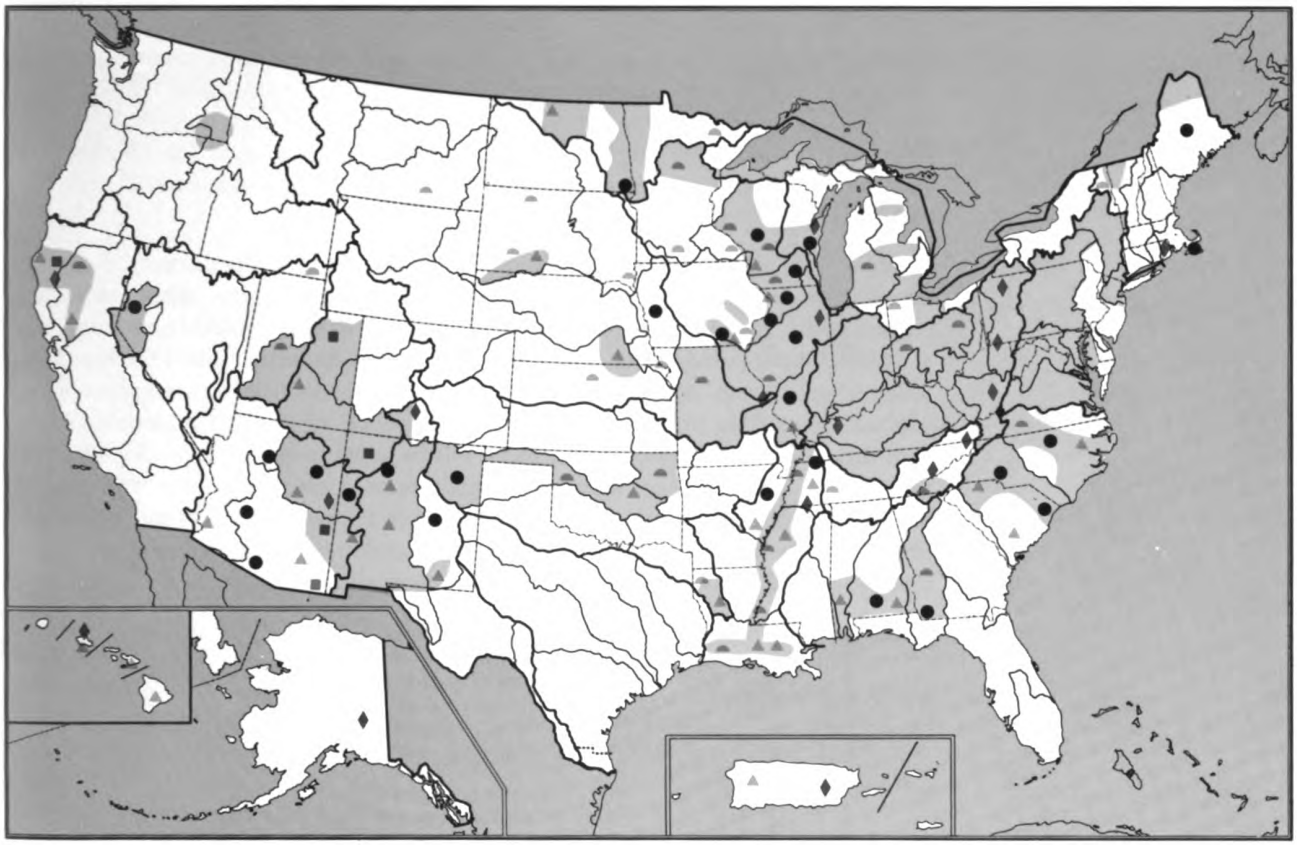

Explanation

Area problem

Area in which erosion or sedimentation is a significant problem

Unshaded area may not be problem-free, but the problem was not considered major

Nature of erosion or sedimentation problems

- Cropland or rangeland erosion or sedimentation
- Urbanization, mining, or industrial and highway construction
- Natural erosion of stream channels
- Shoreline, streambank, or gully erosion
- Sedimentation of farm ponds, lakes, water supply, and flood-control channels

Boundaries

- Water resources region
- Subregion

Erosion and sedimentation problems
(As identified by Federal and State/Regional study teams)

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Dredging and Disposal of Dredged Material (Dredge and Fill)

The large volume of sediment deposited each year in navigable stream channels, reservoirs, and harbors requires regular removal and disposal. Also, major ports and access channels must be deepened to accommodate modern deep-draft vessels. To accommodate these larger transport vessels, and because of the efficiency of waterborne commerce, demands for harbor and channel maintenance probably will expand.

Dredging and the disposal of dredged materials, however, can disrupt or destroy aquatic life necessary for commercial and recreational fishing, upset ecological balances basic to wildlife, and adversely affect water quality and other environmental values. Anticipated development of the Outer Continental Shelf in the Mid-Atlantic and South Atlantic-Gulf Regions for oil and nuclear powerplant siting will add to existing problems of open-water disposal of dredged materials. Along with these off-shore developments, there will be supporting on-shore developments that will require dredging. Loss of wetlands may result from either dredging or filling; consequently, valuable wildlife habitats are removed and nursery and breeding areas for marine fish and shellfish are destroyed. Loss of wetlands also destroys natural anti-erosion barriers and sediment traps.

Dredging and disposal of the dredged material have both short-term and long-term effects that need to be scrutinized carefully so that appropriate management policies can be formulated.

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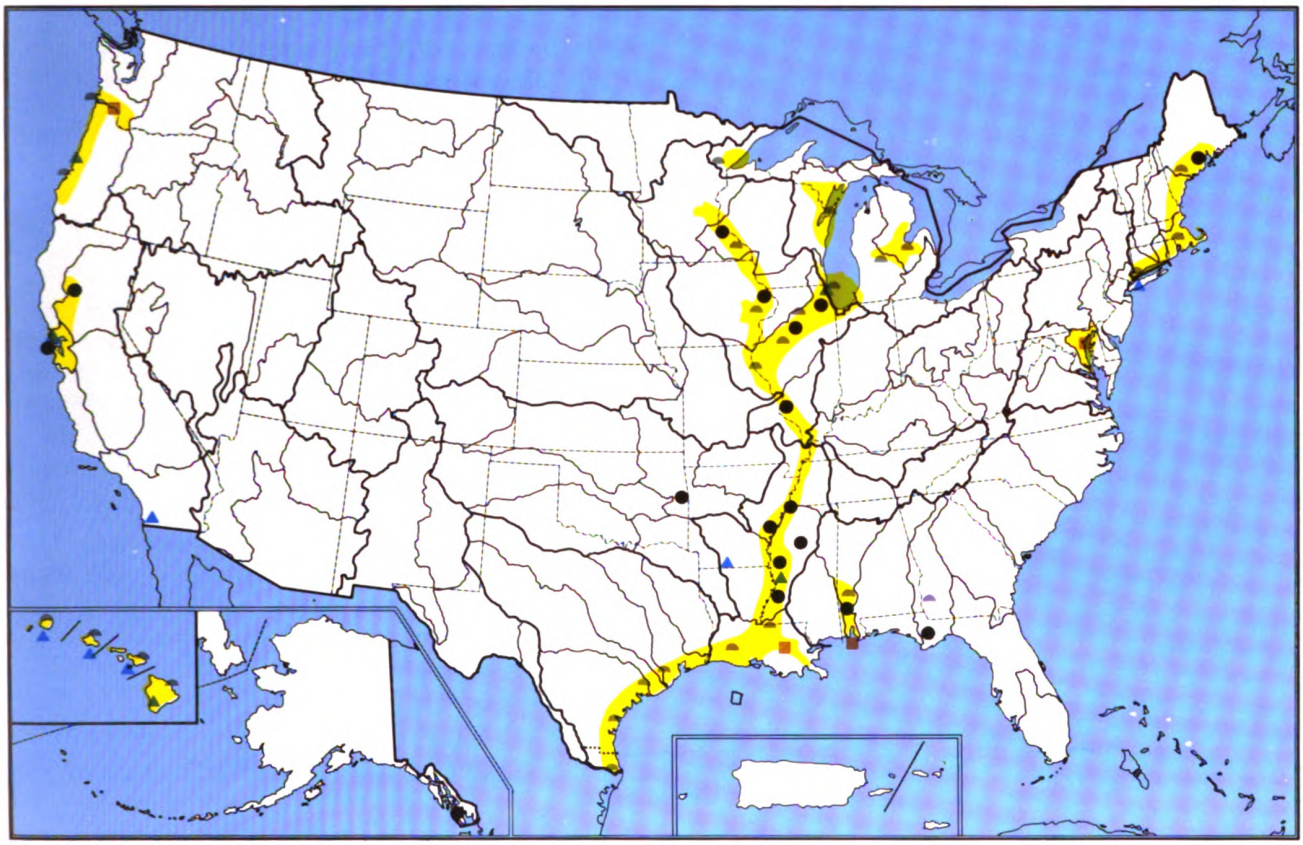

Explanation

Area problem

- Area in which there is a waterway with significant dredge and fill problem
- Unshaded area may not be problem-free, but the problem was not considered major

Specific dredge and fill problems

- Channel maintenance for normal traffic
- Channel deepening and maintenance for deep-draft vessels
- Land and waterfront development
- Damage to fish and wildlife habitat

Boundaries

- Water resources region
- Subregion

Coastal and inland waterways with dredge and fill problems

(As identified by Federal and State/Regional study teams)

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Wet-Soils Drainage and Wetlands

Wet soils occur where land is covered frequently with water or there is a persistently high ground-water table. Wet soils may exist because of natural conditions or because of such changes as irrigation, diking, road construction, levees, reservoirs, and accelerated sediment deposition in streams. Of approximately 400 million acres of wet soils, about 104 million acres is used for cropland.

Not all wet soils need to be drained to produce crops. Indeed a few crops need wet soils. An estimated 43 million acres of cropland needs improved drainage, which can be accomplished by a combination of practices that include improved irrigation water management, land grading, drainage ditches, underground drains, and outlet channels.

There also is potential to convert wet soils in forest and pastureland to cropland by clearing and drainage. Federal laws and policies restrict Federal involvement in this practice, but private landowners continue to find locations where such conversion is profitable. It is projected that by the year 2000 about 11 million acres of land now in forest and pasture will be converted to cropland. This will be offset to some degree by land now in cropland with wet soils that will revert to forest or pastureland as well as by the creation of new wetland areas.

Wetlands are defined as lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living at the surface. They span a range of environments where terrestrial and aquatic systems integrate. However, they do not include all lands with wet soils. Drained croplands are specifically excluded. Wetlands also include areas of open water not mapped as wet soils. Estimates are that over 127 million acres of wetlands once existed. Between 1955 and 1975, 6 million acres of wetlands was destroyed. Currently, there is about 74 million acres of wetlands in the conterminous United States.

Wetlands provide food and cover for waterfowl, wildlife, and sport and commercial fish. Waterfowl depend on wetlands for breeding and wintering habitat, particularly along migratory routes. Wetlands also can retain flood waters and trap pollutants. Because of the conflicts between the interest to drain land for crops and the need for wetlands for fish and wildlife, planning for drainage should include a thorough evaluation of economic, social, and environmental effects.

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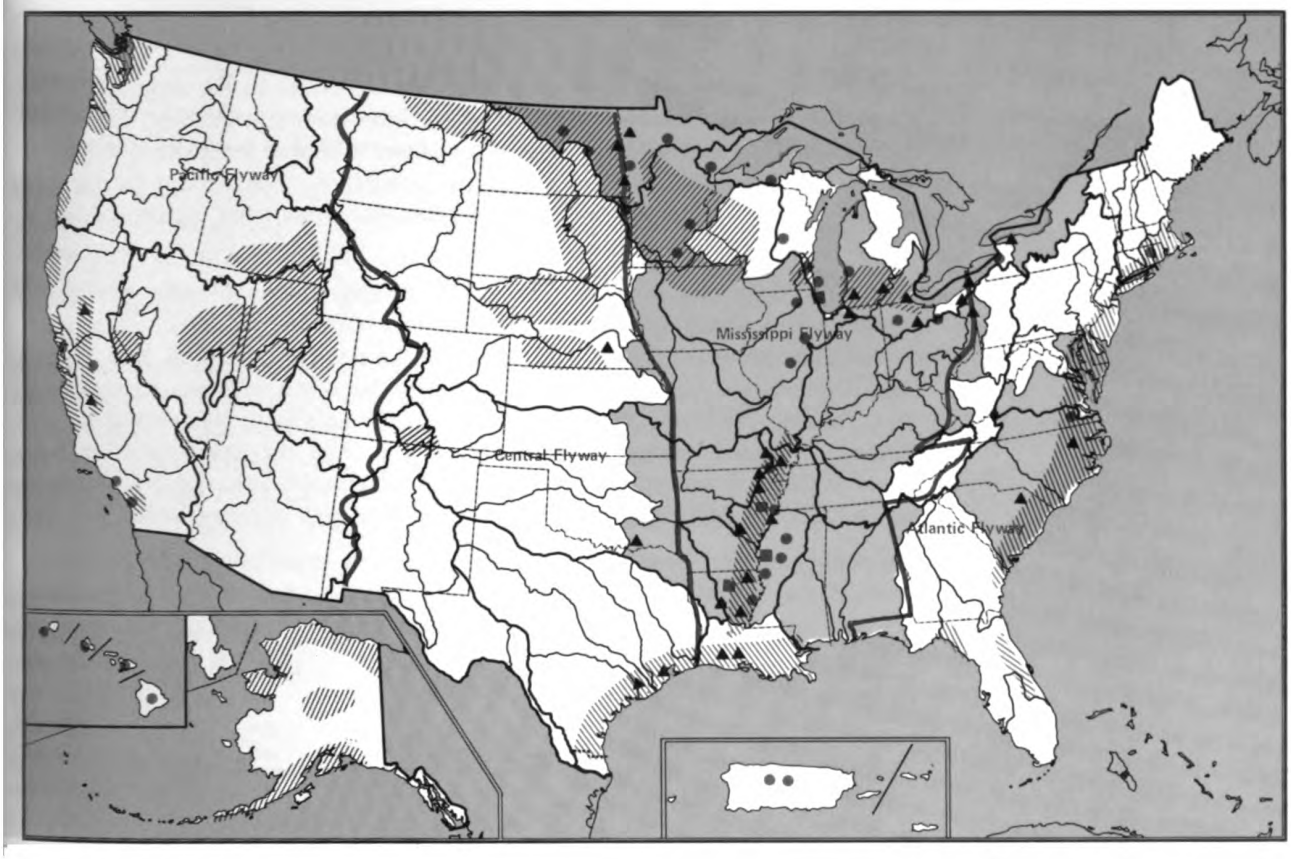

Explanation

Subregion in which 50,000 acres or more of wet-soils are amenable to agriculture if land is drained.

Specific problems *(as identified by Federal and State/Regional study teams)*

- Wetland waterfowl breeding habitat needing protection
- Wetland waterfowl wintering habitat needing protection
- Farmland needing drainage
- Urban areas with inadequate drainage
- Conflict between wetlands and wet-soils use

Boundaries

- Water resources region
- Subregion
- Flyway of migratory birds

Wet-soils drainage and wetlands problems

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Degradation of Bay, Estuary, and Coastal Waters

Bay, estuary, and coastal waters are extremely important to the economy because they provide major transportation routes for international commerce, are essential habitats for fish and wildlife resources, and are a source for recreational opportunities for more than 80 percent of the population. Commercial fishing, sport fishing, waterfowl hunting, and other wildlife-related activities all depend heavily on the health of the bays and estuaries.

The most significant problem relevant to the degradation of bay, estuary, and coastal waters is the discharge of domestic and industrial wastes into these water bodies. The problem is particularly acute in the densely populated New England, Mid-Atlantic, and Great Lakes Regions. Most bays and estuaries have relatively slow flushing rates, and thus their capacity to handle large amounts of waste is limited. Increased nutrient loading, inseparable from the discharge of domestic waste or other organic material, results in cultural eutrophication of the water body, which produces algal blooms, noxious weed growth, high oxygen demand, and odor.

As population and demands increase, the carrying capacity of estuaries remains fixed; many believe that some major bay and estuarine systems already have reached their capacity to absorb waste. Increased environmental awareness has caused planners and managers in coastal regions to critically review plans and proposals for new activities in coastal waters.

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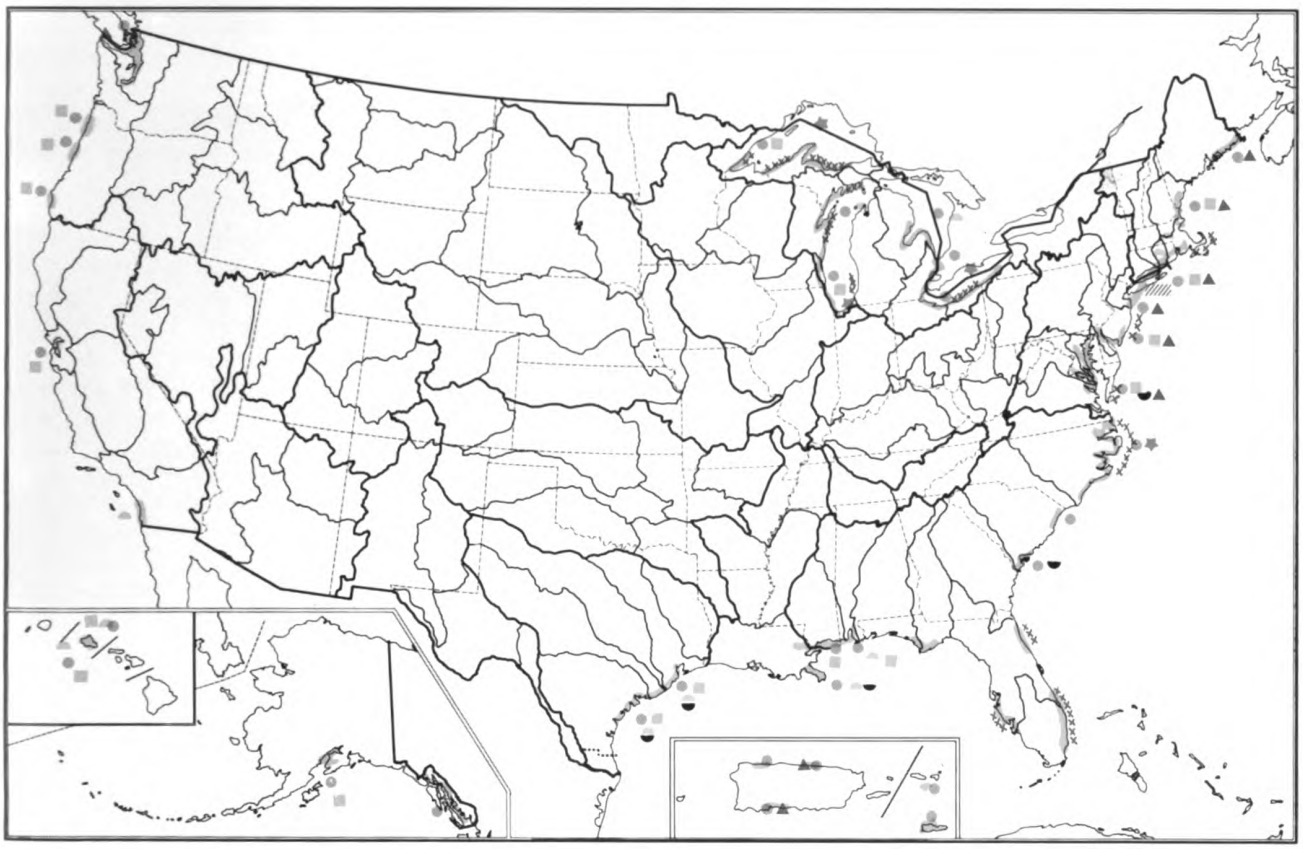

Explanation

Area problem

- Area with major bay or estuarine water-related problems
- Unshaded area may not be problem-free, but the problems were not considered major

Nature of problems

- Pollutant loads from upstream or shoreline point sources
- Pollutant loads from nonpoint sources
- ▲ Pollutant loads from commercial and waterborne traffic-related sources
- ★ Increased nutrient loads
- Loss of coastal wetlands
- Loss of fresh-water flow resulting from upstream consumption use or diversion
- ×××× Shoreline erosion
- //////// Offshore dumping

Boundaries

- Water resources region
- Subregion

Bay, estuary, and coastal water problems

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Critical Problems—Overview

"1975" and 2000

Intensive development and use of the Nation's water resources and pressures to satisfy a wide variety of beneficial purposes have created a number of problems in some areas. Not the least of these problems has been the failure to consider fully the environmental values. Further, there is a special need to provide sufficient water of good quality for fish and wildlife.

Ground-water overdraft is particularly troublesome because expanding economic activities that are ground-water dependent could face an uncertain future in overdrawn areas. One such area is the High Plains that extends from Texas to Nebraska. There, the annual overdraft is about 14 million acre-feet, over one-half of the Nation's total overdraft, an amount nearly equal to the natural flow of the Colorado River.

Water quality continues to be a major local concern. Public expenditures to alleviate impaired quality conditions are beginning to approach the total expended for all other water-development purposes. Optimistically, water-quality conditions will be improved substantially. With the emphasis on more intensive use and reuse of available supplies, improvement in quality should become an important facet of water-management procedures.

To solve the existing and projected major water problems, as discussed above, comprehensive, coordinated water-resources management, as well as the full range of hydrologic prediction capability, is needed. All beneficial purposes must be considered equally in developing management plans. Water-resources management —including unified efforts in planning, development, and project operation by all concerned agencies, and guided by an adequate data base and Federal water policy—is the key to solutions to the Nation's water-resources problems. This assessment can be used to improve program decisionmaking and provide direction for the careful management of our natural resources.

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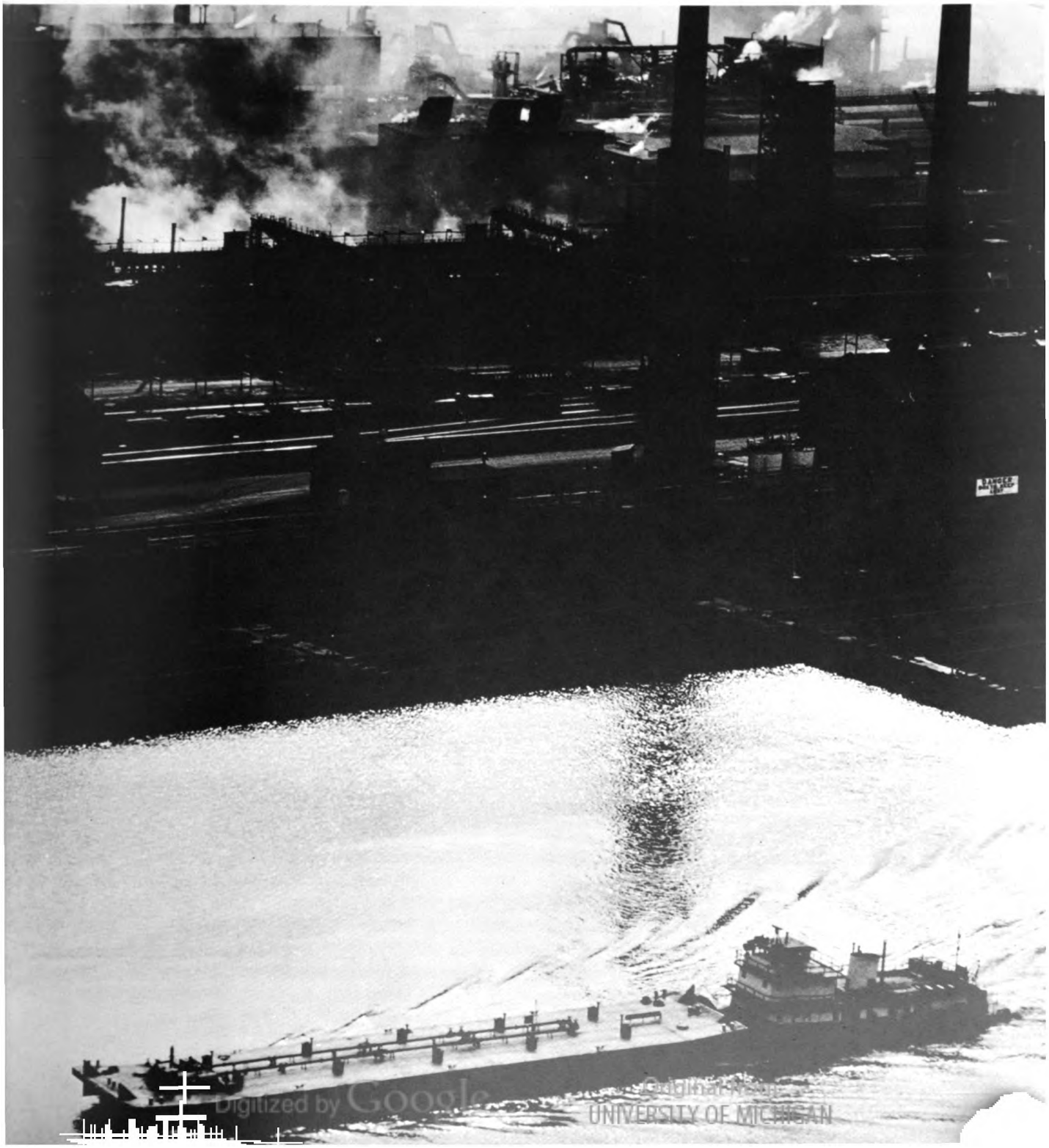
POLICY IMPLICATIONS



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Up to this point, the large amount of data and information compiled for the Second National Water Assessment has been summarized. A study of this summary indicates that several policy areas need attention:

Integrated Comprehensive Planning

Except for a few parts of the country, there is now no water crisis. However, a nationwide effort to coordinate management and planning, along with special efforts to involve all levels of government and to attain support of the individual citizens, is needed to avert a possible water crisis in other parts of the country by the turn of the century.

In the past, evolution of water policies and programs emphasized single- and multiple-purpose planning, largely for economic development. More recently, multiobjective planning and management have broadened the range of planning purposes to include areas of major environmental concern. To avoid a potential water crisis, there must be continued integration of all facets of water-resources planning and management: quantity and quality; economic, social, and environmental aspects; and involvement of local, State, regional, Federal, and international organizations. Further, it appears that effective water management will need to consider the heavy demands on water for energy production, the cost and time involved in rehabilitating urban water systems, methods to prevent adverse effects of accelerated urban storm runoff, nonstructural approaches to resolving water problems, and stronger water conservation efforts.

Integration of Water Quality and Quantity Management

Perhaps the most significant deficiency in the past management of water resources was the failure to adequately consider water quality in many areas. Accordingly, it has been necessary to make major investments in an effort to bring water quality up to an acceptable level. Aggressive programs directed at water-quality management should have been initiated before major problems arose as a result of industrial and agricultural development and urbanization. Even now, as an all-out attempt to alleviate water-pollution problems proceeds, the integration of water-quality planning and management with other aspects of water-resources development tends to be overlooked. Without integration, the water-quality goals will be more difficult, and more costly to meet. The Second National Water Assessment did not address the issue of flow requirements for water-quality management.

Environmental Quality

In the past, adequate consideration of environmental quality, including protection of ecological systems, was not given early enough in the planning and decision-making process. As a result, in some places the environmental quality deteriorated unnecessarily and some workable options that might have protected or enhanced environmental values were foreclosed. The U.S. Water Resources Council's "Principles and Standards for Planning [the Use of] Water and Related Land Resources," which provides for explicit consideration of the environmental-quality objectives in formulating plans and for full disclosure of environmental consequences, is making a contribution in this area.

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Failure to Adapt Policies to Changing Conditions

Federal agencies and beneficiaries of Federal water-resources programs have been unwilling to adapt policies and institutions to changing public priorities and preferences and to meet revised goals that would support the common good of the Nation. Specific examples include failure to adapt water-transportation policies to an overall national transportation policy, failure to adapt irrigation development policies to national agriculture policies, and failure, in some cases, to accept responsibility for maintaining water quality.

Major Water Development

Water-development and water-management programs have contributed substantially to the national objective of economic development. Recently, with competition for the water supplies and concern for the environment, conflicts over economic development and environmental quality have led to a reexamination of the two separate goals: (1) more economic growth and (2) a better, clean, and healthy environment. A thorough review is needed to integrate the two goals so that decisions involving long-term effects can be made.

Sharing of Responsibilities

A mixture of Federal, State, and local government and private responsibilities for water management has evolved, whereby water-management decisions are made by the local and private sectors to the extent possible. The tendency in recent years has been to increase the Federal share of funding and to increase Federal responsibilities, particularly for water-quality control. These increased responsibilities should be given to planners at the State and local levels.

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Integrated Ground- and Surface-Water Management

Critical ground-water problems relating to overdraft have emerged in the High Plains of Texas north to Colorado and Nebraska, in central Arizona, and in parts of California. The negative consequences of the ground-water problems require immediate attention. In some areas the integration of ground- and surface-water management plans is imperative in alleviating problems.

Flood-Plain Management

Loss of life and property from flood waters continues to be a major problem. In 1975, potential flood damage was estimated at $3.4 billion on a flood plain of 140 to 180 million acres. Historically, cities and industries have located on flood plains. Although channels, levees, and dams have been constructed to provide protection from floods, usually they provide only partial protection, and in some instances produce adverse effects downstream.

Since 1965, increasing attention has been given to nonstructural alternatives for control and alleviation of flood damage. But information is sparse on flood hazards, environmental effects, approaches to flood-damage reduction, and institutional arrangements through which unified flood-plain management might be achieved. The "Unified National Program for Flood-Plain Management," recently adopted by the U.S. Water Resources Council, recognizes these deficiencies and provides guidelines for overcoming them.

Drinking-Water Quality

Problems are emerging as a result of using water that contains toxic substances. Toxic substances may travel long distances from the point at which they entered the water source, thus obscuring both the nature of the substances and the point of introduction. To ensure safe, dependable drinking water, new technology for detecting and identifying toxic substances and new water-treatment procedures must be researched and developed.

Conservation

Conservation must recognize that neither "availability" nor "requirements" should be treated as unalterable. Technology and management have the potential of bringing water-supply and demand aspects into balance in the public interest. Assessment findings can be used to target or direct management programs to problem areas that need immediate attention; areas that have basinwide water-supply problems should be given priority for water-conservation projects and programs.

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Inasmuch as concepts and attitudes change considerably over time, water-resources planning must be a continuing process that uses current data and reflects the desires of the public. In view of this, the water-assessment program must be continued and the data base must be updated periodically to ascertain what changes have occurred, what progress has been made, or whether the conditions are getting better or the problems are getting worse. The Second National Water Assessment can be used to show the location of critical water-resources problems, to target programs for effective management, and to assess the adequacy of existing programs and policies in solving the problems and meeting the needs of the 21 water resources regions.

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South Atlantic-Gulf	Southeast Basins Inter-Agency Committee	Douglas Belcher
Great Lakes	Great Lakes Basin Commission	Robert Reed, Allen Curtes, Dave Gregorka
Ohio	Ohio River Basin Commission	Steve Thrasher, Jim Webb
Tennessee	Tennessee Valley Authority	Jack Davis
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Lower Mississippi	U.S. Army Corps of Engineers	Richard Stuart
Missouri	Missouri River Basin Commission	Carroll M. Hamon, Amos Grissel
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Upper Colorado	U.S. Bureau of Reclamation	Ival Goslin
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Caribbean	Puerto Rico Department of Natural Resources	Greg Morris

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[1] The Washington staff of the Federal agencies was augmented by field office staff who participated with Washington offices or through the Regional Study Teams.
[2] Several States had representatives on more than one Regional Study Team. Contributions of those not named were greatly appreciated.

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Authorization

The United States Water Resources Council was established by the Water Resources Planning Act of 1965 (Public Law 89-80).
The purpose of the Council is to encourage the conservation, development, and utilization of water and related land resources on a comprehensive and coordinated basis by the Federal government, States, localities, and private enterprise with the cooperation of all affected Federal agencies, States, local government, individuals corporations, business enterprises, and others concerned.

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THE NATION'S WATER RESOURCES 1975-2000

Volume 2: Water Quantity, Quality, and Related Land Considerations

Second National Water Assessment by the U.S. Water Resources Council

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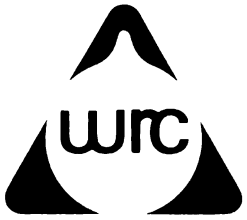

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CONTENTS

U.S. Water Resources Council members ------ inside front cover
Glossary and conversion table ---------- iv

Part I, Introduction
National Water Assessment--Its origin ---------- I-1
Water Resources Council--Participants and functions ---------- I-13

Part II, Water Management Problem Profiles
Introduction ---------- II-1
Inadequate surface water supply ---------- II-3
Overdraft of ground water ---------- II-11
Pollution of surface water ---------- II-19
Pollution of ground water ---------- II-29
Quality of drinking water ---------- II-35
Flooding ---------- II-41
Erosion and sedimentation ---------- II-47
Dredging and disposal of dredged material ---------- II-55
Wet-soils drainage and wetlands ---------- II-61
Degradation of bay, estuary, and coastal water ---------- II-71

Part III, Water Uses
Functional use and flow management ---------- III-1
Socioeconomic characteristics and projections ---------- III-9
Domestic and commercial use of water ---------- III-19
Water for manufacturing ---------- III-33
Food and fiber ---------- III-57
Water for energy production ---------- III-77
Minerals production ---------- III-95
Water for recreation ---------- III-103
Water requirements for navigation ---------- III-117
Water for fish and wildlife ---------- III-127
Water for natural areas, historic resources, and wilderness areas ---------- III-141
Flood-plain management ---------- III-151
Erosion and sedimentation ---------- III-161

Part IV, Water Supply and Water Quality Considerations
Introduction ---------- IV-1
Water supply ---------- IV-5
Water use ---------- IV-29
Analysis of water supply and use ---------- IV-39
Water quality ---------- IV-69
Legal and institutional aspects of water management -------- IV-117

Part V, Synopses of the Water Resources Regions
Introduction ---------- V-1
New England Region (1) ---------- V-3
Mid-Atlantic Region (2) ---------- V-9
South Atlantic-Gulf Region (3) ---------- V-15
Great Lakes Region (4) ---------- V-21
Ohio Region (5) ---------- V-27
Tennessee Region (6) ---------- V-33
Upper Mississippi Region (7) ---------- V-39
Lower Mississippi Region (8) ---------- V-45
Souris-Red-Rainy Region (9) ---------- V-51
Missouri Region (10) ---------- V-57
Arkansas-White-Red Region (11) ---------- V-63
Texas-Gulf Region (12) ---------- V-69
Rio Grande Region (13) ---------- V-77
Upper Colorado Region (14) ---------- V-83
Lower Colorado Region (15) ---------- V-91
Great Basin Region (16) ---------- V-99
Pacific Northwest Region (17) ---------- V-105
California Region (18) ---------- V-111
Alaska Region (19) ---------- V-117
Hawaii Region (20) ---------- V-123
Caribbean Region (21) ---------- V-129

Acknowledgments ---------- inside back cover

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GLOSSARY AND CONVERSION TABLE

Definitions of terms as used in the Second National Water Assessment

**1975$** — most monetary figures are shown in 1975 dollars; source information was often supplied in 1967 dollars and a factor of 1.533 applied to obtain 1975$.

"1975" — base year for assessment information; represents assumed average conditions, not actual data, so is shown with quotation marks.

1985 — 10-year date from base year "1975" for which water supply, water use, and other assessment information is projected.

2000 — 25-year date from base year "1975" for which water supply, water use, and other assessment information is projected.

annual — average daily value for the year.

aquifer — underground formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

assessed streamflow — see *streamflow-related terms.*

assessment geographic divisions

1. **region** — one of the 21 hydrologic regions as designated by the U.S. Water Resources Council; 18 are within the conterminous United States, plus Alaska, Hawaii, and the Caribbean.
2. **assessment subregion** (ASR) — one of the 106 hydrologic subdivisions of a region; once called aggregated subregion; shortened to subregion for this report.
3. **assessment subarea** (ASA) — one of the 106 county approximations of the assessment subregions; once called aggregated subarea; shortened to subarea for this report.

base conditions — typical or average conditions of fresh-water use; used to compare "1975" base year conditions with projections for 1985 and 2000.

best available technology (BAT) — best available technology economically achievable for industrial discharges; 1983 goal of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

best practicable technology (BPT) — best practicable control technology currently available for industrial discharges; 1977 goal of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

bgd — billion gallons per day.

biochemical oxygen demand (BOD) — a measure of oxygen required for the oxidation of organic matter in water.

consumption — portion of surface or ground water withdrawn for offstream uses that is lost by evapotranspiration or by incorporation into a manufactured product.

conterminous U.S. — (also called *contiguous U.S.*) the 48 States with common boundaries; water resources regions 1-18.

critical month — month in which fish and wildlife instream flow needs are least likely to be met under present or future base conditions.

cropland — land used for agriculture but not in permanent pasture, native hayland, rangeland, or woodland.

current streamflow — see *streamflow-related terms.*

dry conditions — present and future water conditions for a moderate drought that occurs on the average one year in five.

earnings — sum of income accruing from wage and salary, proprietor's income, and other labor income.

evaporation — see *net evaporation.*

evapotranspiration — water loss through evaporation (from soil and surface water bodies) and transpiration (from plants).

exceedance — see *"streamflow exceedance"* given under *streamflow-related terms.*

exports — artificial transfers of fresh water from one region or subregion to another, e.g., by pipes or canals.

frequency analysis — method used to determine *"streamflow exceedance"* given under *streamflow-related terms.*

functional water use — category of offstream use, e.g., domestic, commercial, manufacturing, agriculture, steam electric generation, minerals industry.

future streamflow — now called
future modified flow (FMF) — *assessed streamflow.*

gcd — gallons per capita per day.

ground-water overdraft — portion of ground-water withdrawals that exceed recharge; sometimes called ground-water mining.

imports — artificial transfers of fresh water to one region or subregion from another, e.g., by pipes or canals.

instream flow approximations — estimates of monthly flow sufficient to support aquatic life and outdoor recreation; estimated at the outflow point.

instream use — uses of water in the stream channel, e.g. fish and other aquatic life, recreation, navigation, hydroelectric production.

mgd — million gallons per day.

modified central case (MCC) — now called *National Future.*

monthly — a set of average daily values for each month of the year.

NASQAN — National Stream Quality Accounting Network; a data-collection program established by the U.S. Geological Survey to obtain long-term consistent regional and nationwide overviews of the quality of streams.

natural flow depletion — see *streamflow-related terms.*

natural modified flow (NMF) — now called *total streamflow.*

natural outflow — see *streamflow-related terms.*

National Future (NF) — estimates of present and future conditions by the participating Federal agencies; National Future estimates form a nationally consistent information base, which is not necessarily a nationally accepted future; see also *State-Regional Future.*

net evaporation — the difference between rainfall and evaporation; limited to evaporation from manmade reservoirs that have more than 5,000 acre-feet capacity and from farm and stock ponds; zero is used when rainfall exceeds evaporation.

net exports —
net imports — the difference between the water artificially transferred to and from a region or subregion is calculated as a net import or export.

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OBERS — a collection of current socioeconomic information and demographic and economic projections; the *1972 OBERS Series E* projections are the primary base for information used in the second assessment; *OBERS* is a Water Resources Council publication combining information from the Department of Commerce (Bureau of Economic Analysis) and the Department of Agriculture (Economics, Statistics, and Cooperative Service).

offstream use — water withdrawn from a source for functional uses such as irrigation, municipal water supply, steam electric generation, etc.

outflow point — see *streamflow-related terms.*

overdraft — see *groundwater overdraft.*

present modified flow (PMF) — now called *current streamflow.*

public lands — includes only Bureau of Land Management (BLM) lands, national forests, and national parks.

region — see *assessment geographic divisions.*

salinity — a condition in which the water contains more than 1,000 milligrams of dissolved solids per liter, regardless of the nature of the mineral in solution.

State-Regional Future (SRF) — estimates of present and future conditions provided by participating River Basin Commissions, State agencies, and other regional sponsors; see also *National Future.*

STORET (storage and retrieval) — a computerized water quality data system managed by the Environmental Protection Agency.

streamflow-related terms

1. **outflow point**
   a. **above outflow point** — describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion, plus the sum of values for all upstream regions or subregions.
   b. **at outflow point** — the sum of outflows from all of the major streams and rivers draining the area, measured at the downstream boundary of the region or subregion.
2. **streamflow**
   a. **streamflow** — statistically derived estimate of surface freshwater discharge rates at the outflow point of the subregions, with adjustments made where actual stream gage locations are not near the outflow point.
   b. **current streamflow** — average flow for "1975" derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.
   c. **assessed streamflow** — a computed flow that includes effects of consumption, water transfers, and evaporation from manmade reservoirs, but not ground-water overdraft.
3. **streamflow as supply**
   a. **current streamflow supply** — the "1975" streamflow if consumption were eliminated, but ground-water overdraft flows were continued.
   b. **assessed total streamflow** — streamflow that would be available if consumption were eliminated, if "1975" water transfer and reservoir practices were continued, but if groundwater overdrafting were discontinued.
   c. **natural outflow** (natural available streamflow) — estimate of streamflow without artificial manmade constraints.
4. **streamflow depletion**
   a. **current streamflow depletion** — estimated loss to "1975" current streamflow supply from consumption.
   b. **assessed streamflow depletion** — estimated loss to assessed total streamflow from consumption, increases in net exports, and increases in net evaporation.
   c. **natural flow depletion** — estimated loss to natural outflows (natural available streamflow) from all offstream demands (consumption, evaporation, and net exports).
5. **streamflow exceedance** — a statistical estimate of flow probability based on a 100-year period; a 5-percent exceedance flow will be exceeded only in five of the 100 years, which represents a very high streamflow condition.
6. **surplus streamflow** — portion of streamflow at region or subregion outflow point after all offstream and instream uses have been met; value does not include covenants and agreement for maintaining flows at downstream points.

subarea — see *"assessment subarea"* given under *assessment geographic divisions.*

subregion — see *"assessment subregion"* given under *assessment geographic divisions.*

surplus streamflow — see *streamflow-related terms.*

suspended solids — small particles of solid materials that contribute to turbidity and resist separation by conventional means.

total streamflow — see *streamflow-related terms.*

total suspended solids (TSS) — a measure of suspended solids used to evaluate water quality.

water adequacy — capability of a river system to meet both offstream and instream uses without overdraft of ground-water sources.

water transfers — see *imports, exports.*

withdrawal — water taken from a surface- or ground-water source for offstream use.

CONVERSION TABLE FOR WATER-MEASUREMENT TERMS

QUANTITY		
1 acre-foot	=	325,851 gallons
	=	43,560 cubic feet
1 million gallons	=	3.07 acre-feet
1 cubic foot	=	7.48 gallons
FLOW		
1 million gallons per day (mgd)	=	694.4 gallons per minute
	=	1.55 cubic feet per second
	=	1,120 acre-feet per year
1 billion gallons per day (bgd)	=	1.12 million acre-feet per year
1 cubic foot per second	=	1.98 acre-feet per day

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PART I
INTRODUCTION

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CONTENTS

National Water Assessment -- Its origin ---------- 1
Purpose and scope ---------- 2
Assessment modifications and limitations ---------- 5
Organization of assessment report ---------- 5

Water Resources Council -- Participants and functions -------- 13
Functions of member agencies ---------- 13
Functions of observers ---------- 14

TABLE

I-1. Reports of the Second National Water Assessment --------- 10

ILLUSTRATIONS

I-1. Water resources regions ---------- 3
I-2. Water resources subregions used in the Second National Water Assessment ---------- 4
I-3. Information flow for the Second National Water Assessment ---------- 6

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National Water Assessment — Its Origin

During the past 60 years, more than 20 commissions or committees have examined national water policies and problems. The first comprehensive assessment of the Nation's water resources was performed between 1935 and 1937 by the Water Resources Committee of the Natural Resources Committee. The Natural Resources Committee, established by Executive Order under the Federal Emergency Relief Appropriation Act of 1935, was to develop long-range plans and policies for construction of public works. The Natural Resources Committee, in turn, instructed the Water Resources Committee to study national water resources by drainage basins and to outline measures to develop and manage these resources.

Between 1959 and 1961, the Senate Select Committee on National Water Resources also studied the Nation's water resources. This Committee, under the chairmanship of Senator Robert S. Kerr of Oklahoma, was established by the Senate in 1959. Its purpose was to study the extent to which use of water resources affected the Nation as a whole.

By 1959, it was agreed that the planning of Federal water programs should be centralized so that the overall good of the Nation was kept in focus; however, no agreement had been reached as to the organization for this centralized planning nor on the appropriate ideological basis for overall water resources policies. After years of debate over proposed legislation for water resources development, Congress passed and President Johnson signed the Water Resources Planning Act of 1965 (Public Law 89-80) establishing the U.S. Water Resources Council.

Section 102 of the Water Resources Planning Act directs that the Council shall:

(a) Maintain a continuing study and prepare an assessment biennially, or at such less frequent intervals as the Council may determine, of the adequacy of supplies of water necessary to meet the water requirements in each water resources region in the United States and the national interest therein; and,

(b) Maintain a continuing study of the relation of regional or river basin plans and programs to the requirements of larger regions of the Nation and of the adequacy of administrative and statutory means for the coordination of the water and related land resources policies and programs of the several Federal agencies; it shall appraise the adequacy of existing and proposed policies and programs to meet such requirements and it shall make recommendations to the President with respect to Federal policies and programs.

In brief, the U.S. Water Resources Council was to gather and maintain information, to evaluate problem areas or trends, to study the effectiveness of State-regional programs, laws, and policies, and to recommend Federal programs and policies.

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As a result of this mandate, in 1968 the Water Resources Council published the First National Water Assessment entitled, The Nation's Water Resources. This first report provided a comprehensive reference for information on national and regional water resources development and projected needs which had been gathered from Federal agencies responsible for the major water resources programs. For the Second National Water Assessment, the Council enlarged the scope of information sources to include State and regional sponsors as well as Federal agencies, and increased the level of detail on water and related land resources information. This report is a product of the Second National Water Assessment. Council participants and their functions are given at the end of this part.

Purpose and Scope

The purpose of the Second National Water Assessment was to gather and compile the national and State-regional perspectives on current and emerging water and related land resources problems, to analyze the problems as perceived from the two perspectives, and to prepare a report on national water problems.

To accomplish this, the assessment needed a comprehensive and nationally consistent water resources information base for the entire Nation. Consistent and comprehensive data could be gathered for water quantity on a regional and subregional basis, but data on water quality could not be so aggregated or disaggregated for the geographic areas used for the assessment. As a result, data on water quality could not always be compiled for consistent information on the specific regions and subregions of this assessment. However, the importance of water quality in the Nation's need for and use of water resources is discussed in Part IV. Future assessments should include a process whereby information on the water quality aspects of the Nation's water resources can be compiled for quantitative incorporation into the study.

The assessment provides information on three levels: national, regional, and subregional. For information compilation and analysis, the Nation was divided into 21 hydrologic regions called water resources regions. Eighteen are within the conterminous United States. The other three are Alaska, Hawaii, and the Caribbean. Boundaries for these regions are based on surface topography, except where a hydrologic region extends beyond a national boundary. The regions are either the drainage area of: (1) a major river, (2) a large segment of a major river, or (3) the combined area of a series of rivers (Figure I-1).

The 21 regions are subdivided into 106 hydrologic subregions, which are smaller drainage areas within the regions. The subregion is the basic information-collection subdivision used for the Second National Water

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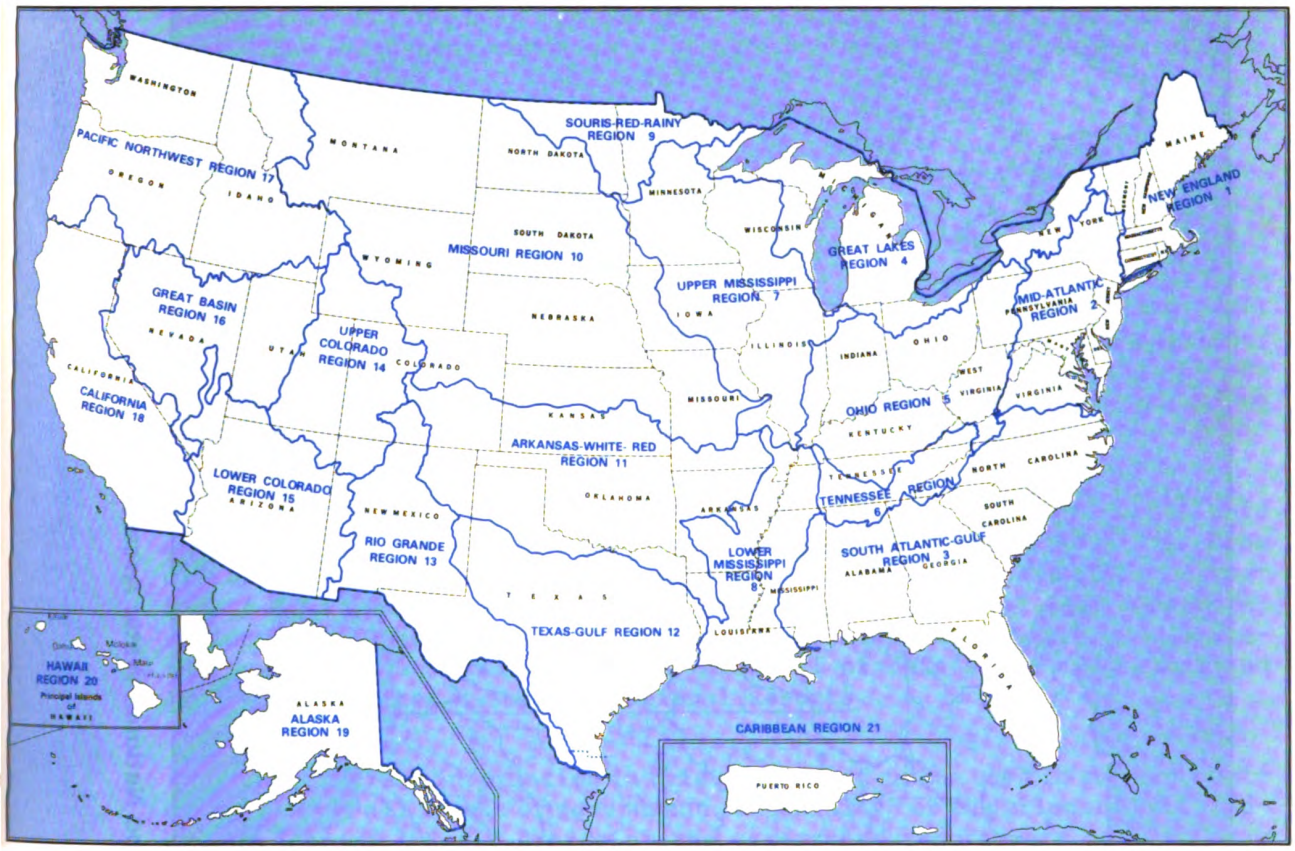

Figure I-1. Water Resources Regions

Assessment. In supporting studies these have been referred to as aggregated or assessment subregions (ASR); however, for simplicity and consistency of reference, the single term subregion is used in this report (Figure I-2).

Another geographic subdivision used in compiling information is the assessment subarea. Although county (political) boundaries determined this subdivision, the grouping of subareas followed the subregional hydrologic boundaries as closely as possible. Some socioeconomic information had to be compiled according to subareas; however, all information in this report is presented in terms of the hydrologic subregions.

In addition to the three-level geographic breakdowns, the Second National Water Assessment organized the information into three basic time

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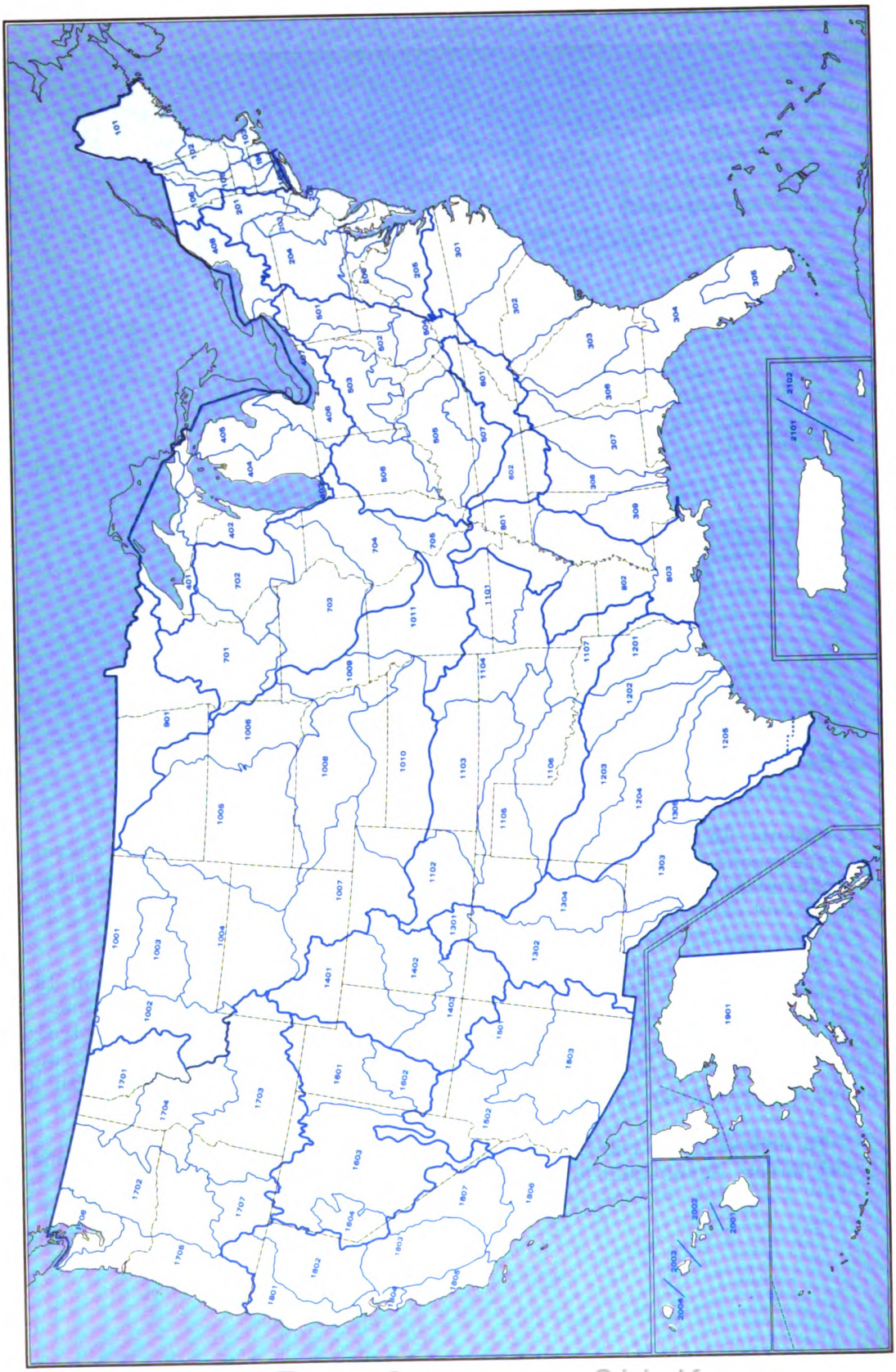

Figure I-2. Water resources subregions used in the Second National Water Assessment

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periods: "1975," 1985, and 2000. This was done so that current assumed conditions could be compared with the near-future projections (1985) and the longer 25 year projections (2000). Information for the "1975" base year represents estimates of water supply and use expected under average conditions and at "1975" population. Since this is an assumed statistical year, the quotation marks are used to distinguish it from the actual, historical 1975.

Assessment Modifications and Limitations

Certain projections and evaluations used in the first assessment have had to be modified for this assessment. Population did not increase at the rate anticipated, so projections for future water needs are lower than those for the first assessment. The heightened awareness of environmental values, problems with deterioration of water quality, limitations of water supplies, and energy demands on water use have realigned values in the management of water resources.

Several regional reviewers did not agree with the nationwide analysis estimates made for their regions. These disagreements arose either from different assumptions by the regional reviewers or from a lack of representative national information for the specific regions. Therefore, regional or State management groups should also investigate the State-regional reports developed during Phase II of this study and summarized in Volume 4, Water Resources Regional Reports.

The detailed information in this assessment can be used to support decisionmaking at all levels of government, especially for the allocation of Federal resources. Early drafts of the assessment report were used to draw up the President's Drought Study Report of March 1977, water conservation and reuse reports, and water for energy analyses. The general public, program administrators, and the Congress can use the assessment to compare Federal and State viewpoints on the Nation's water resources problems.

Organization of Assessment Report

The Second National Water Assessment was conducted in three phases -- (I) a nationwide analysis, (II) a specific problem analysis, and (III) a national problem analysis. These three phases and their relation to the final report are explained below (Figure I-3).

Phase I: Nationwide Analysis - The main objective of this phase was to identify current and potential water problems with "1975" as the base and to develop a consistent set of national projections for 1985 and 2000. To

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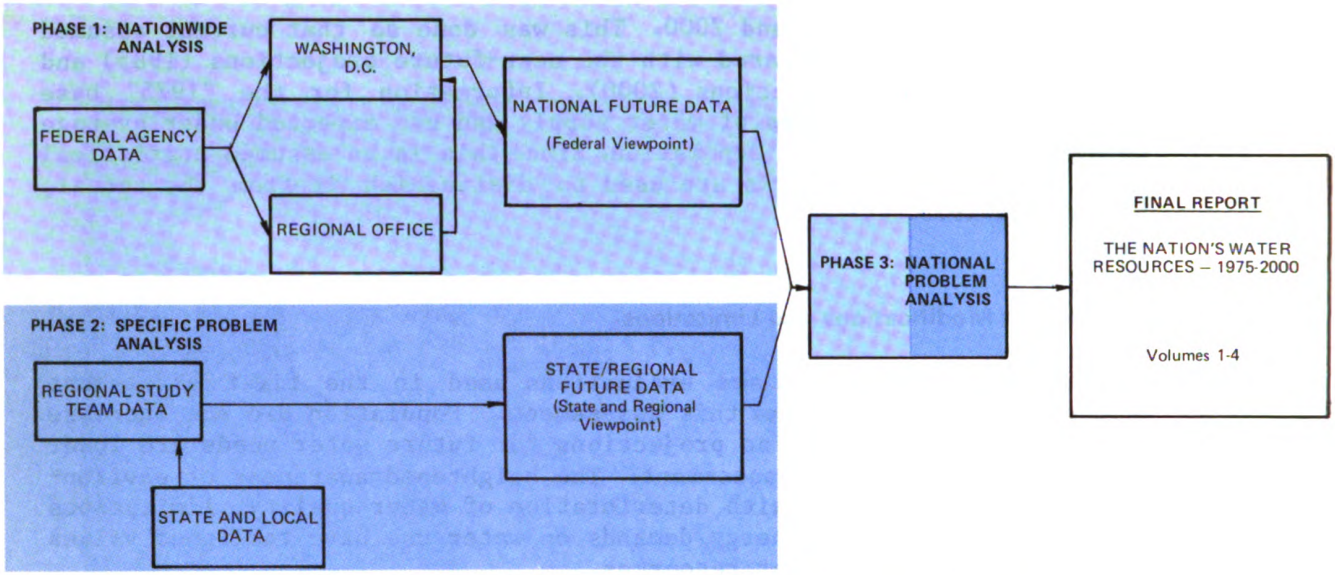

Figure I-3. Information Flow for the Second National Water Assessment

present this national perspective, information was gathered from Federal agencies (Council members) on water requirements, surpluses, and deficiencies for each of the 21 water resources regions. Information was compiled on water supply and demand factors that included population, economic activity, water supply, water quality, energy needs, flood damage, navigation, fish and wildlife habitat, recreational opportunities, and land preservation. The results of these studies are the National Futures (NF) used in the assessment report. The Nationwide Analysis is documented in a summary report and 16 appendixes prepared in September 1977. A series of 21 Federal-regional implications workshop reports also document this. These Water Resources Council reports are available through the National Technical Information Service (NTIS); however, the draft information has not been updated to reflect the greater accuracy needed for the final report (Table I-1).

Phase II: Specific Problems Analysis - This phase was to gather the State-regional viewpoints on the regional water issues. Twenty-one State-Federal teams in State and regional offices prepared these studies, which are referred to as the State-Regional Futures (SRF). They are the regional counterparts of the National Futures given in the Nationwide Analysis study (Phase I).

In Phase II, specific water-related problem issues and geographic problem areas are identified and described from the State and regional perspectives.

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Included in the survey and analysis are:

(1) Current and future water problems
(2) Conflicts that might arise in meeting State and regional objectives
(3) Problems and conflicts that need resolution.

The Phase II study is documented in four reports prepared in mid-1977 by regional teams from each of the 21 water resources regions. These reports are: Technical Memorandum 1, problem identification; Technical Memorandum 2, specific problem analysis and State-Regional Future; Technical Memorandum 3, effects of not resolving problems; and Technical Memorandum 4, summary report (Table I-1).

Phase III: National Problems Analysis - The Water Resources Council prepared this analysis in three steps: (1) evaluated Phases I and II, (2) identified and analyzed the Nation's most serious water resources problems, and (3) prepared the final report. The complete report consists of the following:

Volume 1, Summary, gives an overview of the Nation's water supply and use for "1975," 1985, and 2000 and summarizes the critical problems that are identified in Volume 2.

Volume 2, Water Quantity, Quality, and Related Land Considerations, consists of five parts:

Part I, Introduction, outlines the origin of the national water assessment, explains its documentation, the documents of the second assessment, and identifies the individuals and agencies that contributed to the second assessment.

Part II, Water Management Problem Profiles, identifies the 10 general water problem issues considered significant from the State-regional and Federal viewpoints. It describes the problems, their implications, and potential consequences.

Part III, Water Uses, focuses on the national perspectives on existing ("1975") and projected (1985 and 2000) requirements for water to meet offstream, instream, and flow-management needs for the major functional water use categories. State-regional and Federal perspectives are compared.

Part IV, Water Supply and Water Quality Considerations, analyzes the adequacy of fresh-water supplies (ground and surface) to meet existing

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and future requirements. It contains a national water budget; quantifies surface- and ground-water supplies, reservoir storage, and transfers of water within and between subregions; describes regional requirements and compares them to supplies; evaluates water quality conditions; and discusses the legal and institutional aspects of water allocation.

Part V, Synopses of the Water Resources Regions, covers existing conditions and future requirements for each of the 21 water resource regions. Each regional synopsis discusses: functional and location-specific water-related problems; regional recommendations on planning, research, data, and institutional aspects of solving regional water-related problems; a problem-issue matrix; and a comparative analysis table of National Future and State-Regional Future water information. (The term National Future describes a nationally consistent forecast or projection but is not considered a nationally accepted future.)

Volume 3, Analytical Data, describes the methods and procedures used to collect, analyze, and describe the data used in the assessment. National summary information is included with explanatory notes. Volume 3 is supplemented by five separately published appendixes that contain information for the regions and subregions:

Appendix I, Social, Economic, and Environmental Data, contains the socioeconomic baseline ("1975") and growth projections (1985 and 2000) on which the water supply and water use projections are based. This appendix presents two sets of information. One set, the National Future (NF), represents the Federal viewpoint; the other set, the State-Regional Future (SRF), represents the regional sponsor and/or State viewpoint.

Appendix II, Annual Water Supply and Use Analysis, contains baseline water supply information and baseline and projected water withdrawal and water consumption information used for the assessment. Also included are a water adequacy analysis, a natural flow analysis, and a criticalmonth analysis.

Appendix III, Monthly Water Supply and Use Analysis, contains monthly details of the water supply, water withdrawal, and water use information contained in Appendix II, and includes an analysis of monthly water adequacy.

Appendix IV, Dry-Year Conditions Water Supply and Use Analysis, contains both annual and monthly baseline and projected water withdrawal and water consumption information for dry conditions, which will occur on the average one year in five. A dry-conditions water adequacy analysis is also included.

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Appendix V, Streamflow Conditions, contains detailed background information on the derivation of the baseline streamflow information. A decription of streamflow gages used, correction factors applied, periods of record, and extreme flows of record are given for each subregion. The State-Regional Future estimate of average streamflow conditions is also included.

Volume 4, Water Resources Regional Reports, consists of separate reports for each of the 21 regions. Synopses of these reports are given in Part V of Volume 2.

For a summary of the availability of the reports and supporting documents, see Table I-1.

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Table I-1. Reports of the Second National Water Assessment

FINAL REPORT

The Nation's Water Resources -- 1975-2000

Volume 1, Summary	GPO[1]
Volume 2, Water Quantity, Quality, and Related Land Considerations	GPO
Volume 3, Analytical Data	GPO
Appendix I, Social, Economic, and Environmental Data	GPO
Appendix II, Annual Water Supply and Use Analysis	GPO
Appendix III, Monthly Water Supply and Use Analysis	GPO
Appendix IV, Dry-Year Conditions Water Supply and Use Analysis	GPO
Appendix V, Streamflow Conditions	GPO
Volume 4, Water Resources Regional Reports (separately published report for each of the 21 water resources regions)	GPO

DOCUMENTARY REPORTS

Phase I, Nationwide Analysis

Nationwide Analysis Summary	NTIS[2]
Appendix A-1, Population, Personal Income, and Earnings -- Projections and Historic Data	NTIS
Appendix A-2, Population, Personal Income, and Earnings -- Incremental Projections and Ratios	NTIS
Appendix B, Estimated Flood Damage	NTIS
Appendix C-1, Livestock Water Use	NTIS
Appendix C-2, Domestic Water Use from Noncentral Systems	NTIS
Appendix C-3, Domestic Water Use from Central Systems	NTIS

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Appendix D,	Outdoor Recreation Requirements and Related Problem Issues	NTIS
Appendix E,	Endangered and Threatened Species	NTIS
Appendix F,	Designated and Potential Wilderness Areas	NTIS
Appendix G,	An Assessment of Estuarine and Nearshore Marine Environments	NTIS
Appendix H,	Energy and Related Water Requirements.....	NTIS
Appendix I,	Economic Development, Water Requirements, and Water-Related Problems on Indian Reservations	NTIS
Appendix J,	Water Use Price/Cost Sensitivity Analysis	NTIS
Appendix K,	Water Quality Concerns, Present and Future ...	NTIS
Appendix L,	Toward a Structured Ecological Data Base	NTIS
Appendix M,	Agricultural Resources Assessment System	NTIS
Federal Implications Workshop Reports (separately published report for each of the 21 water resources regions)		NTIS

Phase II, Specific Problems Analysis

For each of the 21 Water Resources Regions:

Technical Memorandum 1, Problem Identification	WRC[3]
Technical Memorandum 2, State-Regional Future, Problems Screening and Documentation of Assumptions	NTIS
Technical Memorandum 3, Description of Selected Problems	NTIS
Technical Memorandum 4, Summary and State-Regional Conclusions and Recommendations	NTIS

Phase III, National Problem Analysis

Food and Fiber and Related Resources Considerations	NTIS
Manufacturing Water Use Requirements	NTIS
Water Use in the Mineral Industry	NTIS

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Recreation Requirements and Related Resource Considerations ..	NTIS
Navigation	NTIS
Preservation of Natural Areas and Historic Resources	NTIS
Flood Damage Reduction and Resources Considerations	NTIS
Erosion and Sedimentation and Related Resources Considerations	NTIS
Fish and Wildlife Requirements and Related Resources Considerations	NTIS
Instream Flows for Fish and Wildlife	NTIS

SUPPLEMENTARY REPORTS

Water for Energy	WRC[3]
Other reports are to follow	WRC

MAPS (scale 1:7,500,000)

Water Resources Assessment Subregions	WRC
Assessment Subareas (County Boundary Approximations of Assessment Subregions)	WRC
Enacted, Proposed, and Potential Wilderness	WRC
Streams of National Significance for Fish and Wildlife	WRC

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[1]Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Each volume is priced separately and separate reports of the volumes are priced individually.

[2]National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151. Each report is priced separately.

[3]U.S. Water Resources Council, 2120 L Street, N.W., Washington, D.C. 20037. Single copies, if available, are free on request.

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Water Resources Council — Participants and Functions

Members of the Council are the Secretaries of the Departments of Agriculture, Army, Commerce, Energy, Housing and Urban Development, Interior, and Transportation, and the Administrator of the Environmental Protection Agency. Observers are the Director of the Office of Management and Budget, the Attorney General, the Chairman of the Council on Environmental Quality, the Chairman of the Tennessee Valley Authority, the Chairmen and Vice Chairmen of the River Basin Commissions, Commissioners of Interstate Compact Commissions, and Chairmen of Interagency Committees.

The President has designated the Secretary of the Interior as Council Chairman. Other departments and agencies are invited to Council meetings when matters pertaining to their responsibilities are under consideration.

Functions of Member Agencies

Functions of member agencies of the Council for planning, management, and operations activities for water and related land resources are described as follows:

Department of Agriculture is involved in the management of national forests for their multiple uses, products, and services; watershed treatment and management; small watershed projects for flood control, water supply, irrigation, drainage, recreation, fish and wildlife, erosion and sediment control, and water quality management; river basin surveys and investigations; economic analyses and projections of rural activities; credit, cost sharing, and technical assistance to farmers for installation of soil and water conservation practices and to rural communities for water supply and sewerage facilities; and supporting research.

Department of the Army develops plans for beach protection, flood control, navigation, and multiple-purpose projects; constructs, operates, and maintains project facilities; regulates the use of navigable waters of the United States with respect to dredging and obstructions to navigation; and provides State and local interests with flood-plain information.

Department of Commerce conducts hydrometeorological studies; provides river and flood forecast and warning services; administers a coastal zone grant program; is responsible for studies of living marine resources that include those within estuaries and coastal areas; performs business and industrial water requirement analyses; projects economic activity; takes census of a broad range of water uses; and conducts supporting research.

Department of Energy makes studies of the power phases of river basin development; licenses and regulates non-Federal hydroelectric powerplants; markets hydroelectric power generated at Federal plants; and, in cooperation with the Water Resources Council, assesses the impacts and requirements of water for energy resources development.

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Department of Housing and Urban Development is concerned primarily with the municipal and urban aspects of water and related land resources, including flood insurance and urban hydrology. It makes financial grants to States and to metropolitan and urban communities for comprehensive planning and community development that may include support for water and sewer facilities, open space, recreational areas, and historic and esthetic preservation.

Department of the Interior has responsibilities in water resources research and data collection; desalination; conservation of and development on public lands; studies of outdoor recreation; administration of certain wild and scenic rivers, sports fisheries, and wildlife and their habitat, and endangered species; weather modifications; and development and operation of irrigation and multipurpose water resource projects.

Department of Transportation is involved with the navigation, marine safety, pollution by vessels, and highway and bridge aspects of water resources development.

Environmental Protection Agency, in cooperation with State and local governments and industry, is concerned with the abatement of water pollution and enhancement of the water quality of rivers and bodies of water, and makes financial grants to State and local governments for the administration of related water quality programs to initiate and coordinate planning, including the construction of publicly-owned waste-water treatment plants. It establishes standards for control of effluents to improve the quality of receiving water and for purity of drinking water. It enforces its regulations for carrying out these standards.

Functions of Observers

Office of Management and Budget assists in developing efficient implemention and coordination mechanisms for government programs and policies; assists the President by clearing departmental advice on proposed legislative enactments; and promotes evaluations to assist the President by ensuring effective program performance and efficiency.

The Attorney General, as head of the Department of Justice and Chief Law Officer of the Federal Government, represents the United States in legal matters, generally including those concerning water and related lands, and gives advice and opinions to the President and to the heads of the Executive Departments as requested.

Council on Environmental Quality formulates and recommends national policies to promote the improvement of the quality of the environment. The Council performs a continuing analysis of changes or trends in the national environment and assists the President in the preparation of the annual Environmental Quality Report to the Congress.

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Tennessee Valley Authority, a corporation of the Federal Government, was established by Congress in 1933 as a regional resource development agency. TVA assignments in the Tennessee drainage basin and adjoining territory are to control flood waters of the Tennessee River, improve navigation on the Tennessee River, generate and sell electricity, encourage agricultural and industrial development, promote reforestation, and advance the economic and social well-being of the people.

River Basin Commissions. To meet the need for broad participation in planning, the Water Resources Planning Act provides for the establishment of Federal-State river basin commissions on request of the State and the recommendation of the Water Resources Council. The affected States and Federal agencies have representatives on these commissions. The Chairman is appointed by the President and the Vice Chairman is elected by the States. Commissions have been established for the Pacific Northwest, the Great Lakes, the Ohio river, the Missouri River, the Upper Mississippi River, and the New England river basins. Commission functions are:

- To serve as the principal coordinating agency for water and related land management plans
- To prepare and keep current a comprehensive coordinated joint Federal-State plan for water and related land resources development within the basin
- To recommend priorities for data collection and for investigations, planning, and construction of projects
- To foster and undertake such studies as are necessary in preparing and maintaining the comprehensive plan
- To submit to the Water Resources Council a comprehensive plan and recommendations for implementing the plan

Interstate Compact Commissions. The Federal-Interstate Compact Commission for the Delaware River Basin was established by the legislatures of four states and the Congress in 1961. It is the first compact in which the United States is a signatory party. The Delaware River Basin Commission, created by compact, is composed of representatives of the four basin states and the Federal Government. It is vested with broad powers to manage and control the water and related land resources of the entire Delaware Basin. Significant activities have been: the handling of interstate conflicts about short water supplies during a prolonged drought; leadership in developing water quality standards; and careful review and approval of hundreds of individual water facilities including wells, industrial installations, and municipal water supply and sewerage systems to ensure coordinated development. Although the commission is empowered to construct and operate water projects, it has not as yet done so. A similar Federal-interstate compact has been established for the Susquehanna River Basin. Federal-interstate compacts have been proposed for other river basins.

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Interagency Committees. Before 1965 and the establishment of the U.S. Water Resources Council, interagency committees were created by an ad hoc council. After 1965, some of the committees were replaced by river basin commissions. Three interagency committees--Pacific Southwest, Arkansas-White-Red Rivers, and Southeastern river basins--remain and continue to operate under the aegis of the Water Resources Council. These committees do not have legal status (presidentially appointed full-time Chairman and central staff) but have about the same representation (Federal and State) as the river basin commissions. Their functions, however, are usually limited to serving as a coordination entity and discussion forum.

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PART II
WATER MANAGEMENT PROBLEM PROFILES

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CONTENTS

Introduction ---- 1
Inadequate surface water supply ---- 3
Definition of problem ---- 3
Implications ---- 5
Specific problems ---- 6
Options for resolution ---- 9
Overdraft of ground water ---- 11
Definition of problem ---- 11
Implications ---- 13
Specific problems ---- 14
Options for resolution ---- 17
Pollution of surface water ---- 19
Definition of problem ---- 19
Surface-water pollution from point sources ---- 19
Surface-water pollution from nonpoint sources ---- 23
Eutrophication of manmade and natural water bodies ---- 24
Implications ---- 25
Specific problems ---- 26
Options for resolution ---- 27
Pollution of ground water ---- 29
Definition of problem ---- 29
Implications ---- 31
Specific problems ---- 31
Options for resolution ---- 32
Quality of drinking water ---- 35
Definition of problem ---- 35
Implications ---- 37
Specific problems ---- 38
Options for resolution ---- 39
Flooding ---- 41
Definition of problem ---- 41
Implications ---- 41
Specific problems ---- 43
Options for resolution ---- 45
Erosion and sedimentation ---- 47
Definition of problem ---- 47
Implications ---- 47
Specific problems ---- 49
Options for resolution ---- 53
Dredging and disposal of dredged material ---- 55
Definition of problem ---- 55
Implications ---- 57
Specific problems ---- 57
Options for resolution ---- 59
Wet-soils drainage and wetlands ---- 61
Definition of problem ---- 61
Implications ---- 63
Specific problems ---- 65
Options for resolution ---- 68
Degradation of bay, estuary, and coastal water ---- 71
Definition of problem ---- 71
Implications ---- 74
Specific problems ---- 76
Options for resolution ---- 77

ILLUSTRATIONS

II-1. Inadequate surface-water supply and related problems ---- 4
II-2. Ground-water overdraft and related problems ---- 12
II-3a. Surface-water pollution problems from point sources (municipal and industrial waste) ---- 20
II-3b. Surface-water pollution problems from nonpoint sources (dispersed) ---- 21
II-3c. Surface-water pollution problems–eutrophication ---- 22
II-4. Ground-water pollution problems ---- 30
II-5. Quality of drinking water problems ---- 36
II-6. Flooding problems ---- 42
II-7. Erosion and sedimentation problems ---- 48
II-8. Coastal and inland waterways with dredge and fill problems ---- 56
II-9. Wet-soils drainage and wetlands problems ---- 62
II-10. Bay, estuary, and coastal water problems ---- 72

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Introduction

Part II of this report is concerned primarily with the identification of significant locations and conditions of current or potential water resources problems. The problems presented here emerged from an extensive survey of the current ("1975") and potential water situation in each of the Nation's 21 water resources regions and 106 subregions.

In each of the 21 regions, regional sponsors who represented Federal-State organizations, States, and the public were asked to develop a list of current and potential water-related problems for their region. The sponsors were to delineate the geographic areas affected by the problem, examine the interrelationships of the problem, and characterize the problem as severe, moderate, or minor. They were also to note whether the problem was being or not being adequately handled by an ongoing Federal, State, or other program. Generally, those problems with adequate support were dropped from further listings. Part V of this report, Regional Assessment Summaries, shows the results of these assessments.

The Water Resources Council staff tabulated the data and grouped the problem issues into 100 water problems. The Council then presented these 100 to regional, State, and Federal agency representatives for discussion. After discussion and evaluation, the water issues were again regrouped into 17 general problem areas. These 17 national water problems, accompanied by maps delineating the severity of the problem in geographic areas, were presented at the Second National Conference on Water in St. Louis, Missouri, May 23-25, 1977. As a result of the conference discussions, the Water Resources Council again regrouped the issues into 10 common functional problem areas. These are:

1. Inadequate surface-water supply
2. Overdraft of ground water
3. Pollution of surface water
4. Pollution of ground water
5. Quality of drinking water
6. Flooding
7. Erosion and sedimentation
8. Dredging and disposal of dredged material (dredge and fill)
9. Wet-soils drainage and wetlands
10. Degradation of bay, estuary, and coastal waters

Each of these 10 was then examined with respect to public health, environmental quality, economic efficiency, resource conservation, international relations, pervasiveness, and urgency. The problems, their implications, and potential consequences are presented in the following chapters.

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Although presented separately, the problems are interrelated. For example, ground water and surface water, erosion and dredging, drainage and water quality are all closely interrelated. Because any solution for one problem affects the others, effective planning for water resources must be broad enough to encompass these interrelationships.

The following presentations emphasize physical resource problems. However, legal and institutional aspects--e.g., water rights, land-use planning, water conservation, policy and organization, data and information, research, and public participation--are considered in the recommended options for problem resolution.

Each problem profile defines a problem and shows the area of the Nation most directly affected by it. The implications of the problems are also identified and specific problem examples and options for dealing with the particular problem are given. The examples may illustrate severity, uniqueness, or typicality of the problem. The purpose of this technique is to increase awareness so that once the full problem is understood, the program emphasis can be effectively directed toward solving it. A followup assessment could evaluate the progress toward problem resolution.

These chapters show that this Nation has already faced and is currently facing problems of water management. In view of the long lead-time needed for planning, research, education, and implementation of programs to resolve these conflicts, a comprehensive, coordinated program is vital to long-term national well-being.

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Inadequate Surface-Water Supply

Definition of Problem

Seventeen of the 106 subregions already have or by the year 2000 will have a seriously deficient supply of surface water (Figure II-1). In almost every region west of the Mississippi, the supply of surface water, expended at current quantities and output efficiencies, is inadequate for irrigation.

In addition to the short supply, water users are becoming more and more aware that water left in a stream is not necessarily "unused." Instream requirements for esthetics, recreation, waste assimilation, and fish and wildlife habitat maintenance are getting increased attention. However, with the rising cost of energy sources and production, the more economically feasible hydroelectric developments to increase peaking power may conflict with other uses of streamflow. The regulation of streamflow required for hydropower generation causes rapid fluctuations of stream levels which in turn create problems for recreation, navigation, and aquatic ecosystems. New energy imperatives are offsetting the values of old systems that took advantage of seasonally available water flows and pump-storage units that were less harmful to other surface-water uses. Evaluation of tradeoffs is becoming more and more serious.

In addition to the manmade, fluctuating demands on surface water, natural phenomena also make demands on surface-water supplies. Droughts are normal climatological phenomena. Man cannot as yet forecast their occurrence with certainty or (once they are upon us) determine how long they will last. No part of the Nation is immune to drought. Even the humid East has experienced drought, although droughts of several years duration are rare. The East generally has short-term, seasonal droughts. The Northeast drought of 1962-66 was an event expected on the average of only once every 150 years.

During the 1930's the Great Plains were beset by abnormally low precipitation. In combination with high winds and extreme temperatures--compounded by years of overgrazing and generally poor farming techniques--great dust storms developed so that much of the land lay useless for many years. In the late 1940's and early 1950's, a drought occurred in the Southwest and in places in the southern midcontinent. In some parts of the Southwest the drought continued for more than 10 years. Even though the drought of the early 1950's was more severe than that of the mid-1930's, the national impact was far less severe. This was because the stronger national economy could more easily absorb the loss and because conservation programs had made many areas less vulnerable to drought. In 1976-77, the Nation was again beset by a drought that centered in the West, Northwest, and upper parts of the Midwest. The humid East suffered from locally dry areas as well. In some areas, precipitation levels were well below the lowest on record. In long-range planning, natural phenomena, like political, economic, and environmental influences, must be considered in surface-water management.

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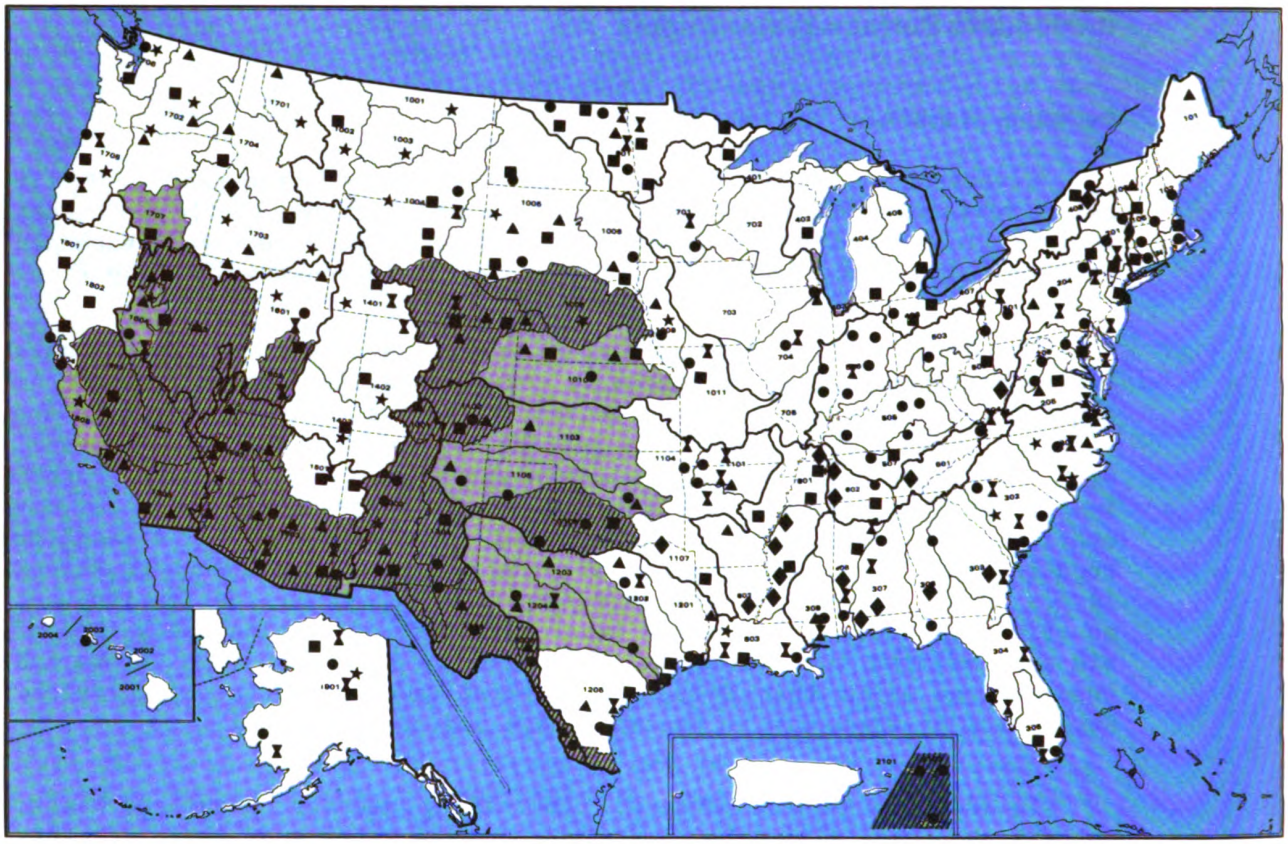

Explanation

Subregion with inadequate streamflow ("1975"-2000)

- 70 percent depleted in average year
- 70 percent depleted in dry year
- Less than 70 percent depleted

Specific problems *(as identified by Federal and State/Regional study teams)*

- ★ Conflict between offstream and instream uses

Inadequate supply of fresh surface water to support–

Offstream use

- ● Central (municipal) and noncentral (rural) domestic use
- ⧗ Industry or energy resource development
- ▲ Crop irrigation

Instream use

- ■ Fish and wildlife habitat or outdoor recreation
- ♦ Hydroelectric generation or navigation

Boundaries

- Water resources region
- Subregion

Figure II-1. Inadequate surface-water supply and related problems

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Implications

If the present national patterns of surface-water use continue, conflicts will arise for which no simple solutions are available. Population increases and distribution patterns are rapidly increasing the demand for municipal and rural domestic water. Some communities are restricting water connections, zoning land use, and defeating bond issues for water supply projects. Recent court cases have required communities to develop extensive conservation plans, including water reclamation, before they make plans to divert water from other basins.

With increasing concern for national energy independence, major new developments for oil, coal processing, and mining operations can be expected. In areas of new energy development where water supply is already limited and fully allocated, water will have to be imported or transferred from an existing use. In the West this transfer will almost inevitably be from irrigated agriculture, because energy producers are willing to pay a far greater price for water than are irrigators. Retirement of irrigated farmlands, however, will result in a loss of agricultural production, a decline in rural lifestyle, and an increase in urban development. On the other hand, limiting energy development and industrial growth because of inadequate water supplies could cause serious problems for regional, even national, economic health. A conservation program to increase the efficient use of water for irrigation could provide water for alternative purposes such as energy production. Ironically, however, some conservation actions such as sprinkler systems require additional electric energy.

The relationship between quantity and quality of water is clear. With increased consumption, streamflows will continue to decrease. In some places this may mean that irrigation return flows and sewage effluents will constitute an increasing portion of stream volumes. Fish and wildlife maintenance and water-related recreation activities have already suffered from the problem in the Pacific Northwest and in California. In both the East and the West, reduced river flows have also created water quality problems.

Conflicts between regulation of flow and downstream water uses could also have major interstate and international implications. Inadequate instream flows hamper waterborne transportation. Changing energy demands for greater peaking production in hydroelectric plants cause discharges from reservoirs to fluctuate wildly in short periods. The resulting rapid rising and falling of stream or reservoir levels could be a hazard to water recreation safety and could cause navigational problems.

The existence of adequate average streamflow does not mean that the water will be usable for offstream purposes without regulation. Irrigation, in particular, requires that the water be available when needed. Inevitably this means regulation by dams and reservoirs. Ponding of streams will, in most of the Nation at least, slightly increase evaporation, reduce the downstream flow, and affect the seasonal flow pattern.

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Specific Problems

The following local problems illustrate the distribution and variety of problems caused by inadequate surface-water supply. The information was furnished largely by regional sponsors.

Problem area: Lower Colorado River (Lower Colorado Region). See Figure II-1.

Water from the lower Colorado River main stem being used in Arizona and California consists of (1) natural runoff originating in the adjacent tributary area and (2) a portion of the main stem Colorado River water released from the Upper Colorado Region at Glen Canyon Dam under provisions of the Colorado River Compact and operating criteria agreements. Although the Colorado River system is one of the more heavily depleted river systems in the Nation, more than half the population of the West depends on its inadequate and poorly distributed supply.

Because current ("1975") surface-water uses of 4.6 billion gallons per day exceed available renewable surface supplies by about 2.4 billion gallons per day, central Arizona and southern Nevada make up the difference by pumping from wells, chiefly for irrigation. Almost half of the irrigated acres in the region depend entirely on ground water. As a result of that pumping, however, ground-water levels are declining at an average of 8 to 10 feet per year. As ground-water levels decline, other problems may emerge: land subsidence, formation of earth fissures, decrease in streamflow, and increase in pumping lifts. Direct water reuse is fast becoming imperative in this area.

An additional pressure on supplies is the Mexican Water Treaty of 1944, which provides for delivery of 1.5 million acre-feet annually to Mexico. Since the average annual supply of the Colorado River is so heavily depleted, the meeting of treaty and compact commitments will be difficult.

Problem area: Middle North Platte River Basin (Missouri Region, subregion 1007). See Figure II-1.

This drainage area in southeastern Wyoming has major problems of insufficient streamflow, inadequacy of minimum pool storage, and practices that dewater reaches of basin streams. These deficiencies adversely affect fish habitat and recreation uses of the waters.

With one exception, these flow problems are more acute on tributary streams than on the North Platte River itself. Many streams are regularly dewatered during the irrigation season and flows are so erratic that they provide no fishery. Tributary reservoirs are also subject to severe fluctuations in pool level because of seasonal inflows and drawdowns. The large main-stem lakes can usually withstand greater variances and still maintain some fish habitat and recreation surface.

One instance in which practices on the main stem of the North Platte system do pose a serious problem occurs at Guernsey Reservoir, the farthest downstream reservoir in Wyoming. The reservioir water level is annually

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drawn down rapidly to flush sediment into the irrigation canals and laterals to seal them against leakage. This practice is detrimental to fishing in two ways: the North Platte River fishery is degraded by the heavy sediment load, and Guernsey Reservoir is drawn down to a point where it is nearly empty, necessitating extremely low winter releases to fill it for the next season's irrigation needs.

Problem area: Sacramento Valley (California Region, subregion 1802). See Figure II-1.

The major water issue in this California area is the lower American River. Since completion of Folsom Dam, minimum summer and fall stages have been several times greater than they would have been before the dam was built. The higher stage and increased flow have much improved the instream conditions for recreation and the fishing in general. These improved instream conditions will exist, however, only during the interim period until all withdrawals for authorized project purposes are made. Then, unfortunately for recreationists, the large releases to which they have grown accustomed will probably not continue since recreation uses are not included in the authorization. Recreationists have mounted considerable agitation to maintain minimum flows and stages so that at least some opportunities for recreation will remain.

Problem Area: Beaumont-Port Arthur Metropolitan Area (Texas-Gulf Region, subregion 1201). See Figure II-1.

In Jefferson County in southeastern Texas, industries require large quantities of water for cooling, boiler feed, manufacturing and refining processes, and other industrial uses. In the Beaumont area, the city of Beaumont supplies water to several industries. In Jefferson County, the major supplier of industrial water is the Lower Neches Valley Authority.

The Lower Neches Valley Authority diverts water seasonally from its intakes on the Neches River and Pine Island Bayou to irrigate about 78,500 acres of rice in Jefferson County and portions of Liberty and Chambers Counties. This water is diverted across the basin divide, used, and discharged into the Neches-Trinity coastal basin.

The tidal reach of the Neches River extends from its mouth on Sabine Lake, where it intersects the Sabine-Neches Canal, to a temporary salt-water barrier at river mile 37. During certain periods of the year, however, the withdrawals of fresh water from the Neches River and Pine Island Bayou equal the actual flow of the river. The result is a practically no-flow condition in the Neches River below the fresh-water intakes. Without a barrier and in the absence of fresh-water inflow, salt water moves up the Neches River. This salt-water intrusion makes it necessary for the Lower Neches Valley Authority to construct temporary sheet piling barriers across the Neches and the Pine Island Bayou to prevent salt water from reaching their intakes. These barriers effectively block all flow in the river except flood flows, which occasionally wash out the barriers. The barriers normally are required during late summer and early fall because diversion rates increase during the rice irrigation season. It has been

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necessary to install the barriers almost every year since 1948. The barriers, which are removed when they are no longer needed, have remained in place for as long as 6 months.

With the salt-water barriers in place, the Neches River essentially becomes a dead-end navigation and waste disposal channel. The flow below the barriers consists largely of treated industrial and municipal effluent return flows, a very limited fresh-water inflow from a small drainage area, and the tidal salt water.

Problem area: Snake River (Pacific Northwest Region, subregion 1703 and 1704). See Figure II-1.

The Snake River flows from western Wyoming, through Idaho, to Oregon and Washington where it joins the Columbia River. Any increased diversion of water for irrigation and other uses will reduce flows in the middle and lower Snake River, thereby curtailing energy production at power dams in those reaches of the river. The resulting difference between capability and load will have to be made up from alternative sources, principally thermal. The cost to energy consumers will, of course, increase as the cost of alternative sources of energy increases.

The only free-flowing reach of the middle Snake River provides habitat for important resident and anadromous fish species and offers outstanding scenic and recreation values. As a recently designated National Wild and Scenic River, it has both national and regional importance. Excessive reduction in streamflow would detract from its attributes as a wild river and would impair the fishery habitat.

Problem area: Passaic and Raritan Rivers and Northern New Jersey (Mid-Atlantic Region, subregion 202). See Figure II-1.

The water-supply situation in the near term is critical in this area for virtually all users--municipal, self-supplied industry, agriculture, recreation, and fish and wildlife. In the Passaic and Hackensack River basins, surface supplies are approaching optimum development. In the near term, intraregional development (Raritan River) will be required to supply 5 million people and the bulk of New Jersey's industries with water. Emergency planning for water supply crises arising from system breakdown or drought conditions is presently inadequate.

Problem area: Wabash River Basin (Ohio Region, subregion 506). See Figure II-1.

The Wabash River basin includes most of Indiana, central Illinois, and a small part of western Ohio. Twenty-three communities in the basin are expected to have problems with water supply service by 1980. Another potential water supply problem stems from the possible installation of coal conversion plants. Were these to be sited in the basin, they would pose a serious water consumption problem.

Problem area: Little Tennessee-Hiwassee (Tennessee Region, subregion 601). See Figure II-1.

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This problem area is located in the extreme southwest corner of North Carolina, the southeast corner of Tennessee, and along the midnorthern border of Georgia. A major loss of recreation user days will continue at the Tennessee Valley Authority reservoirs. With optimum reservoir levels, recreation use would ultimately double current operating procedures. The increased recreation use would increase employment, income, and the retirement population.

Major changes in the present operation of the reservoirs to enhance recreation would seriously affect the hydroelectric power generation of the TVA-ALCOA projects. Recent studies by TVA indicate that for 1975 observed flows and temperature conditions, maintenance of high summer levels in all storage reservoirs would vastly increase power generation costs. No specific figures were available, but costs in the Little Tennessee-Hiwassee area alone should be substantial.

Losses in power production would occur in three different ways. First, maintaining higher reservoir levels in the summer by modifying the releases would lower the generation capability during the peak summer period when hydrogeneration is most valuable. Conversely, this would increase the hydrogeneration capacity at the end of the summer recreation period when load demands are lower and hydrogeneration is therefore not as valuable. Second, the lowered generating capability in the summer would require that alternate capacity be obtained. Any reduction in hydropower generation would have to be made up by an increase in steam-generated power, which, of course, at present would affect the Nation's coal and oil reserves. Third, the high reservoir levels at the end of the summer recreation season would have to be drawn down rapidly to reach the flood control levels needed for winter. The increased spilling of water would waste a natural resource.

Options for Resolution

The technical resolution of inadequate surface-water supply is straight forward: (1) increase the available supply and (2) reduce the present or projected demand. Techniques to increase supply include development of new sources, increase of the recycling or reuse of existing supply, and enhancement of efficiency in its distribution and use. Techniques to reduce demand include increase of price to consumers, institution of a conservation program to reduce use or eliminate waste, and changes in the institutional structures to increase efficiency of use or to shift demand geographically.

Mechanisms to allocate the supply include State water laws; Federal laws, subsidies, and practices; treaties; interstate compacts; State utility commissions; and other public and private institutions. The present cumbersome and inflexible institutional arrangements can only increase litigation and legislation. An important short-run step to reduce conflict is an increased efficiency of water use and expanded conservation measures. In the long run, however, it is obvious that more flexible allocation mechanisms are needed.

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Overdraft of Ground Water

Definition of Problem

The ground water of the United States is a vast resource estimated to have a volume far greater than that of all the surface water, more than the total capacity of all the Nation's lakes and reservoirs (including the Great Lakes). The volume is equivalent to about 35 years of surface runoff nationwide. Yet, as illustrated in Figure II-2, demands upon this resource, although localized, are producing impacts that vary in kind and intensity in many parts of the Nation.

Diminishing artesian pressure, declining spring and streamflow, land subsidence, and salt-water intrusion all indicate long-term excessive use of ground waters. Although the quantity of ground water in storage is an extremely important factor, use of that water at rates exceeding natural recharge (that is, overdraft) hastens the day when (1) alternative sources must be found, or (2) sound decisions must be made concerning the continued operation of water-dependent industries, irrigation developments, and the implementation of proposed community expansion plans. In some areas declining water levels will cause a cessation of pumping because of the increase in the cost of the energy required to bring water to the surface.

Examples of ground-water overdraft are found in the Trans-Pecos areas of Texas and in the San Joaquin Valley of California. The water level declines in these areas have resulted from decades of pumping for irrigation and, more recently, for home and industrial use. In the Trans-Pecos area, a reduction in irrigated acreage began recently when the high pumping lifts--combined with sharp increases in prices for natural gas used to run the pumps--resulted in uneconomical conditions for continued production.

In some areas, municipalities that depend on ground water for public supply are facing problems. Because ground waters traditionally have been assumed to be relatively inexpensive sources of unpolluted water of generally uniform temperature, cities have generally chosen ground waters rather than surface waters. As population increased, so did pumping rates and the number of wells. Some cities have deepened their wells to increase well yield. Others have drilled new wells farther inland to stem the progress of salt-water intrusion. If present use patterns continue, however, conservation practices will need to be implemented or possibly combined with alternative water supplies, probably at much higher cost per unit.

Low flows in many larger streams (the base flow) are mostly ground water that has returned to the surface. The interconnections may not be obvious inasmuch as the surface-water drainage patterns may have little or no apparent relation to the ground-water drainages. This is particularly true of larger ground-water systems. Because excessive use of ground water in one area may reduce the base flow, surface water could be depleted in downstream reaches. The benefit in one area may be at a cost to another.

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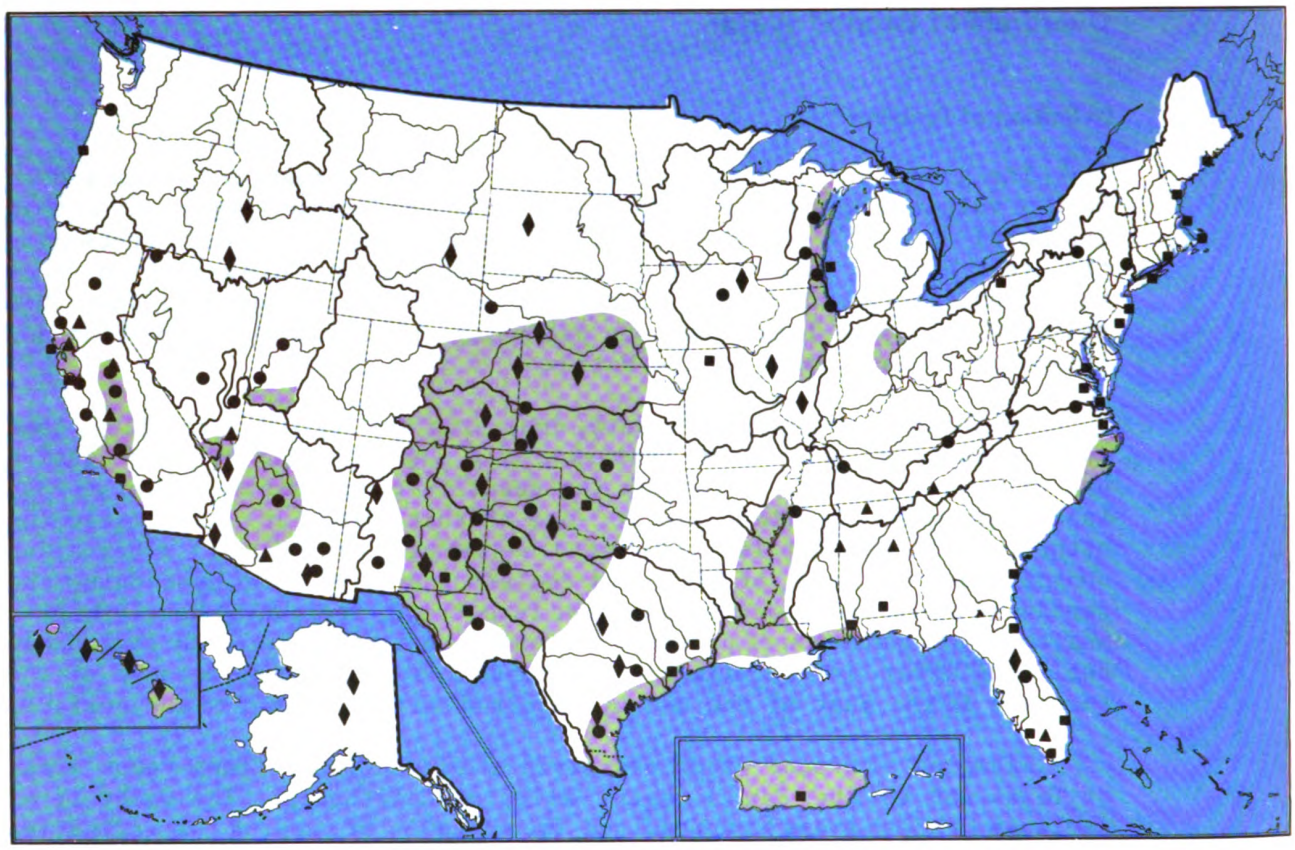

Explanation

Area problem

Area in which significant ground-water overdraft is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific problems *(as identified by Federal and State/Regional study teams)*

- Declining ground-water levels
- Diminished springflow and streamflow
- Formation of fissures and subsidence
- Saline-water intrusion into fresh-water aquifers

Boundaries

- Water resources region
- Subregion

Figure II-2. Ground-water overdraft and related problems

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Where large amounts of water are removed from a ground-water reservoir without adequate recharge so that the water level declines substantially, land subsidence may follow. In such situations the elevation of the ground surface may drop several feet over a relatively large area. In some low-lying coastal areas that previously were affected little by tidal action, subsidence has caused periodic flooding by higher tides. Subsidence can also damage structures such as buildings, highways, and railway tracks. In some areas, ground fissures have developed that allow the entry of polluted surface waters. Buildings have been damaged, and highways and railroads have developed alignment problems.

In island areas and at places along the Nation's coasts, fresh water "floats" on the more dense salt water. Even in the interior United States, aquifers containing saline water sometimes underlie, and are connected to, the fresh-water aquifers. Pumping of fresh ground water in such areas will cause the saline water to migrate into the zones of fresh water. If the fresh-water wells are pumped at high rates for a substantial time, the water obtained from them will increase in salinity and the value of the wells as a fresh-water supply source will be reduced. In this situation, larger wells may cause problems for many smaller wells which by themselves, because of the lower aggregate pumping rate, would have been in balance with recharge and with the salt-water/fresh-water interface.

Where aquifers near the surface contain water of inferior chemical or bacteriological quality, pumping of deeper aquifers--to the extent that water levels decline substantially--can allow the inferior water to migrate downward to deteriorate the quality of the fresh water in the deeper aquifer. Careless handling of waste waters at the land surface can, of course, pollute the shallow aquifers that earlier contained fresh water. Natural movement of water in aquifers is typically slow. Thus, whereas a polluted surface reservoir may be flushed out and become useable within a relatively short time, ground-water reservoirs, once polluted, may take years to become safe water supply sources again.

As with surface-water systems, aquifers are no respecters of political boundaries. Although water rights laws in some areas cover ground waters, the same problems exist for managing surface waters that cross State or national boundaries.

Another problem of ground-water management is the lack of information on the extent, volume, recharge rate, and effect of various pumping schemes on the ground-water reservoirs. Too often, wells are dug, pumping begun, and problems of ground-water overdraft realized only when ground-water levels have declined substantially. And, of course, the more wells, the greater the complications stemming from uncontrolled pumping. Fortunately, sophisticated modeling capabilities to simulate basinwide ground-water systems are becoming available. With this capability to predict the consequences of ground-water pumping programs, the beneficial value of the conjunctive use of surface and ground waters can be planned effectively.

Implications

Those areas dependent solely on ground-water sources as an economic

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base may require special consideration from a national perspective. For example, the High Plains of West Texas and eastern New Mexico contain the largest irrigable land mass in the world -- 52 million acres or a land mass larger than 37 States of the Nation. As of 1975, the productivity of nearly 10 million irrigated acres overlying aquifers in the Ogallala Formation is threatened because of incipient inadequacy in the quantity of ground water available for use. The ground-water problems of this area are currently the object of a study being led by the Department of Commerce under the authority of Section 193 of Public Law 94-587. The loss of the agricultural production of this area would be of significant national importance. Because local surface-water sources are also inadequate, large importations of water are being considered to replace that heretofore obtained from the Ogallala.

In the absence of an alternative source of water supply, some irrigated lands now dependent upon ground-water overdraft will revert to dry land production. On-farm income and production will be reduced, and ultimately the size of the farms will have to be increased in order to make operations economical.

Although ground-water overdraft may have diverse causes and a variety of adverse effects, the demand for ground water will undoubtedly continue. While in most areas ground water may continue to meet much of the increasing need on a short-term basis, State governments, perhaps with the assistance of the Federal Government, will need to bring rates of withdrawal into greater balance with rates of recharge. Toward this end, in normally humid areas, joint-use planning may recommend extended use of ground water for irrigation only during short-term seasonal droughts, even if land productivity decreases.

Specific Problems

The following representative specific problems illustrate the distribution and variety of problems. The information was furnished by regional sponsors.

Problem area: Gila River Basin (Lower Colorado Region, subregion 1503). See Figure II-2.

The water supply of the Gila River Basin in the southern two-thirds of Arizona and western New Mexico has been developed and utilized for many decades. Except for infrequent large floods or an exceptional surface runoff sequence, outflow from the basin under present conditions of development is negligible. Further development of surface water within the basin is confined principally to the conservation of a portion of the water that may become outflow, implementation of measures to increase surface runoff, and reduction of noncrop consumption associated with irrigation and other uses. The expanding economy of the area has been supported by an overdraft of ground water. Current ground-water pumpage exceeds surface-water diversion by several times.

Ground-water overdraft is expected to remain at about 4.1 million acre-

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feet annually through 1985. An increase in demand for municipal and industrial needs, mineral development, and thermal electric powerplant cooling is expected to be balanced by a decrease in about 68,000 acres of irrigated cropland. The depletion of ground water in storage would total about 25 million acre-feet over the 10-year period.

In 1990, the Central Arizona Project is expected to convey 1.4 million acre-feet of water to the area; this would reduce ground-water overdraft by about 60 percent. However, by the year 2000 increased water use will exert renewed pressure on the ground-water resource.

At some time in the future it will be necessary to balance water supply and use, if not through legislation, then probably through economic pressures as increased pumping depletes water supplies and energy costs reach a level where irrigated agriculture is no longer profitable. If water use and supply are to be balanced by year 2020, a reduction of over 600,000 irrigated acres or about 63 percent of the land area irrigated in 1975 would be needed.

Declining ground-water levels present a number of problems. In 1970, 4.3 million acre-feet of ground water was pumped from the aquifer above Gila Bend, Arizona. For each foot of increased pumping head an equivalent of about 6 million kilowatt hours of electric energy is required. Land subsidence also results in some areas as aquifers are dewatered. The best documented instance is in western Pinal County and parts of the Lower Santa Cruz Basin where the maximum subsidence was 7.5 feet near Eloy during 1948-67. Earth fissures as much as 8 miles long occur along the edge of the area. Subsidence has damaged the Picacho Reservoir, water wells, railroads, streams, highways, and agricultural land.

Problem area: High Plains (Missouri Region, subregion 1010 and Arkansas-White-Red Region, subregion 1103). See Figure II-2.

The plateau formed by the Ogallala Formation gives shape and definition to the High Plains in parts of Nebraska, Colorado, Kansas, Oklahoma, New Mexico, and Texas. Because of its rich and relatively level mantle of High Plains topsoil, the Ogallala Formation has given rise to one of the largest, if not the largest, irrigated agricultural developments in the world.

In Kansas, levels are declining in wells that tap water-yielding zones in the Ogallala Formation. If this decline continues, indicating a decline in ground-water supply, the irrigation developments there eventually will be adversely affected.

Problem area: San Joaquin Valley (California Region, subregion 1803). See Figure II-2.

The San Joaquin Valley has the largest ground-water overdraft of any area in California. Though the annual overdraft has declined from its peak in the mid-1950's, data indicate that an average of 1.5 million acre-feet per year of overdraft is still occurring as of "1975." If overdraft

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continues, land supported by overdraft will be forced out of production because of quality degradation and/or excessive pumping lifts.

Problem area: Upper Susquehanna River Basin (Mid-Atlantic Region, subregion 204). See Figure II-2.

This problem area includes the drainage into the Susquehanna above Towanda, Pennsylvania. Ground-water yields generally are low in the areas with increasing demand. The relationships between surface and ground water, such as the elapsed time between the start of pumping and the start of base-flow depletion, must be determined. Doubtless, further development of ground water would be possible if the relationships between ground water and surface water were specifically known, especially in and around Elmira, New York.

Withdrawals of ground water for the municipal and industrial needs of Elmira and for irrigation in the area exceed recharge and pose a threat to both surface- and ground-water supplies. Protection of recharge areas and management of withdrawals are required in the Upper Camisteo and Cohocton River valleys and in the Cortland and Binghamton urban areas.

Problem area: Southeast Georgia (South Atlantic-Gulf Region, subregion 303). See Figure II-2.

Under present rates of pumping, salt water can intrude into fresh-water aquifers. Ground-water quality is threatened in the Savannah area, and salt-water intrusion has already begun in the Brunswick area. Ground-water withdrawals, expected to double between 1970 and 2000, would greatly accelerate the salt-water intrusion. The poor quality of surface water in the vicinity and the high costs to divert and transport water from distant streams make it almost prohibitive to use surface sources for domestic water supplies.

The degradation of ground-water quality is expected to force industries to change their pumping systems to handle the more corrosive water. Present water management methods have restricted development in prime industrial areas adjacent to Brunswick. If this restriction in development continues, it could cause an economic loss to the community.

Some small domestic and industrial water users who are beyond the distribution network of public water systems will have to install costly wells to tap deeper, uncontaminated aquifers. This will extend the areas of salt-water encroachment in those deeper aquifers penetrated.

Problem area: Houston-Galveston Area (Texas-Gulf Region, subregion 1202). See Figure II-2.

Pumping of ground water in the Houston-Galveston area has steadily increased in recent years. As a result, artesian pressures have declined and subsidence has accelerated. A recent study found that annual costs and property value losses resulting from the subsidence in the area is about $31.7 million per year. These costs were borne primarily by resi-

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dential, commercial, and industrial property owners. However, over $500,000 per year in costs were included for repairs to public facilities.

Ground-water overdraft not only causes subsidence, but it also leads to salt-water encroachment and damage to the affected aquifers. Some low-lying areas along Galveston Bay are subject to inundation by normal tides, and an even larger part of the area may be subject to catastrophic flooding by hurricane tides. Surface drainage has become less effective and in some cases subsidence has reversed the drainage patterns.

Subsidence in the Galveston Bay area is expected to continue at a rate corresponding to the decline in pressure resulting from future ground-water pumping. However, surface water now being delivered from the adjacent Trinity River Basin and the Brazos River is available for major ground-water users in the southern part of Harris County--the heart of the subsidence zone. The switch from ground water to surface water has already led to some recovery of artesian pressure that has slowed the rate of subsidence. However, to further reduce the effects of subsidence, additional surface-water supplies must be developed to replace ground water.

Ground-water overdraft in this problem area supports approximately 600,000 acres of crops. The gross production value for this amount of land approximates $300 million in 1967 dollars based on 1974 marketplace conditions. The economic loss to the State from lost productivity of 600,000 acres could be as high as $1.2 billion, based on the 4:1 generating ratio of other activities to gross farm income.

Problem area: Oahu (Hawaii Region, subregion 2003). See Figure II-2.

On Oahu, the most densely populated of the Hawaiian Islands, highly permeable soils and rocks permit much of the rainfall to infiltrate and form a reservoir of ground water. The fresh ground water floats on a base of sea water. The quality of the fresh water is very high, but the balance of fresh water to salt water is fragile. The withdrawal of fresh water from wells must be carefully controlled to prevent deterioration in quality by salt-water intrusion.

As of 1975, pumping from ground-water supplies was within safe limits. Overdraft is foreseeable in the Pearl Harbor aquifer on the Island of Oahu if additional water development facilities are constructed without compensating conservation measures. Voluntary controls by the water users on Oahu are being attempted to prevent overdraft in the Pearl Harbor aquifer; however, the State Department of Land and Natural Resources is ready to implement a ground-water management program if voluntary controls fail.

Options for Resolution

The water supply in some parts of the Nation, particularly where irrigation of croplands is intensive and where agricultural production causes ground-water overdraft, makes economic and social dislocations inevitable. One option is to do nothing--to allow the economic and social

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factors to adjust themselves. Large acreages of presently irrigated cropland would probably return to dry land farming or ranching. This change could cause a reduction in production, social readjustment, population redistribution, and a major business-economic restructuring to reflect the area's changing conditions.

To protect against such major social and economic consequences, another option is to search for alternative sources of water supply. Major and extremely costly diversions of excess interbasin and intercontinental waters have been suggested. The surface-water supply conditions of the Nation, however, indicate that there are no areas with enough excess water to stem the overdraft of ground water in the Texas High Plains and other areas. Furthermore, these transfers would probably involve interstate and international boundaries and could lead to more intense interregional conflicts. However, smaller interbasin waters probably could be diverted.

A first step in resolving the problem should be the development of institutional mechanisms to increase flexibility in the use of ground waters and to permit ground and surface waters to be conjunctively managed. The volume of available water could be increased by using the huge storage potential of the Nation's aquifers to supplement surface supplies during periods of drought. The aquifers then could receive artificial recharge during periods of surplus surface runoff. This may require national programs of technical and financial assistance.

Those States not now adequately controlling ground waters could be provided incentives to start a program of control. For example, a program of ground-water withdrawal permits could reduce pumping and thus provide the basis for improved management. Studies could be started to analyze the social, economic, and environmental costs that are likely to accrue from the failure to implement such programs. This information, plus added basic hydrology data that the State's themselves could collect, would provide a base for effective program design.

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Pollution of Surface Water

Definition of Problem

Historically, the Nation's streams, rivers, lakes, and oceans have been convenient, and seemingly inexpensive and inexhaustible, dumping areas for human and animal wastes and for residues from industrial production. On the other hand, people have always depended, directly or indirectly, on these same streams, rivers, and lakes for drinking water, water-related recreation activities, and esthetic beauty. By 1975, few of the Nation's fresh-water bodies could be used as a water source without substantial treatment. Figures II-3a, II-3b, and II-3c show surface-water pollution throughout the country, at least for the major basins.

Stringent legislative efforts to cope with pollution culminated in the passage of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). Efforts to clean up surface water and prevent further degradation have received priority attention and, as a result, the quality of the surface waters has improved near some urban areas.

Surface-Water Pollution From Point Sources

A point source of pollution is a specific entity that discharges untreated or partly treated wastes. These sources of pollution are generally municipal and industrial. The Federal Water Pollution Control Act currently requires a minimum of secondary treatment for municipal wastes and "the best practicable treatment" for industrial discharges.

Treatment practices for municipal wastes differ widely. There are some instances of untreated municipal wastes, many examples of only primary treatment, and additional cases where the secondary treatment is insufficient to maintain water quality standards. These situations are being rectified under specified conditions of the NPDES (National Pollution Discharge Elimination System) permits required for each point-source discharge in the United States.

Industrial discharges range from those that are compatible with municipal wastes and conventional waste treatment techniques to those requiring specialized techniques for treatment before safe discharge. Treatment techniques often lag behind product development--that is, the fluids discharged may not be amenable to standard treatment methods. Pollution caused by the discharge of PCB (polychlorinated biphenyl) waste often persists long after discharge has been discontinued. Discharging liquid waste from metal-plating plants to municipal treatment facilities has caused malfunctions of those facilities.

Discharges, in general, can contribute oxygen-demanding substances, excess nutrients, a variety of toxic substances, and fecal coliform bacteria. The presence of fecal coliform bacteria in water supplies indicates the possible presence of disease-causing organisms, including those responsible

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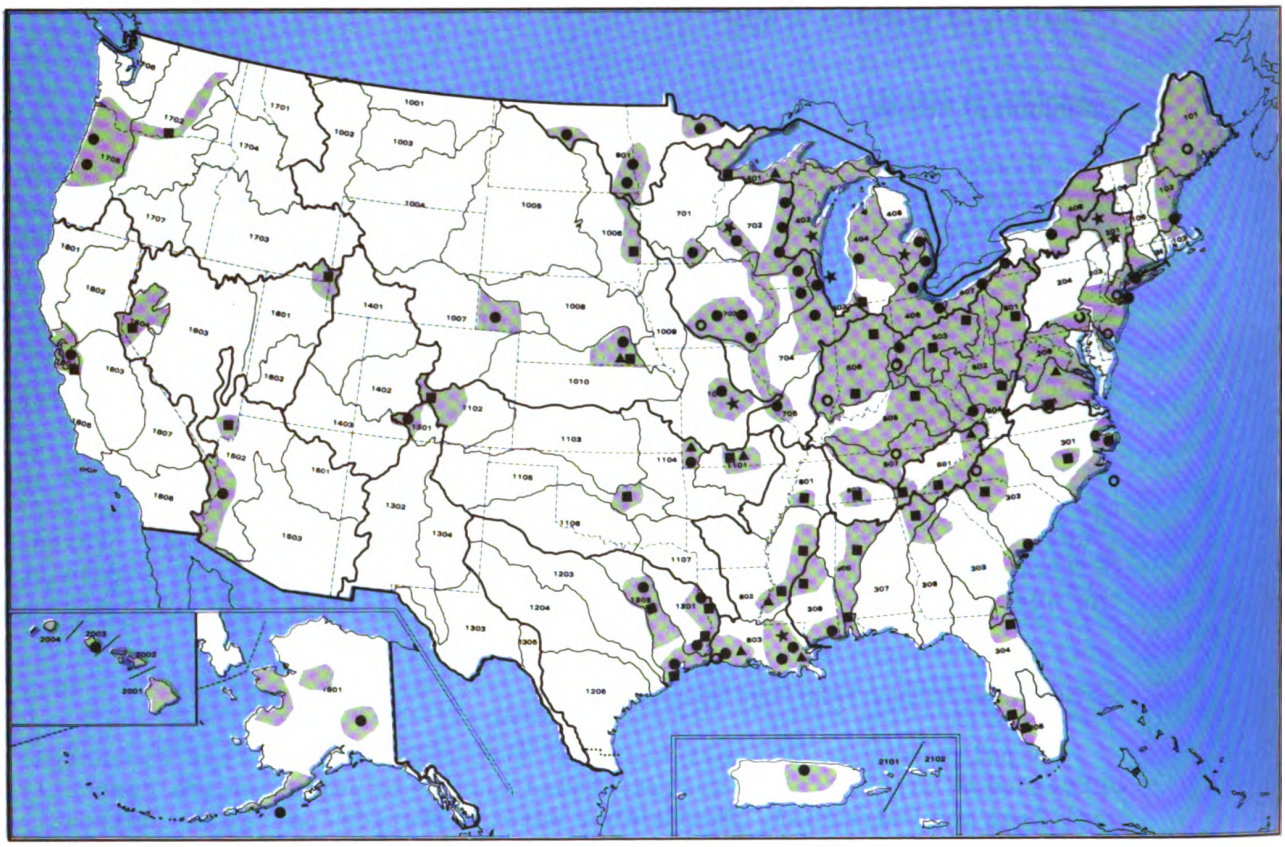

Explanation

Area problem

Area in which significant surface-water pollution from point sources is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific types of point-source pollutants

- ● Coliform bacteria from municipal waste or feedlot drainage
- ★ PCB (polychlorinated biphenyls), PBB (polybromated biphenyls), PVC (polyvinyl chloride), and related industrial chemicals
- ▲ Heavy metals (e.g., mercury, zinc, copper, cadmium, lead)
- ■ Nutrients from municipal and industrial discharges
- ○ Heat from manufacturing and power generation

Boundaries

Water resources region

Subregion

Figure II-3a. Surface-water pollution problems from point sources (municipal and industrial waste)

(As identified by Federal and State-Regional study teams)

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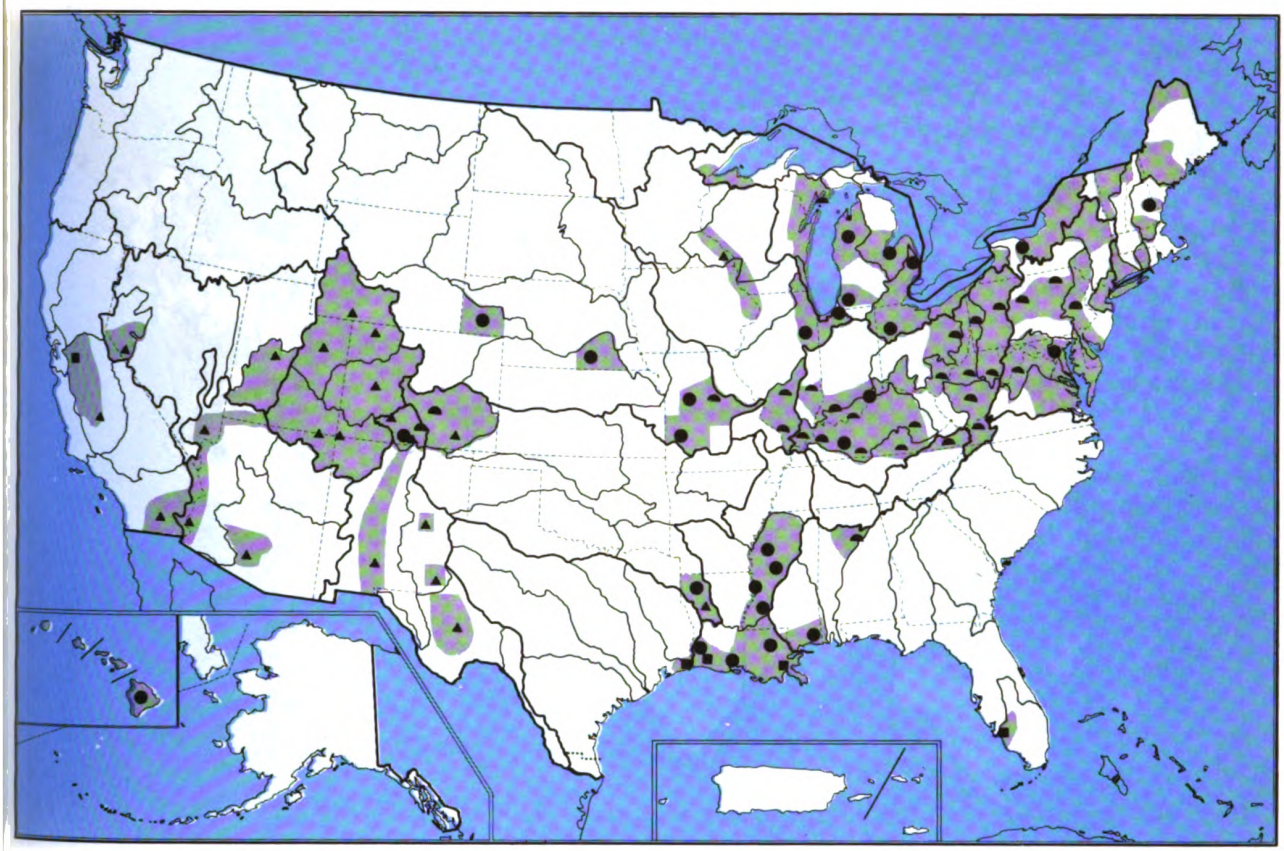

Explanation

Area problem

Area in which significant surface-water pollution from nonpoint sources is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific types of nonpoint-source pollutants

- Herbicides, pesticides, and other agricultural chemicals
- Irrigation return flows with high concentration of dissolved solids
- Sea-water intrusion
- Mine drainage

Boundaries

- Water resources region
- Subregion

Figure II-3b. Surface-water pollution problems from nonpoint sources (dispersed)
(As identified by Federal and State-Regional study teams)

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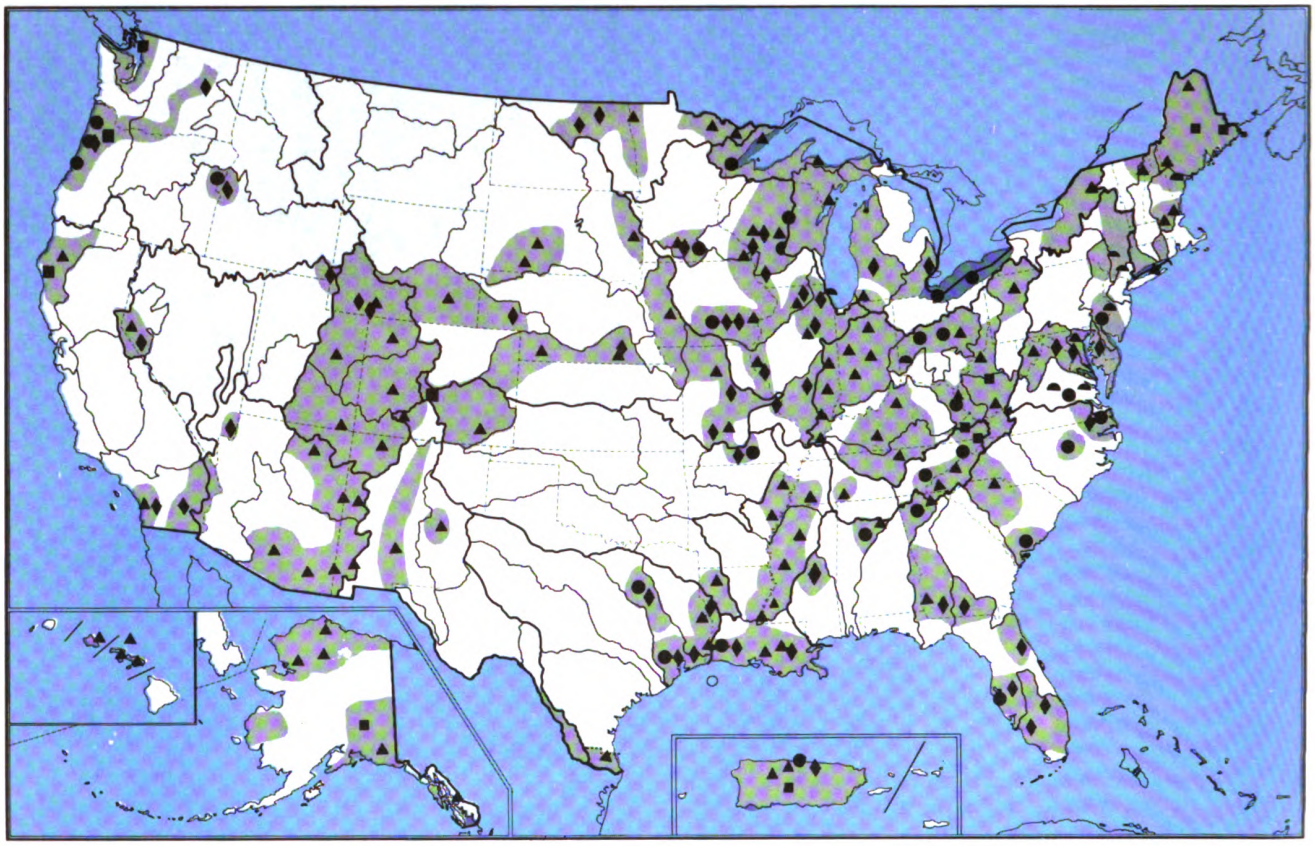

Explanation

Area problem

Area in which significant eutrophication of manmade and natural water bodies is occurring

Unshaded area may not be problem-free, but the problem was not considered major

Specific causes of eutrophication

- Low levels of dissolved oxygen
- High levels of nutrients
- Natural sedimentation from streambank, cropland, and other natural erosion
- Man-induced sedimentation from urban, industrial, and construction/earth moving activities
- Heat from manufacturing and power generation

Boundaries

- Water resources region
- Subregion

Figure II-3c. Surface-water pollution problems—eutrophication
(As identified by Federal and State-Regional study teams)

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for typhoid fever, paratyphoid fever, dysentery, and cholera. Inadvertent cross-connections between water supply distribution lines and waste disposal lines in some populated areas mean that any malfunction in either system could cause disease outbreak or other adverse health effects.

With the increased number of industrial and municipal waste treatment plants, pollution from industrial and municipal wastes is projected to be under control before the year 2000. However, since chlorine is the disinfectant of choice for most waste and water supply treatment plants, new health problems may be introduced even as others are resolved. Harmful chlorinated hydrocarbons, including chloroform, a carcinogen, can be produced in both water supply and waste treatment processes when water containing organic material is treated with chlorine.

Discharge into a stream of cooling water from steam electric generation and manufacturing processes may raise the temperature of the stream water, thereby decreasing in dissolved oxygen concentration and threatening the survival of many aquatic flora and fauna. With an anticipated 350 percent increase in waste heat from manufacturing and power operation by the year 2000, the natural environment may be severely strained unless proper corrective actions are taken.

Surface-Water Pollution From Nonpoint Sources

In the past, little attention was given to pollutants carried by surface runoff from nonpoint (dispersed) sources. The Federal Water Pollution Control Act of 1972 (Public Law 92-500), however, has focused attention on these nonpoint-source problems. General areas of concern have been identified, areawide planning to address the problems is now in progress, and methods for abatement and control are now being developed. Control of these diffuse pollution sources is not simple, however, because the total load of pollutants is a function of pollution concentration buildup plus the volume and duration of runoff.

Nonpoint sources of pollution are either manmade or natural. Manmade runoff from urban, agricultural, forest, or mining areas can generally be remedied by management and abatement. More difficult to control, however, are the natural sources such as the salt flats in the Southeast, which cause streambank erosion and contribute high concentrations of dissolved solids and salinity to surface waters.

Most States report agricultural activities as the primary source of sediment in streams and other surface-water bodies. Along with sediments washed off the land surface are herbicides, insecticides, and undesirable levels of fertilizers and other nutrients, all of which enter the streams. The National Residuals Discharge Inventory indicates that about 33 percent of the oxygen-demanding loads, 66 percent of the phosphorus, and 75 percent of the nitrogen discharged into the streams in 1973 came from dispersed agricultural sources.

Forestry activities also contribute to nonpoint-source pollutants.

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Increased surface runoff from clear cutting of trees causes scarring from rapid erosion that often ensues before tree cover and related vegetation can be re-established. Erosion of the forest soils and their natural nutrients will degrade both the soil's productivity and the quality of the streams and rivers receiving the eroded material.

Many States identify mine drainage, particularly when the water draining from the mine is acidic, as a major problem. In certain areas where deep or strip-mining is or was prevalent, acidic mine drainage pollutes both surface- and ground-water supplies. Abandoned mines compound the problem because often no one will acknowledge responsibility for the damage caused by the drainage.

Excessive salinity constitutes a water quality problem in several States in the West and Southwest. Water used for irrigation leaches salts from the soil, causing the salinity concentrations to increase in the return flows to surface-water courses. Each subsequent irrigation tends to increase the salinity concentration in the return flows to the point where plants are no longer tolerant of the concentrations. It has been estimated in the lower Colorado River that for each milligram per liter increase in salinity the annual cost to the economy is approximately $230,000.

With increased consumption use of the Nation's waters, the flow of fresh water into the surrounding boundary salt waters decreases. As a result, the dynamic balance of fresh water to salt water is adversely affected. As the streamflow decreases, the saline water intrudes farther upstream. As a consequence, water diverted for use along these streams becomes more and more saline. The user is thus faced with either using the degraded water or finding alternative and more costly sources. Intrusion of highly saline sea water into tidal estuaries has been identified as a problem in California, Florida, Louisiana, and Texas. The potential, however, exists along all coastal areas.

The combination of storm-water runoff and urban sewer overflows has caused significant problems with sedimentation, nutrient balance, infiltration of heavy metals, and biological pollution. These problems are not amenable to easy solution because of the high cost of separating the two flows and of disposing of them effectively. With increasing urbanization, the problems of storm-water runoff can be expected to intensify. The magnitude of such pollution has been investigated only recently.

Eutrophication of Manmade and Natural Water Bodies

Eutrophication is the process by which a surface water becomes enriched in nutrients. When this process is hastened by the acts of man, it is called cultural eutrophication. The primary nutrients--carbon, nitrogen, and phosphorus--are essential to the growth of aquatic plants. Normally these are present in surface water in only small concentrations. When these elements are added to water in relatively large concentrations, however, aquatic plants proliferate to the point where they deplete oxygen

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during nighttime or other periods when oxygen-producing photosynthetic processes are dormant. Moreover, thermal discharges associated with the cooling water needs for manufacturing and power generation lower the dissolved oxygen concentrations. Oxygen depletion causes the death of aquatic plants and animals, with consequent decay and odor.

Primary nutrients generally occur in domestic sewage, irrigation return flows, urban runoff, atmospheric fallout, septic field leachates, and certain industrial waste discharges. Allowing these discharges to flow into surface-water bodies is the basic cause of cultural eutrophication.

Implications

Poorly operated municipal plants may discharge liquid waste containing large quantities of bacteria and viruses, some of which are nearly always pathogenic. Industrial discharges, particularly toxic chemical wastes, can make surface waters a health hazard for public use. Trace levels of polybrominated biphenyls (PBB), polychlorinated biphenals (PCB), heavy metals such as chromium and nickel, asbestos fibers, and other pollutants constitute some of the health hazards.

Urban (dispersed-source) runoff containing bacteria, toxic substances, trace heavy metals, and accumulated urban debris is washed into surface-water courses (and in some instances finds its way into ground-water supplies). Runoff from irrigated areas, together with the return flow caused by overirrigating, may contain high concentrations of bacteria, insecticides and herbicides, fertilizer, sediment, and salts and minerals leached from the soil. These return flows have progressively higher concentrations of dissolved solids. Some of these substances are toxic in themselves; some are carcinogenic.

Excessive concentrations of nutrients--phosphorus and nitrogen, in particular--can cause algal blooms and prolific growth of the aquatic plants which, by means of photosynthesis, produce an abundance of dissolved oxygen. However, when photosynthesis is reduced by cloud cover, or ceases at night, or particularly when these plants die and thus increase the BOD (biochemical oxygen demand), the consequent oxygen depletion causes death of aquatic fauna and flora. After a water body has become eutrophic to some degree, the water becomes a breeding ground for insects such as mosquitos, which in some parts of the country carry diseases. Anaerobic conditions associated with eutrophic waters encourage the growth of pathogenic organisms found in the dead carcasses of diseased fauna.

Oxygen-consuming wastes from urban, industrial, and rural sources, together with low flow and higher surface temperatures, impair water quality. Many chemical wastes are soluble and easily dispersed in surface waters. Others precipitate and are transported with the streambed load. Some insecticides and herbicides will accumulate in the flesh of fish. The effects of these insecticides and herbicides, which may persist for years, are potentially hazardous to both aquatic animals and humans. Bacteria, toxic chemicals, and a host of deleterious substances can also render shell-

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fish unsafe for consumption. The greater the quantity and type of pollutants in the water, the more complex and energy intensive will be the operations required to clean up the water to the level appropriate for its intended use.

The control of point-source discharges, as mandated by Public Law 92-500, is a pressing problem. As point sources are brought under control, the true impact of nonpoint sources will be realized. If both point and nonpoint sources can be brought under reasonable control, the conditions that induce eutrophication of lakes and slow-moving streams will have been checked. If not, deterioration of rivers, streams, and lakes will continue, and, of course, the problem of water quality as an issue between the United States and its neighbors can only be aggravated.

Specific Problems

The following specific problems illustrate the distribution and variety of surface-water pollution problems. They are not necessarily the most serious instances but are considered representative. The information was furnished by regional sponsors.

Problem area: Mississippi River below Minneapolis-St. Paul, Minnesota (Upper Mississippi Region, subregion 701 and 702). See Figures II-3a through 3c.

In the Mississippi River below Minneapolis-St. Paul, localized point sources of pollution are: municipal and industrial waste discharges at major urban centers, oil and chemical spills from barges and adjacent rail traffic, and sewage wastes from pleasure and work boats. The Mississippi River is subject to high turbidity from erosion and natural runoff. A significant nonpoint pollution comes from runoff from irrigated land that causes high chemical and bacterial concentrations, high nutrient levels, and lake euthrophication. Point-source pollution is added from municipal and industrial sources.

Two large lakes totaling 1,050 acres in Grant County, Wisconsin, are classified as "very eutrophic." Water quality problems also arise from surface runoff from lead and zinc mines in southwestern Lafayette County and southeastern Grant County in Wisconsin. PCB also seriously pollutes fish habitat areas in Lake Pepin. Concern has been expressed about the deterioration in ground-water quality in the fractured and cavernous limestone areas of southeastern Minnesota.

Problem area: Tennessee River Basin (Tennessee Region, subregion 601). See Figures II-3a through 3c.

Water quality in the North Fork Holston River is adversely affected by leachate from muck ponds at an abandoned chemical plant site in Saltville, Virginia. Runoff from heavy rains causes the muck ponds to overflow. Chloride concentrations greater than 500 mg/l and mercury are impairing use of the river. In the reach between Saltville, Virginia, and Kingsport,

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Tennessee, the mercury concentrations in the fish exceed that allowed by the U.S. Food and Drug Administration.

Problem area: Lake Okeechobee Area, Florida (South Atlantic-Gulf Region, subregion 305). See Figure II-3a through 3c.

Agricultural runoff, urban runoff, and both untreated and treated liquid waste degrade the water quality in the canal systems, coastal streams, and estuaries. The nutrients being added to the area's lakes and ponds are making them eutrophic, resulting in large accumulations of organic matter including aquatic weeds. South of Lake Okeechobee, a large area has been receiving significant amounts of irrigation return flow.

Options for Resolution

Point sources of waste-water discharge may be effectively controlled at point of discharge. Goals of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) are in the process of being met. All point sources should have the equivalent of secondary treatment for municipal and domestic discharges or "best available treatment" for industrial discharges by 1983. This goal is expected to be met uniformly throughout the country.

New technology is needed to effectively and inexpensively render industrial wastes harmless. Potential actions include incentives for industry to find suitable uses for industrial waste products. For example, ethylene glycol, once a waste product of the chemical industry, is now the cornerstone of the antifreeze additive business.

Use of septic tanks and cesspools where soils and site conditions are unfavorable for proper operation should be discouraged and alternatives to such private waste disposal practices provided. These alternatives should allow a high degree of waste-water treatment and should minimize the local impact of the waste-water discharges.

Techniques available to reduce nonpoint-source pollution include non-structural means, such as street sweeping, catch-basin maintenance or similar alternatives, and structural means such as detention ponds. In most areas, separating existing combined sewers into separate sanitary and storm sewers appears to be uneconomical. An alternative solution is the installation of combined sewer relief valves so that each rainstorm does not result in a combined sewer overflow. Further, the option of constructing detention tanks should be strongly investigated.

Greater use of soil conservation and streambank stabilization practices in agricultural and construction areas will reduce pollution. Better management practices by farmers will reduce soil losses from their lands. Better methods are also needed to prevent the overapplication of herbicides and pesticides. Incentives are needed to increase use of detention ponds to minimize pollution from urban storm runoff and settling ponds to remove sediment from runoff from irrigated tracts.

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The implementation of waste-water and nonpoint-source policies and technologies should advance concurrently with more effective water treatment practices. This will require increased research into improving present treatment practices and devising new treatment options. Toxic substances and carcinogens already have been found in some water supplies. Expanded research is needed to establish safe levels for those pollutants that occur only in trace concentrations.

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Pollution of Ground Water

Definition of Problem

Both natural and manmade pollution of ground-water sources are growing issues across the Nation. Because aquifers lie below the surface, out of sight, the seriousness of ground-water pollution is only gradually being realized. Many regions reported some form of ground-water pollution in the second assessment as indicated in Figure II-4.

People have come to expect safe water to be produced from wells because of the natural filtering action of the soil through which the water must pass. However, this filtering action is not always effective. Ground-water supplies have become polluted from a variety of sources, both natural and man-induced. Once polluted, the ground water becomes a resource of limited value. That is, aquifers are not as easily restored to a healthful condition as are surface-water bodies because water moves very slowly through the aquifer.

Natural pollution includes the high mineralization of ground water from excessive levels of such chemicals as magnesium, iron, sulfur, nitrates, phosphorus, calcium, fluoride, arsenic, and high chloride water such as brine. Natural radioactivity may also pollute certain ground-water supplies. Instances of radioactivity of water have been found in Florida, Maine, New York, Illinois, Iowa, and Missouri. Natural pollution may not always make ground-water supplies totally unusable, but it certainly makes them less desirable. The drilling of oil and gas wells has caused the intrusion of brine, oil, or gas into otherwise high quality ground waters, making them undesirable for use. Decline in water levels in coastal aquifers caused by the withdrawal of water from them has led to salt-water intrusion.

In a few communities across the country, toxic and hazardous wastes injected into deep wells have migrated into overlying fresh-water aquifers.

Seepage from landfills containing municipal and industrial wastes also adversely affects ground-water quality. In the past, highly toxic substances have been buried indiscriminately in landfills or dumps. In some areas, because the location of abandoned dumps is unknown, their effect on surface and ground waters is also unknown.

In rural areas, water used to irrigate croplands can leach salts from the soil zone and carry them downward into the aquifers, representing yet another source of potential pollution. The materials carried downward are, for example, herbicides, insecticides, and fertilizer, in addition to other substances leached from the soil zone.

As discussed earlier, subsurface percolation systems such as septic tanks and cesspools are a potential source of ground-water pollution, particularly in urban areas that were recently rural or suburban. In these areas, centralized water and sewage facilities are frequently not available. Septic tanks that pollute local aquifers are found at many places in the

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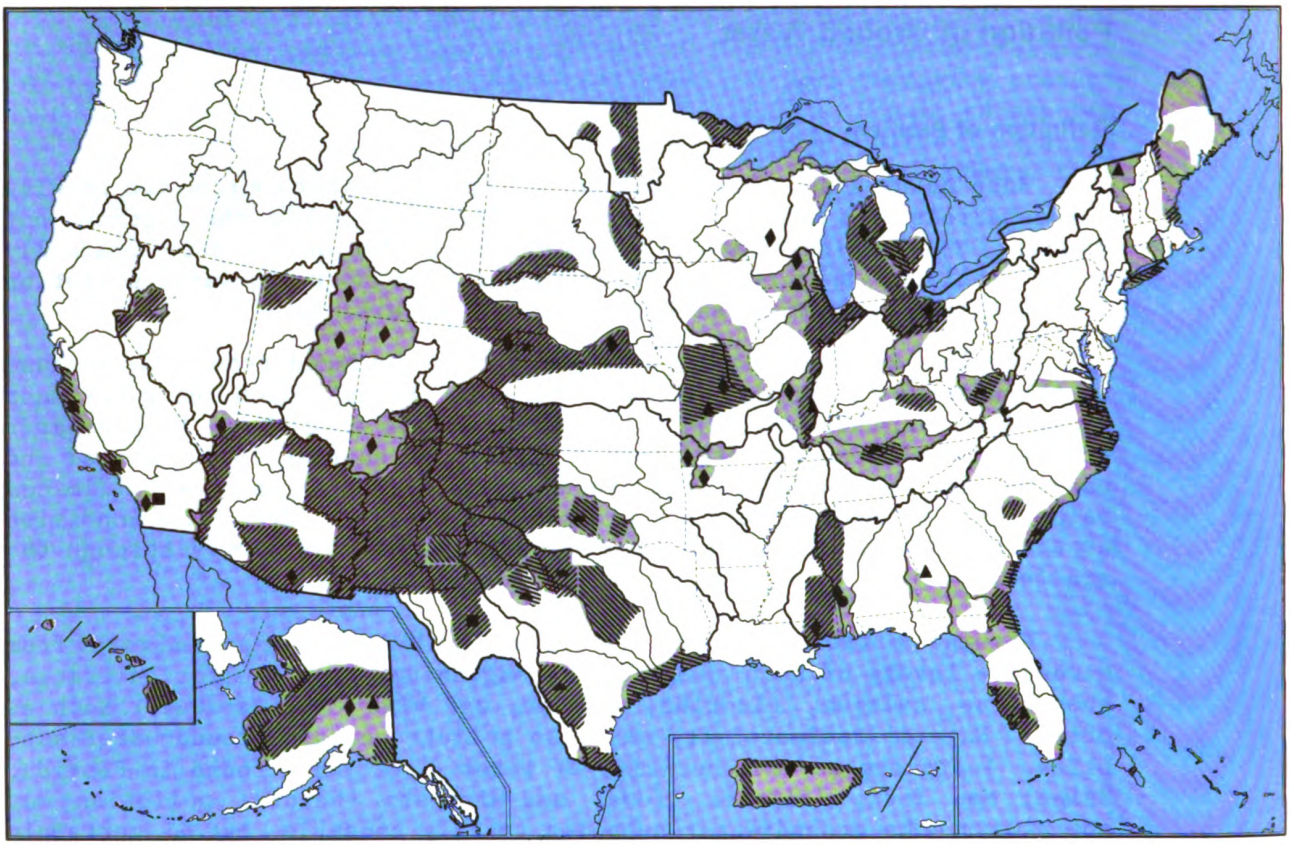

Explanation

Area problems

- Significant ground-water pollution is occurring
- Salt-water intrusion or ground water is naturally salty
- High level of minerals or other dissolved solids in ground water
- Unshaded area may not be problem-free, but problem was not considered major

Specific sources of pollution

- ● Municipal and industrial wastes including wastes from oil and gas fields
- ♦ Toxic industrial wastes
- ▲ Landfill leachate
- ■ Irrigation return waters
- ◓ Wastes from well drilling, harbor dredging, and excavation for drainage systems
- ★ Well injection of industrial waste liquids

Boundaries

- Water resources region
- Subregion

Figure II-4. Ground-water pollution problems
(As identified by Federal and State-Regional study teams)

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Nation. Other subsurface sources of pollution are oil and gas wells, dry wells, sink holes, and drainage from inactive mines.

During the rainy season, surface streams and water bodies may recharge the ground-water reservoir. Pollution of surface waters will, in turn, impair ground-water supplies, especially in areas where recharge is significant. Conversely, during the dry season, surface water, initially fresh, may become polluted when base flow originates from polluted ground water. The linkages between surface water and ground water are complex. Because some aquifers extend across the boundaries of one or more States, counties, and local jurisdictions, concerted study and careful management are often complicated because of legal and political constraints.

Implications

Ground-water pollution, in one form or another, is recognized in many of the regions. High levels of mineralization are often identified in the aquifers. Pollution or potential pollution of aquifers by fecal coliform bacteria from septic tank drain fields is an often-cited problem in rural areas and in areas recently urbanized. Industrial, municipal, and agricultural wastes are degrading fresh-water aquifers, or have the potential for doing so. Inasmuch as 50 percent of the population derives drinking water from ground-water sources, pollution, whether real or potential, poses a significant health threat. In 1975, for example, nearly 800 cases of waterborne diseases were attributed directly to untreated ground water. Unreported cases are probably even more numerous.

In areas dependent upon ground water for municipal, industrial or agricultural uses, continued degradation of ground-water quality will have significant implications in the economies of the affected communities. Extended overdraft will produce the same results. One effect will be an increase in the cost of treating the polluted water to meet existing quality criteria. And, of course, water quality may be so poor that the ground water cannot be successfully treated at reasonable cost.

The well-established relation between water quality and water demand is particularly true for ground water. For example, continued overdraft, especially in coastal areas, fosters salt-water intrusion of aquifers. Furthermore, water use patterns usually involve ground-water withdrawal, conveyance to users, and, finally, conveyance of waste waters to some other area. Such a use pattern may result in ground-water depletion in one area and ground-water pollution in another downstream area. Such transfers of water may not be specifically planned, but just happen as water supply needs are met and waste-water treatment options are exercised. To avoid inadvertent transfers of poor quality water from one area to another, the nature of both polluting and cleaning mechanisms that affect aquifers must be better understood.

Specific Problems

The following representative specific problems illustrate the distribution and variety of problems of ground-water pollution. The information has been furnished by regional sponsors.

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Problem area: Lake Champlain (New England Region, subregion 106). See Figure II-4.

Improper sewage disposal systems, overcrowding of individual systems in confined areas, and leachate from landfills have caused ground-water pollution in this area.

Problem area: Brunswick, Georgia (South Atlantic-Gulf Region, subregion 303). See Figure II-4.

Because ground-water levels in the area are high, during rainy weather the septic tank tile fields may intersect the water table, thereby polluting the shallow aquifer with septic tank effluent. The shallow aquifer consisting of sand and gravel is used by individuals and some industries as a water supply source.

Problem area: Pascagoula, Mississippi (South Atlantic-Gulf, subregion 309). See Figure II-4.

Although ground water is plentiful, in parts of Mississippi this abundant supply is of poor quality. In the Miocene-Pleistocene sands along the Gulf Coast, there are places where the ground water has a high iron concentration, has a low pH, and is corrosive. The effects of deep-well injection of liquid wastes on fresh-water aquifers in some parts of the State are not well known. Of particular concern is the injection of well-field brines associated with oil extraction.

Problem area: Ozarks Area of Benton and Washington Counties, Arkansas (Arkansas-White-Red Region, subregion 1104). See Figure II-4.

There is a lack of ground-water data for the Ozarks area. However, a small research project conducted by the University of Arkansas revealed that in the study area of 100 square miles as much as 80 percent of the ground-water sources in 90 percent of the area tested was being polluted with coliforms.

Problem area: Santa Ana River Basin, California (California Region, subregion 1806). See Figure II-4.

Both the Upper Santa Ana River Basin and coastal Orange County have ground-water overdrafts. Agricultural return flow with high concentrations of nutrients, and downward percolation of sewage effluent with high concentrations of dissolved solids have degraded the poor quality of ground-water resources.

Problem area: Jackson County-Port Lavaca, Texas (Texas-Gulf Region, subregion 1205). See Figure II-4.

Ground-water overdraft has caused salt-water intrusion along the coast.

Options for Resolution

To resolve ground-water pollution problems, more needs to be known

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about ground-water mechanisms and the fate of pollutants after they invade the aquifer. A first order of business is the collection of water samples and data on water levels from existing wells and from new observation wells drilled for that purpose. These data can then form the basis for analytical studies, including physical and mathematical modeling, of ground-water mechanisms.

Septic tank problems stem from poor siting, construction, and operation. If alternative and more efficient individual waste treatment systems could be found and used, both the shallow ground-water bodies and nearby surface waters would benefit.

The relation between polluted surface water and fresh ground water must be better understood. The relation between aquifers containing saline water and those containing fresh water also needs study. Old oil and gas wells, new well drillings, mining sites, and the like are prime places to study such interconnections. A program to plug abandoned oil wells and to make certain that new wells are properly cased is desirable. State licensing and inspection of well-drilling operations may be advantageous in carrying out such a program. Methods of irrigation that minimize the leaching of salts from soils (such as sprinkler irrigation) need to be encouraged.

Disposal of solid waste in landfills without a detailed study of the ground-water hydrology in the vicinity can lead to trouble, particularly when toxic and hazardous substances are an important segment of the waste. Obviously, efficient management will dictate methods of operation to minimize the quantity of leachates entering the ground-water system. Even more basic is the application of conservation practices that would reduce the quantity of solid material being dumped, practices that involve reuse of solid materials where possible, and that eliminate elaborate packaging of consumer products.

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Quality of Drinking Water

Definition of Problem

In 1974, the Safe Drinking Water Act (Public Law 93-525) was passed to ensure that in the future there would be adequate supplies of potable water, thus preventing serious health crises. In general, strides in providing safe drinking water in the last 50 years have been so effective that the public has lost an awareness that serious disease could occur with system malfunctions. However, much of the Nation's drinking water could be polluted if the continued production, use, and discharge of toxic chemicals is not abated. This problem resulted in the enactment of the Toxic Substances Control Act of 1976 (Public Law 94-469).

Figure II-5 presents an overview of the problems with drinking water quality. Many of these problems result from the increasing production and dispersal of toxic substances.

- As of 1975, more than 2 million chemicals have been identified, of which more than 30,000 are in commercial production.
- Little is known about the health effects on health of most natural or synthetic organic chemicals that could find their way into drinking-water sources. The National Academy of Sciences, in collaboration with the Environmental Protection Agency, has begun an assessment of the health effects of those chemicals actually identified in drinking water. Some 22 chemicals are recognized as either known or possible carcinogens.
- Many chemicals may be toxic at concentrations not detectable with currently available measurement techniques.
- Many chemicals transported by water settle into bottom sediments, then infiltrate the aquifers. These chemicals may enter the aquatic food chain and successively accumulate in the flesh of fish or other predators, and continue up the food chain.
- Many chemicals are not amenable to normal on-line detection and removal by conventional water or waste-water treatment systems.
- Many chemicals, once in a water course or in an aquifer, may be able to combine with other chemicals to form new toxic or carcinogenic substances. The current weakness in scientific knowledge and monitoring systems to determine the extent and effect of these chemicals make these a significant threat to public health.

Heavy metals such as cadmium, copper, iron, lead, mercury, and zinc dissolved in water, even at very low concentrations, are lethal to fish.

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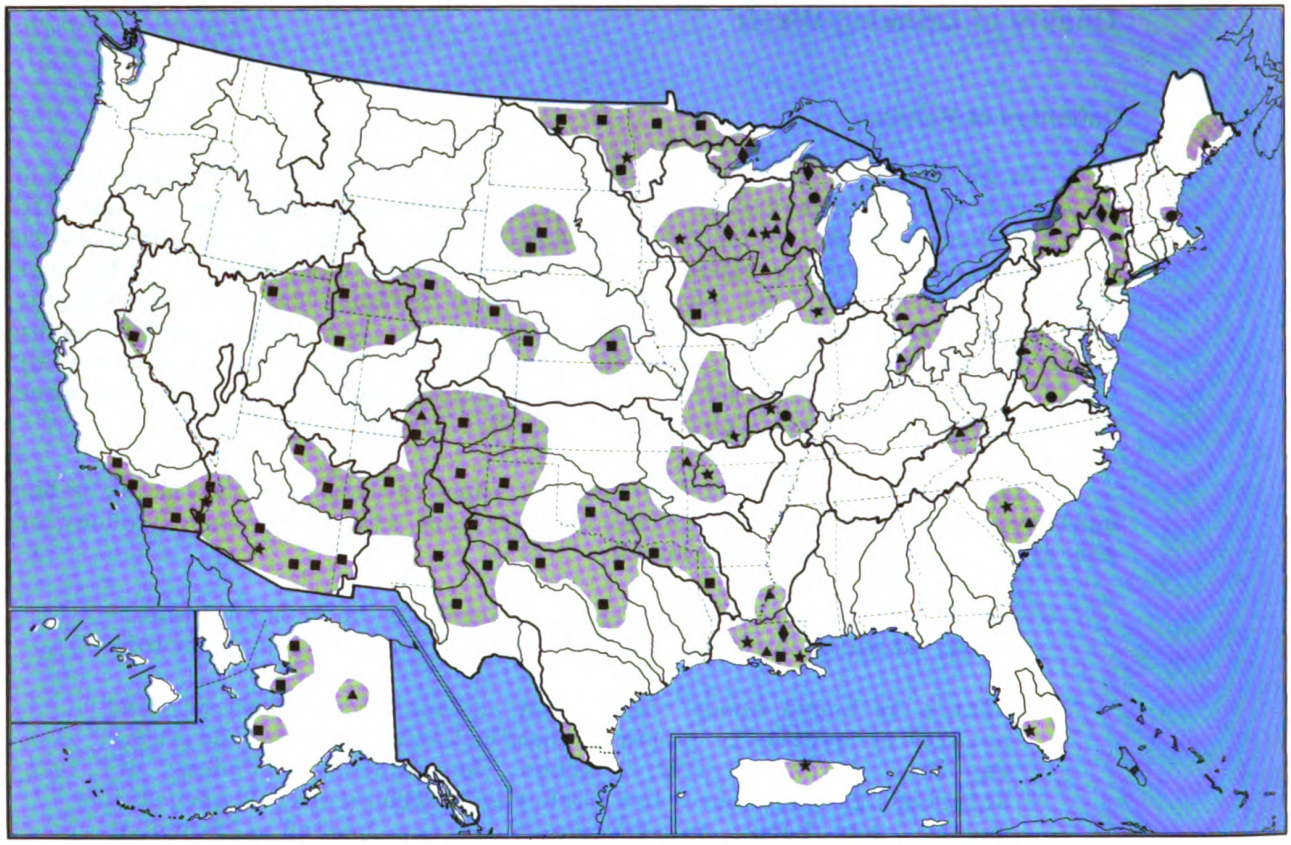

Explanation

Area problem

Area in which existing or potential pollution of domestic water supply was reported

Unshaded area may not be problem-free, but the problem was not considered major

Specific sources of pollution

- ● Industrial chemicals other than chlorinated hydrocarbons
- ♦ Chlorinated hydrocarbons from treatment processes and energy development
- ▲ Heavy metals (e.g., mercury, zinc, copper, cadmium, lead)
- ★ Coliform and other bacteria
- ■ Saline water
- ◓ General municipal and industrial wastes

Boundaries

- Water resources region
- Subregion

Figure II-5. Quality of drinking water problems
(As identified by Federal and State-Regional study teams)

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Cadmium has caused fatal bone diseases in humans, and lead and mercury have caused brain damage. Sources of these heavy metals include industrial discharges, urban runoff, pipe corrosion, and mining activities. In some instances, they occur naturally. In States along and east of the Mississippi River, the primary sources of these toxic elements are urban runoff and industrial discharges. In the less populated western States, primary sources are mining operations that chiefly involve lead and zinc.

Industrial chemicals such as cyanide, phenols, polybrominated biphenyls (PBB), and polychlorinated biphenyls (PCB) also are threats to human and aquatic life. They do not biodegrade; they are carcinogenic; they have caused human poisoning; and, their presence in the Great Lakes, the Hudson River, and other water bodies has led to fishing bans. PCB has been found in both surface and ground water.

Organic compounds such as chloroform and carbon tetrachloride are also a serious concern because of their carcinogenic nature. In water, chloroform is formed by the interaction of chlorine (used as a disinfectant in both fresh-water and waste-water treatment processes) with organic residues, such as humus found in the streambed.

Most surface water receives extensive treatment at the community level before distribution. This treatment may include disinfection, coagulation, sedimentation, and filtration, among other possibilities. Ground water, however, often receives little more than disinfection.

Chemical quality deficiencies attributable to excess salinity are a problem nationwide; whereas, the presence of toxic elements such as lead, zinc, and the like were identified in only a few of the subregions. The problem of carcinogenicity will become a major issue as it becomes more widely known that latency periods before disease symptoms can be identified may be longer than a year, possibly even many years.

In the past and in the absence of disease outbreaks, drinking water has been judged safe if minimum State and Federal standards have been met. More recent research has found that water quality monitoring of drinking water for the bacterial and chemical categories of concern has been insufficient. Since June 1977, all community systems are required to monitor and report deficiencies to both consumers and State-level regulatory agencies.

Implications

The pollution of ground and surface sources of public water supplies has serious potential public health consequences. Any breakdown in treatment or distribution can cause widespread outbreak of waterborne illnesses. Increasing accumulations of specific pollutants in both surface- and ground-water supplies pose a constant threat, since water polluted with organic, inorganic, radioactive, bacterial, and viral substances are known agents for the spread of either chronic or acute disease. Increasing concentrations of those pollutants in raw waters place a burden on conventional

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water treatment plants and generally increase the operating costs of the plants.

Toxic and hazardous materials found in water supplies normally cannot be removed by conventional treatment. Industries are required by law to treat wastes before discharging them to sewers. Effective, and possibly more expensive, treatment processes must be developed. Spills of toxic substances are not fully preventable. Thus, substantial financial resources will also be needed to develop monitoring equipment and techniques, health effects research, and advanced waste treatment techniques.

Both the law and economic efficiency urge treatment of all wastes at point of discharge, where definable, to render them acceptable. Multiple in-plant recycling from high quality water needs to lower quality needs is feasible. Control practices to limit nonpoint-source pollutants will also contribute to the preservation of our high quality water resources. However, control of nonpoint sources and treatment of point sources of pollutants may make additional demands on energy.

Specific Problems

The following representative specific problems illustrate the distribution and variety of problems caused by domestic water supply pollution. The information was furnished by regional sponsors.

Problem area: Lower Mississippi River (Lower Mississippi Region, subregion 803). See Figure II-3.

Between St. Francisville and Venice, Louisiana, some 60 industries discharge highly concentrated wastes into the Mississippi River. As a result, fish caught in the river below Baton Rouge are not marketable because of the off-flavor of their flesh. This reach, however, serves as a raw water supply for 40 utilities that serve a population of 1.5 million. Treated water supplies at two locations contain trace amounts of six organic chemicals capable of inducing histopathological changes in animals. Treated water supplies also contain three organic chemicals described as carcinogenic.

Problem area: St. Louis Vicinity (Upper Mississippi Region, subregion 705). See Figure II-5.

In localized areas, particularly in northern Jefferson County and in the East St. Louis area, shallow ground-water supplies are polluted with bacteria, nitrates, and other chemicals. Inadequate disposal systems for solid and liquid waste and improperly constructed wells are responsible for this pollution. Moreover, saline-water intrusion from both natural and man-induced causes is a problem. Where alternate sources of water are not available, many localities are forced to use this highly mineralized water.

Problem area: Lake Superior (Great Lakes Region, subregion 401). See Figure II-5.

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Asbestiform fibers in public drinking water may have long-term effects on this area's health. An increase in the incidence of asbestos-caused cancer may not become apparent for many years. Taconite tailings also increase the turbidity of Lake Superior waters, which may be harmful to the aquatic life as well as to deep-water spawning beds. The taconite tailings dumped at one site contain 35 chemical materials, including lead, mercury, cadmium, nitrate, phosphate, and silicate.

The water in the St. Louis River from Cloquet to Lake Superior is of poor quality. It is affected by severely low dissolved oxygen levels resulting from industrial pollutants, organic wastes from paper and pulp mills, urban runoff, discharges from shipping vessels, and municipal wastewater treatment plants. Water quality problems may be aggravated by the operation of two of the five upstream hydroelectric plants. These cause the flow of the river to fluctuate; sometimes the flow is inadequate to dilute many of the small streams into which the waste is being disposed.

Problem area: Middle Iowa River (Upper Mississippi Region, subregion 703). See Figure II-5.

Restricted use of surface water as a potable water supply for domestic and livestock uses and as a suitable water supply for industrial processing and cooling is due primarily to excess turbidity and sedimentation. Increased cost of water treatment for municipal and industrial supplies taken from surface-water sources is common. Restricted use of untreated ground water as a potable water supply is due to excessive hardness and concentrations of iron.

Options for Resolution

Overcoming domestic water-supply pollution depends on the results of implementing three Federal laws: the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), the Safe Drinking Water Act of 1974 (Public Law 93-523), and the Toxic Substances Control Act of 1976 (Public Law 94-469). These laws deal with the control of discharges at the "source." The Safe Drinking Water Act of 1974 (Public Law 93-523) deals with all aspects of water supply, from raw water to the product delivered to the consumer's tap. These concerns are being translated, in part, into regulatory programs to monitor, report, and control water quality at the consumer level and to identify and control numerous activities known to degrade ground-water quality.

Of great concern to communities is the high cost of collecting water samples and analyzing them. Smaller treatment systems may not be able to afford the technology needed to bring the water quality up to the standards presently promulgated, much less to those being proposed.

Low-cost treatment techniques to demineralize ground water throughout the country need to be devised. Without them, many domestic water quality treatment problems will continue. On-line monitoring techniques are also needed to minimize costs of satisfying the monitoring requirements of the Safe Drinking Water Act yet provide enough sophistication to assist in the stable operation of treatment systems.

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Flooding

Definition of Problem

Much of the Nation's productive land is located in the coastal and riverine flood plains. Flood-plain resources include water supply, easy transportation, productive soils, and moderate topography. These resources have encouraged extensive urban and economic development, which, in turn, has led to a potential for significant loss of life and damage to property. Floods have led to an average loss of 83 lives per year. The total potential damage in "1975" is estimated at $3.4 billion, with urban damage estimated at $1.1 billion. The remaining $2.3 billion estimated for agriculture represents 2 percent of the Nation's agricultural production value.

Floods are natural phenomena. They can occur when rain, snow, or storms produce water on the land surface faster than the water can be carried away by streams. In some cases flooding is caused by massive tidal waves that inundate ocean coastlines. Floods can occur during any part of the year and in most parts of the country: when heavy and prolonged rains fall in the humid areas of the Midwest, East, Southeast, and Northwest; when thunderstorms produce flash floods, especially in the normally dry areas of the Southwest; in late winter and early spring when the melt of accumulated snow drives many streams beyond their banks; and in late summer and early fall when hurricanes and tropical storms dump large quantities of water on the islands of the Caribbean and the Atlantic and Gulf coasts from Maine to Texas. Figure II-6 shows those areas where the impact of flooding is greatest.

People in general do not comprehend the risk of flooding, especially in the absence of a recent flood experience or when risk is expressed as a probability statement. Defining and describing the area inundated by the flood with a 1 percent chance of occurring in any given year--the so-called 100-year flood plain--does not stimulate a sense of urgency. Floods, like droughts, take on more meaning if the frequency of occurrence is expressed in action-related time units such as a 25-year mortgage for which there is approximately a one-in-four chance of experiencing the so-called 100-year flood. Because a 100-year flood occurred last year does not preclude the the possibility that it will recur this year, next year, or any time in the near future.

Implications

Although floods are a natural phenomena, when man intrudes upon flood plains or alters the watershed drainage conditions, he frequently contributes to flood severity and the ensuing losses. Large areas of the Nation experience flooding which has been aggravated by human activity. That these activities result from irresponsible or unwitting decisions is not relevant. What is relevant is the fact that development in flood-prone areas must be managed to prevent flood losses.

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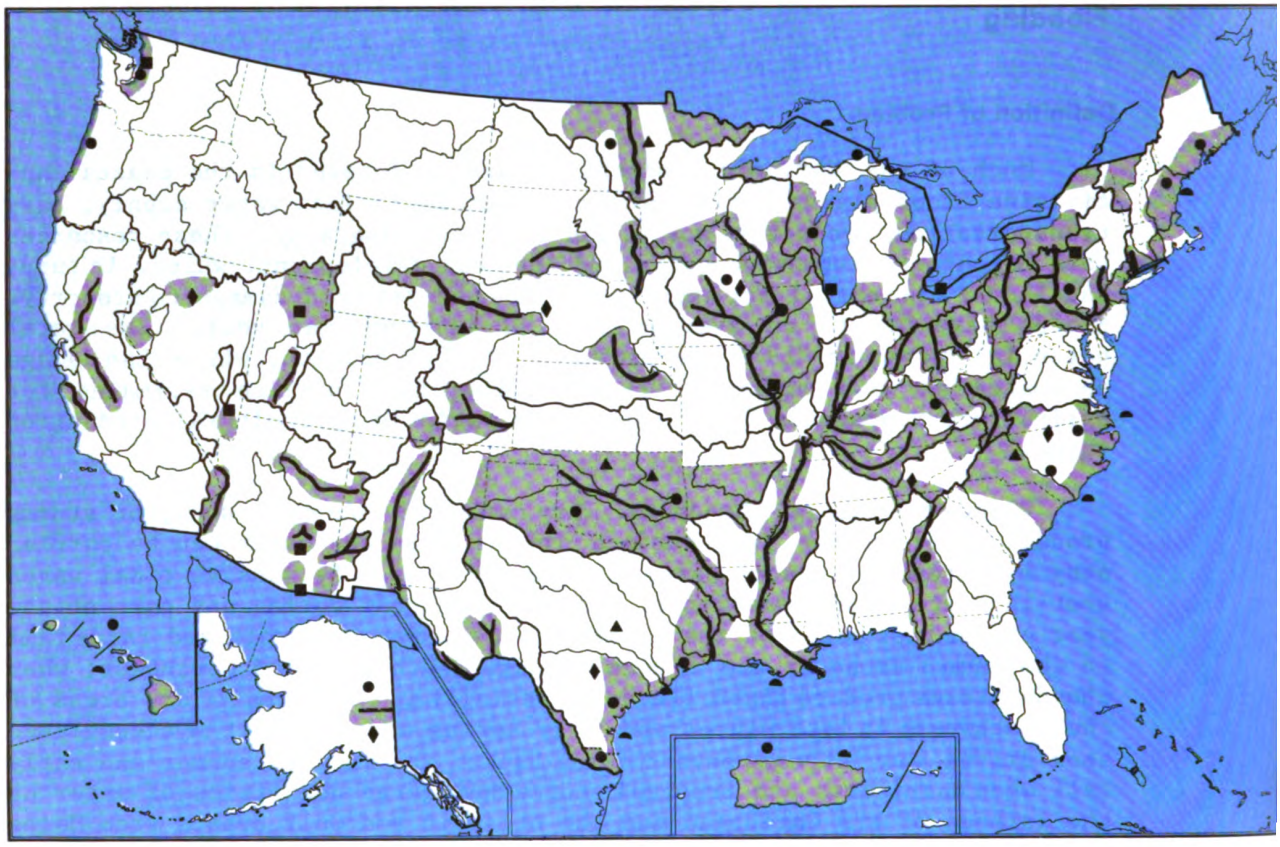

Explanation

Area problem

Area in which flooding causes major damage to agricultural, urban, and other developments

Unshaded area may not be problem-free, but problem was not considered major

Major streams and tributaries with periodic overbank flooding

Reasons for intensified flood damage

- Urban, suburban, and industrial development on flood plains
- Accelerated runoff from urban areas
- Inadequate upstream watershed management
- Loss of flood control from inadequate structural systems
- Tidal effects along coasts during storms and hurricanes

Boundaries

Water resources region

Subregion

Figure II-6. Flooding problems
(As identified by Federal and State-Regional study teams)

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There are three ways to cope with the overall flood problem. They are: (1) actions to control flood waters, (2) actions to reduce the effects of flood waters on life and property, and (3) actions to reduce the consequences of flood losses for individuals and communities. Actions to control flood waters are called structural means; the other actions are nonstructural means.

Structural means include the construction of reservoirs, channel improvements, and small watershed structures that reduce flood damage by delaying or reducing the flow of excessive water. Approximately $13 billion has been spent by the Federal Government since 1936 for flood control structures, with an estimated $60 billion savings in reduced flood damage. Even so, structural means have been inadequate to arrest the rising spiral of flood damages. Furthermore, structural solutions may change the natural conditions of flow and sediment load to which existing ecosystems are adapted and upon which they depend. Even though the resulting destruction or disruption to an ecosystem may not be permanent--in fact, different but possibly equally valuable systems may establish themselves--an increased emphasis is being placed on the complementary role of nonstructural solutions.

Nonstructural solutions include flood-plain regulations and acquisitions to remove persons or property from flood-prone areas and/or to prevent location of potential flood victims and property in these locations in the future. Nonstructural solutions also include disaster preparedness and recovery plans; flood forecasting, warnings, and evacuation plans; flood insurance; and tax adjustments. The nonstructural measures that may be compatible with the natural ecosystems are complementary to and possibly alternatives to the structural solutions.

The regulation of existing and future flood-plain development is a critical element for limiting future urban flood damage. A continued increase in the number and value of buildings and their contents will increase flood damages year after year. Without increased flood-plain regulation, it is estimated that by 2000 the potential urban flood damage will be $1.6 billion, an increase of 38 percent.

Agricultural flood damage is not expected to grow as rapidly, but it will be widespread, nonetheless. Under the most probable conditions for 2000, potential agricultural damage is projected to reach $1.7 billion.

The Federal Government is faced with the prospect of rising flood damages and associated disaster relief costs, which, in the absence of adequate flood-plain management, could have an enlarged adverse effect on the national budget.

Specific Problems

The pervasiveness of flooding provides many examples of specific problems. Several example problems serve to illustrate the prominent types of flooding and flood damages throughout the United States. Regional sponsors for the assessment have furnished the following information.

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Late summer brings annual climatic changes that produce major tropical storms and hurricanes in the Atlantic Ocean, Gulf of Mexico, and the Caribbean. Such storms struck the Gulf in 1965 (Betsy), in 1967 (Beulah), 1969 (Camille), 1970 (Celia), and 1971 (Fern), resulting in the inundation of large areas by extensive rainfall and high tides.

The destructive potential of these storms reaches hundreds of miles inland, affecting agricultural production as well as domestic and urban communities. Direct damage from some of these storms was $54.6 million (Beulah), $22.6 million (Fern), and nearly $1.5 billion each for Betsy and Camille. Much of the damage occurred in the same 10 counties of Texas each time. Numerous deaths also occurred in these floods.

Early warning systems and structural developments, such as flood walls, prevented the damage from being even higher. The residents of these areas have experienced many similar storms and most heed early warning reports that track each storm's progress. Preparations for the storms are generally extensive since the residents of the area assume some, if not all, of the risk associated with living in a flood-prone area. Home, auto, and personal property insurance rates are, of course, higher. Federal assistance is required as a result of such storms. Continued use of warning systems and flood education should prevent extreme loss of life and property.

Severe thunderstorms that deposit large quantitites of rain in short periods of time cause rapid-rising or flash floods. Such floods often catch residents without warning, as illustrated by the Big Thompson flood of Colorado (1976), the Jamestown, West Virginia, flood (1977), and the Johnstown, Pennsylvania, flood (1977). Many areas of the Southwest are subject to flash flooding, a prime example being the urban area of Las Vegas, Nevada.

Problem area: Las Vegas Metropolitan Area (Lower Colorado Region, subregion 1502). See Figure II-6.

The Las Vegas Metropolitan Area is arid, vegetation is sparse, and rainfall is low (3.76 inches per year average). Rapid development in flood-plain areas has produced many expensive structures. Throughout the last 50 years, flash floods have occurred periodically, each succeeding flood causing greater damage. A combination of flood-plain information, planning, structural diversions, and regulation of future flood-plain development is needed to reduce damage in the Las Vegas Valley. These elements should be organized in a comprehensive flood-plain management program for the area.

Problem area: Middle Mississippi River (Upper Mississippi Region, subregions 704 and 705, and Lower Mississippi Region, subregion 801). See See Figure II-6.

Melting show and heavy rainfall over a large drainage area cause frequent flooding along the middle Mississippi River. In 1973 and 1974, long-duration, slow-rising floods covered large agricultural and urban areas of the relatively flat Mississippi River Valley. Extensive agricultural damage has also been reported on the highly productive lands along the

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river. Annual damage of $17,400 per mile by 1980 is projected along the middle Mississippi main stem. Annual damage projected for most cities along the river is high. For example, Hannibal, Missouri, a low-lying city, incurs an average flood damage of about $3.3 million annually. Projected downstream damage of $55.3 million annually is anticipated by the year 2000, with agricultural damage being 45.6 percent of this total. With the rapidly increasing value of nonagricultural properties in the flood plain, agriculture's proportion of the total damage will be somewhat lower in the year 2000 than it was in "1975."

Flood-plain management would reduce future property damage. Loss of life is usually minimal since flood warning systems are effective in estimating arrival times and heights of flood peaks of these almost annual floods on the main stem.

Problem area: Great Lakes (Great Lakes Region). See Figure II-6.

Flooding problems throughout the Great Lakes Region are caused primarily by two major factors: (1) storm surges and shore erosion on the lakes, especially during high stage and (2) extreme inland storm events that increase stream runoff flows. Flood damages in economic losses, however, are historically related to the increased development of flood-prone areas.

The region has experienced an annual average loss of $75 million for urban areas and about $20 million for agricultural damage (1970 conditions at 1975 prices). If past practices of flood-plain regulations and structural measures continue, damage is expected to increase for both urban and agricultural areas. By year 2000, annual average urban flood damage is projected to increase to $11 million (1975 dollars). Unless floodproofing measures or relocation of facilities are undertaken, the average annual damage due to flooding will continue to increase.

Options for Resolution

The risk of flooding can never be totally alleviated, even by the best of flood-plain management programs. However, through a cooperative flood-plain management effort among Federal, State, and local governments, private individuals and industry, the level of flood damages can be reduced to an acceptable level. Accepting the premise that both current and projected flood damage levels are unacceptable, the options for reducing flood damage generally focus upon the Federal role in flood-plain management: continue the present situation or increase the acceptance of responsibility at the local level.

Currently it is judged in the national interest that the Federal Government assume a major portion of flood risk. This role is the outgrowth of more than 40 years of growing reliance upon federally funded structural flood control and disaster assistance programs. Though these programs have led to a substantial increase in knowledge and technical capability and have been relatively successful in achieving their objectives, the programs have been inadequate for arresting the rise in flood damages.

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Recently established Federal programs, including subsidized flood insurance and flood forecasting and warning, are beginning to affect flood damage. However, to be fully successful, these new programs rely upon complementary non-Federal programs--local or State flood-plain regulations in the case of insurance, and local warning dissemination and evacuation programs in the case of flood forecasting. To continue the current heavy reliance upon Federal assumption of flood risks is to accept an option with limited promise.

The second option is to encourage local and State governments and private parties to assume a greater share of the responsibility for flood risks. The Federal Government can provide more information on the risk of flood-plain occupancy and more technical assistance to cope with these risks. Farmers, developers, and property owners must be encouraged to take steps to avoid unwise new development and to protect existing development in flood-prone locations. Local and State governments must be encouraged to establish and exercise flood-plain management programs, including regulations controlling new development and redevelopment. Assumption of greater responsibility for flood risk by non-Federal parties should greatly reduce flood damages, increase the effectiveness of Federal efforts, and reduce Federal expenditure for disaster assistance.

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Erosion and Sedimentation

Definition of Problem

Erosion and resulting sedimentation are among the most widespread water-related problems in the Nation. Locations in which erosion and sedimentation problems have been identified are shown in Figure II-7. Severity of erosion, is greatest in the humid areas of the country. Gullying, streambank erosion, and shifting sands along the coastlines are more obvious than the uniform wearing away of the land mass. Often erosion and sedimentation accelerate as human activities disturb the natural setting, but because the process is slow, the effects often go unnoticed. Erosion from natural causes is more prevalent in the arid West where protective cover is lacking.

In agriculture, which depends on soil and plant management, there is little short-term incentive to control the soil loss that often impairs long-term land productivity. The "1975" average cropland soil loss caused by sheet and rill erosion was 8.6 tons per acre; for some areas the average loss exceeded 25 tons per acre. Overgrazing of pasturelands leads to plant cover reduction which accelerates erosion. Activities related to timber harvest and off-road recreation also accelerate erosion.

In urban areas, runoff from residential and industrial development and highway construction carries sediments into streams and reservoirs. As surface-mining expands to support national energy needs, the erosion potential will increase.

Channel banks, beaches, and shorelines are likewise threatened by the scouring action of flowing waters. Wakes from barges and ships, construction activities, and changes in river flows from impoundments by reservoirs damage shorelines.

Sediment from various types of erosion is carried into streams, held in suspension, and, as streamflow diminishes, deposited. This causes sediment buildup in slower stream reaches, causing a further slowing and spreading of the flow. Sediment deposited in lakes and reservoirs also causes a loss of water storage capacity. Low-lying lands along rivers are often covered with sediment. Sediment can carry pollutants such as phosphates and pesticides and can adversely affect the environmental quality of water bodies by covering fish and wildlife habitats and damaging spawning and nesting areas.

Erosion and sediment affect both private and public land and water users. Strong local, regional and national programs are needed to control erosion and reduce sedimentation.

Implications

Erosion and sedimentation affect virtually every area of the United

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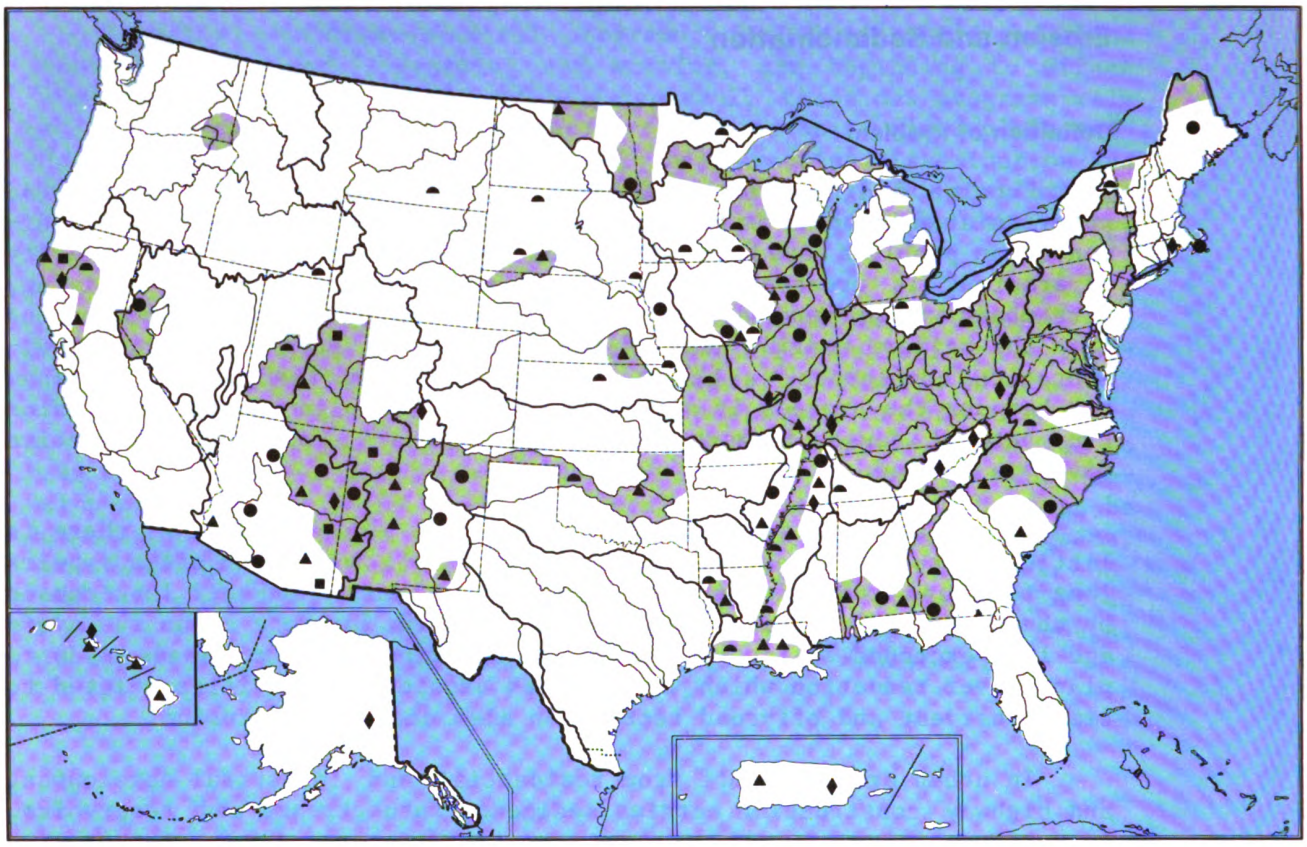

Explanation

Area problem

Area in which erosion or sedimentation is a significant problem

Unshaded area may not be problem-free, but the problem was not considered major

Nature of erosion or sedimentation problems

- Cropland or rangeland erosion or sedimentation
- Urbanization, mining, or industrial and highway construction
- Natural erosion of stream channels
- Shoreline, streambank, or gully erosion
- Sedimentation of farm ponds, lakes, water supply, and flood-control channels

Boundaries

- Water resources region
- Subregion

Figure II-7. Erosion and sedimentation problems

(As identified by Federal and State-Regional study teams)

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States. The depletion of the land base is a major concern as additional pressures increase extraction of natural resources from cropland, forest, and rangeland, and through surface-mining. Over long periods, erosion of the land base causes a local economic decline as the feasibility of continued agriculture and silviculture declines. The cost of soil depletion is often beyond the planning horizons of individual farmers and ranchers. The major economic impact of erosion is generally borne by a second party or by the public sector rather than by those who own or operate the land on which the erosion occurs. Thus, economic incentives for proper practices to keep soil on the land are poor. Although production loss from eroded land is primarily a long-range concern, the related water quality and sedimentation problems generally are more urgent in the short term.

Sediments suspended in water flowing over the land carry nutrients and pesticides into the rivers and lakes. Research into the transport mechanisms is needed. These pollutants, which increase the rate of eutrophication of water bodies, are a potential hazard to public health. Aquatic habitat is damaged by sedimentation and the introduction of nutrients and pesticides. Marine life is altered or destroyed. Esthetic values are affected--dirty water is not attractive for fishing, swimming, boating, or viewing.

If soil loss increases or continues at present levels, the cost of constructing and maintaining reservoirs and water supply systems will increase. Sediment accumulates in reservoirs so that extra storage must be provided to accommodate it. Sediment must be removed from water supplies before the water can be delivered to users. Irrigation systems are clogged by sediment deposits which must be removed on a regular basis. Navigation channels require periodic dredging to maintain adequate depths.

Sediment deposits can be beneficial to certain low areas as they add rich soil, but in most instances, they can damage crops, orchards, residential improvements, and roadways.

Specific Problems

The following representative examples of erosion and sediment problems illustrate their widespread nature and variety. The information was furnished by regional sponsors.

Problem area: Upper Mississippi River (Upper Mississippi Region). See Figure II-7.

The upper Mississippi River between Minneapolis-St. Paul and St. Louis has significant erosion damage. The highly erosive character of the loess soils and glacial ridges combined with the increased flooding and the changing shoreland uses have accelerated these erosion problems. Because of the amount of sediment deposited in the river bed, maintenance dredging for navigation is required. Sediment deposits have damaged fish and wildlife habitat and recreation areas along the river. In that part of Wisconsin adjacent to the main stem of the Mississippi River, over

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800,000 acres or 57 percent of the land needs soil conservation treatment. In nearly 8 percent of this area, annual soil losses exceed 20 tons per acre. The average daily sediment load of the Mississippi River at Hannibal, Missouri, is over 70,000 tons per day. With the contribution from the Missouri River, the load at St. Louis is about 500,000 tons per day.

Problem area: Lower Mississippi River (Lower Mississippi Region). See Figure II-7.

Sedimentation in the lower Mississippi River reduces navigation depths and deep-draft access to the ports of New Orleans and Baton Rouge, Louisiana. In order to maintain deep-draft port access, maintenance dredging operations must be performed from January to November each year to remove material deposited on the channel bottom at various locations in the Mississippi River below Baton Rouge.

Manmade levees and jetties cause Mississippi River sediment to be carried into the Gulf of Mexico beyond the 100-foot depth contour. The average annual transported sediment load in the Mississippi at its mouth is 300 million tons, which amounts to an average rate of 825,000 tons of sediment per day. Studies indicate that the sediment load of the Mississippi River, if properly controlled, could create new land at an average rate of about 12 square miles per year.

Problem area: Hiwassee-Little Tennessee Rivers (Tennessee Region, subregion 601). See Figure II-7.

Erosion and sediment problems are serious in the drainage areas of the Hiwassee and Little Tennessee Rivers in the extreme southwest corner of North Carolina, the southeast corner of Tennessee, and along the mid-northern border of Georgia. Land-use pressures are increasing in this area because of its beauty and numerous recreation opportunities. The rugged terrain increases susceptibility to erosion from highway construction, second-home development, logging operations, and farming.

Erosion over the problem area averages nearly 37 tons per acre per year. When the eroded material reaches the streams, it creates adverse effects, both as suspended solids and as bottom sediment. As suspended solids, the material increases the turbidity of the water, cutting down light penetration and thus reducing photosynthesis. A more direct effect on the fish occurs in their gills which tend to become irritated and even clogged. Some sight-feeding fish like bass and trout have difficulty locating food. Consequently, the fishing industry is adversely affected by these conditions. As the suspended solids settle, they tend to smother benthic organisms in the stream bottom and to cover the spawning areas of some reservoir fish. The capacity of the streams and the reservoirs is reduced by sediment. If the problem is not solved, there will be increases in the amount of severely eroded land which in "1975" totaled about 700 acres, as well as increased damage to roadways.

Problem area: Great Lakes Shoreline (Great Lakes Region). See Figure II-7.

According to the U.S. Army Corps of Engineers, about 1,200 miles of the

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total 3,470 miles of the U.S. shoreline of the Great Lakes is eroding significantly. More than 200 miles of shoreline are critically eroding, resulting in severe property damage.

Erosion of the Great Lakes shoreline is caused chiefly by wave action that is aggravated during high lake levels. Steep slopes and sometimes easily erodible soils, such as the clay bluffs along parts of the Lake Superior shoreline of northwestern Wisconsin, compound the problem.

Each year the U.S. shoreline of the Great Lakes is estimated to contribute about 400 million metric tons of mostly sedimentary material to the nearshore waters (about nine times the sediment from land surface erosion). This is based on preliminary Pollution from Land-Use Activities Reference Group estimates of sediment contributed by tributaries in the United States as a result of sheet and gully erosion. In an average year, erosion of the shoreline of the Great Lakes in the United States contributes approximately 9,000 metric tons of total phosphorus, or about the same as that contributed from land surface erosion. The Corps of Engineers estimated that property damage to the total U.S. Great Lakes shoreline for the 1951-52 period of high lake levels was $61 million (or $168 million in 1973 dollars). The Corps of Engineers is currently conducting another shoreland damage survey for the 1972-74 period of high lake levels. Based on pilot studies in 11 counties, damages have been estimated at $430 million (1976 dollars), although the data from which this estimate was derived vary in degree of reliability and accuracy.

Problem area: Sheboygan-Green Bay (Great Lakes Region, subregion 402). See Figure II-7.

Gully, bank, and sheet erosion and sedimentation are problems in the Sheboygan-Green Bay area, which includes that part of Wisconsin adjacent to Lake Michigan, from the city of Sheboygan north to the end of the Door Peninsula between Lake Michigan and Green Bay. Red clay erosion is a problem in the streams of the Sheboygan and Manitowoc River Basins. In Kewaunee County new construction activities are taking place on medium-to-steep slopes with large attendant amounts of erosion. Sediment damages of the following types at significant levels or quantities were reported by the following counties:

- Sediment problems in roadside ditches and drainage channels -- Kewaunee County
- Deposition of sediment in storm sewers, on streets, etc.-- Brown, Calumet, and Sheboygan Counties
- Muddy or turbid conditions in lakes or ponds used for recreation -- Calumet, Kewaunee, and Sheboygan Counties
- Damage to fish and wildlife and their habitat -- Brown, Calumet, Manitowoc, Sheboygan, and Kewaunee Counties
- Abnormally high nutrients levels in water bodies from nonpoint sources -- Brown, Calumet, Kewaunee, Manitowoc, and Sheboygan Counties.

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Problem area: Rio Grande Headwaters (Rio Grande Region, subregion 1301). See Figure II-7.

The expanding use of recreation vehicles on hiking and mountain roads of the Rio Grande headwaters in southern Colorado is creating an erosion and sediment problem. Improved roads, hiking and skiing trails, campgrounds, and picnic areas are needed.

Problem area: Graham and Greenlee Counties, Arizona (Lower Colorado Region, subregion 1503). See Figure II-7.

Among the problems identified within Graham and Greenlee Counties in southeastern Arizona are severe erosion of the area, particularly on the desert and grassland, and the excessively high sediment contents of the Gila and San Carlos Rivers. The high sediment concentration in the Gila and San Carlos Rivers increases maintenance costs of irrigation facilities, constrains water storage development, reduces the life of existing water storage facilities, and degrades recreation and fishing resources. Flood flows of the intermittent San Simon River contribute large sediment loads to the Gila River.

Problem area: Upper Roanoke (South Atlantic-Gulf Region, subregion 301). See Figure II-7.

The problem area includes 12 counties in south-central Virginia and north-central North Carolina in the Piedmont and the Blue Ridge areas. Almost 11,000 acres in Virginia and 11,000 acres in North Carolina are subject to erosion damage. The Roanoke River Basin has 5,983 miles of stream, of which 391 bank miles are subject to erosion.

In the Blue Ridge part of the problem area, streambank erosion is moderate and generally confined to reworking of alluvial material. In the upper part of the Piedmont, much of the area is wooded and of such characteristics that little streambank erosion occurs, but in the lower part of the Piedmont, bank erosion becomes more pronounced, especially during periods of high water. Erosion attacks not only preworked alluvial material, but also the weathered metamorphic rocks beyond the alluvial flood plains. Streambank erosion reaches a maximum at the edge of the Piedmont and in the upper coastal plain.

In 1967 land use in the Roanoke River Basin was 18 percent cropland, 14 percent pastureland, 65 percent forestland, and 3 percent other. The relative erosion of these lands shows that well-maintained pasturelands have soil losses about twice that of forestland, whereas cropland may lose 10 to 100 times as much soil as forested land.

Although the steeper Blue Ridge slopes have rapid surface runoff, they are often forested so that soil losses are low. The moderate slopes in the highly erodible Piedmont area that are mainly used for crop production are subject to much erosion.

The 200-square-mile area draining into Hyco Lake is typical of the Piedmont area. The area is sparsely populated, has conditions conducive

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to rapid surface runoff, and has soils composed mostly of sandy clay loams. Average annual sediment yields range from 98 to 333 tons per square mile for three headwater streams which flow into Hyco Lake on the Hyco River, a tributary to the Roanoke, in Person County, North Carolina. The sampling station 2 miles below Hyco Dam had a yield of 12 tons per square mile; the remainder from upstream tributaries settled in Hyco Lake (19,000 tons per year or about 9 acre-feet per year).

For the water years 1969 and 1970, the average annual sediment measured in the Roanoke River at Randolph, Virginia, (drainage area 2,977 square miles) was 60 tons per square mile or about 0.1 ton per acre. During the period 1950-1959, sediment accumulated in the John H. Kerr Reservoir in northern North Carolina and in southern Virginia at a rate of one ton per reservoir-acre per year, or twice the rate anticipated when the project was designed.

Options for Resolution

There are numerous methods to reduce erosion and sedimentation. Management of the use of erosion-prone land is a logical starting point. Erosion can be reduced by limiting disturbance of soils that erode easily because of their makeup or location, such as those on steep slopes. Construction activities, tillage, or grazing of this land could be limited by restricting these activities on public land and through a system of financial incentives or penalties on private land.

Many agricultural practices can be altered to help control erosion. Tilling and planting on the contour, fertilizing, adding manure, leaving crop residues, and alternating row crops with pasture all retard water runoff and erosion. Irrigation practices also can be adjusted to reduce the erosion caused by spreading water over the land. Minimizing the slope of the land will reduce the erosiveness of the flowing water. Shorter lengths of field, alternate furrow irrigation, and reduced tillage also help. Structural measures that are helpful include grassed waterways, sediment filters, settling basins, and grade stabilizers.

Erosion from pastureland can be reduced by keeping stock numbers down to avoid overgrazing. The addition of fertilizer and replanting also are helpful. Stock should also be limited to the carrying capacity of rangeland, and grazing animals which have lower impact on ground cover could be chosen. Other practices that would reduce erosion of rangeland include brush management, range seeding and fencing, and positioning of water to avoid concentrating the stock.

Forest areas will have less erosion with controlled grazing, prescribed burning, firebreaks, planned modern harvest operations, controlled size and location of clearcut areas, and improved timber stands.

Surface-mined areas require a specific site-oriented reclamation plan. The reclamation plan must allow for slope alterations, vegetative cover, and structural measures to control water and sediment flow.

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Erosion from areas of urban and highway development can be reduced by good planning and implementation of controls. The area and duration of soil exposure should be minimized. Open areas could be covered with mulch or seeded with grass if exposure is long. Structural measures can be taken to reduce water flow rates or to divert the water from open soil areas. Sediment can be trapped in water storage areas. Streambanks can be protected by structures, by hand-placed or dumped stone, or by vegetation.

In the final analysis, implementation of the existing methodologies and those that will be developed by further studies and research will probably require incentives and/or penalties. Although the problem has regional and national implications, it is probably best handled at the State level as part of the Federal Water Pollution Act Amendments of 1972 (Public Law 92-500).

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Dredging and Disposal of Dredged Material

Definition of Problem

Channel dredging for navigation is necessary to maintain effectiveness of the national transportation network. The United States has 25,000 miles of inland and intracoastal waterways, the Great Lakes-St. Lawrence Seaway system, and numerous ports and harbors. Figure II-8 shows the location of problems with dredging and disposal of dredged material in maintaining this water transportation network.

The Mississippi River system is the largest and most improved component of the inland waterways. It has 9,000 miles of navigable channels, 65 percent with depths of 9 feet or more. The Gulf Intracoastal Waterway and tributaries contain 5,400 miles of navigable channels, 50 percent with depths of 9 feet or more. The waterways of the Atlantic Coast include the Atlantic Intracoastal Waterway and the waterways in New York and New England with their tributaries. There are 7,000 miles of navigable channels on the Atlantic Coast, 60 percent with 9-foot minimum depths. The Columbia River-Snake River navigation system and the channels extending inland from San Francisco Bay are the principal waterways of the Pacific Coast. Of the 3,600 miles of the Pacific Coast channels, 65 percent have a minimum depth of 9 feet.

Navigation is an important part of the Nation's economic system. Large amounts of bulk commodities are moved through this system because navigation is the least expensive form of transportation for these products. Over one-half of these commodities are energy related (e.g., coal and petroleum and their products). In recent years, recreation boating has also grown rapidly on the navigable waterways.

The continuing use of the waterways requires that channel depths be maintained by regular removal and disposal of sediment deposit. (The previous section of this report described the erosion and sedimentation problem.) However, dredging and the disposal of dredged materials can disrupt or destroy aquatic life necessary for commercial and recreation fishing, upset ecological balances basic to wildlife, and adversely affect water quality and other environmental balances.

Anticipated development of the Outer Continental Shelf in the Atlantic and Gulf regions for oil drilling and nuclear powerplant siting will add to existing problems of open-water disposal of dredged materials. Along with these offshore developments, supporting onshore developments involving dredging will emerge.

Loss of wetlands through either dredging or filling removes valuable wildlife habitat and destroys nursery and breeding areas for marine fish and shellfish. The natural anti-erosion barrier and sediment traps provided by wetlands also will be lost. Federal and State laws are now curtailing the loss of wetlands from dredge and fill operations.

In the Great Lakes border areas, dredging is suspected of accelerating

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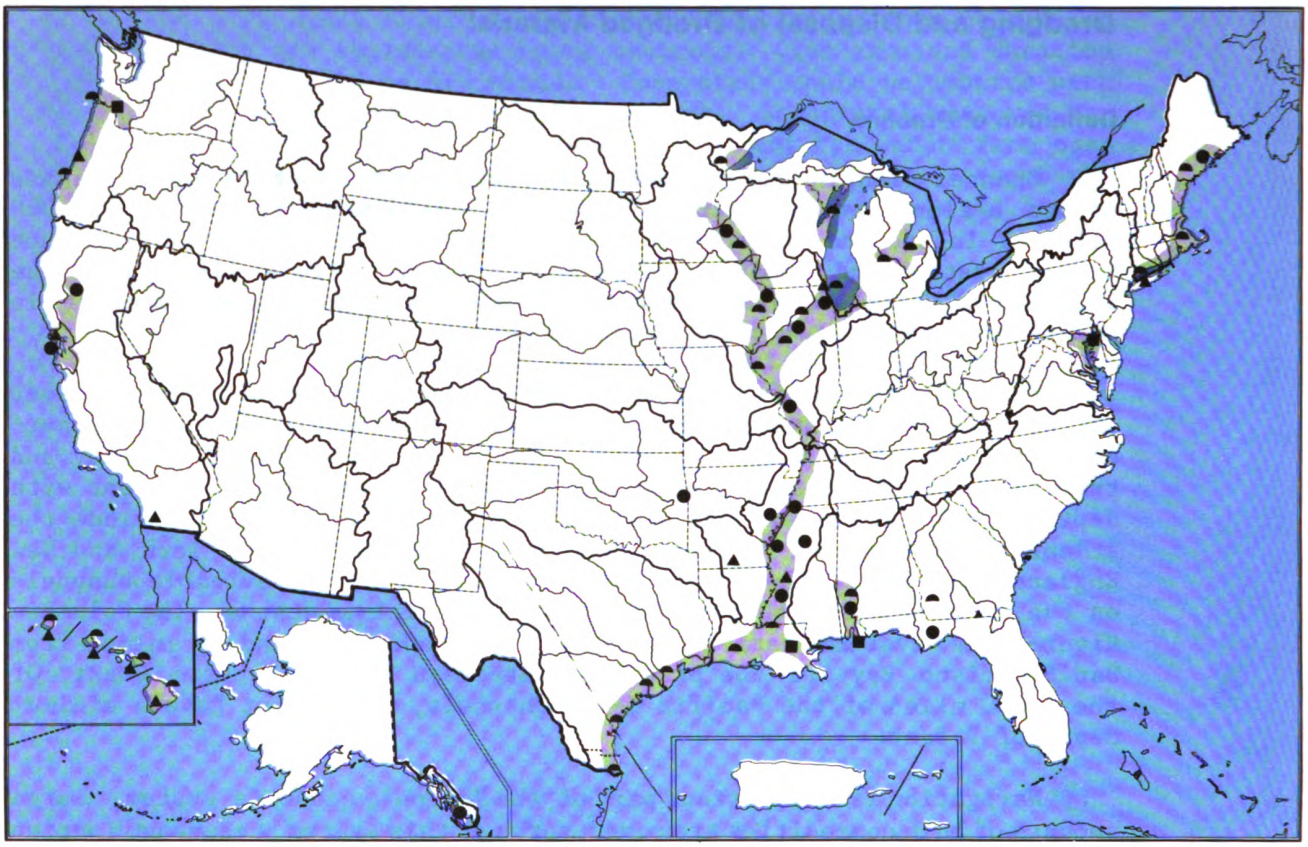

Explanation

Area problem

Area in which there is a waterway with significant dredge and fill problem

Unshaded area may not be problem-free, but the problem was not considered major

Specific dredge and fill problems

- Channel maintenance for normal traffic
- Channel deepening and maintenance for deep-draft vessels
- Land and waterfront development
- Damage to fish and wildlife habitat

Boundaries

Water resources region

Subregion

Figure II-8. Coastal and inland waterways with dredge and fill problems
(As identified by Federal and State-Regional study teams)

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the degradation of water quality for fisheries and wildlife in the five lakes and adjacent water areas. Dredging and filling have both short-term and long-term effects that need careful scrutiny so that appropriate management policies can be formulated.

Implications

Continued dredging to maintain waterways is destined to become more expensive as sedimentation continues and as legal restrictions on site location and dredging methods become more restrictive to protect the environment. Severe marine transportation dislocations will probably occur if major ports and their access channels cannot be dredged to appropriate depths to accommodate modern deep-draft vessels. Disposal of dredged material without appropriate environmental consideration can adversely affect sport and commercial fishing through habitat degradation or loss.

Dredging can affect water quality and create disposal problems for polluted dredged material. Much of the bottom material in the channels of the major ports is polluted by accumulations of industrial wastes. Sites are needed for the disposal of this polluted material.

Loss of wetlands through either dredging or depositing of dredged material on them represents the loss of a valuable wildlife habitat, reduction of a food resource and nursery/breeding area for marine fisheries and shellfishes, and loss of a natural anti-erosion barrier and sediment trap. These effects have both short- and long-term consequences. The conflict between waterborne commerce interests and environmental interests over the extent of dredging is likely to continue.

Specific Problems

The following representative specific problems illustrate the distribution and variety of dredge and fill problems. The information was furnished by regional sponsors.

Problem area: Gulf Intracoastal Waterway (South Atlantic-Gulf Region, subregions 306-309; Lower Mississippi Region, subregion 803; Texas-Gulf Region; and Rio Grande Region, subregion 1305). See Figure II-8.

The Gulf Intracoastal Waterway extends along the Gulf of Mexico from Apalachee Bay, Florida, to the Mexican border. Dredge and fill problems are reported for the Louisiana and Texas sections. In the Louisiana section, maintenance of the waterway requires approximately 900 acres for disposal of dredged material each year. The use of wetlands as disposal areas causes loss of fish and wildlife habitat. Existing disposal areas are used as long as possible inasmuch as rights-of-way for new disposal areas are difficult to obtain.

Problem area: Upper Mississippi River (Upper Mississippi Region). See Figure II-8.

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A major land-use conflict along the main stem of the Upper Mississippi River is overdisposal of dredged material. Deposition of dredged materials and natural siltation in sloughs, backwater areas, wetland areas, fish and wildlife habitat, and rivers and streams has created problems. Conflicts exist between Federal and State policies on dredging techniques and placement of dredged materials. Until the creation of the multi-agency Great River Environmental Team in 1975, continuing channel maintenance, dredging operations, and navigational practices on the lower Mississippi River were based on the single criterion of navigation system efficiency. Environmental and social costs of the waterway system have not been reflected in funding to maintain the system. Present Federal and State funding is inadequate to deal effectively with disposal of dredged materials and other dredging-related problems.

Problem area: Great Lakes (Great Lakes Region). See Figure II-8.

Several areas of the Great Lakes Basin have serious dredge and fill problems. Winter conditions and inadequate depths limit the navigation season and economically affect the region by causing increased transportation costs of land-based commerce, stockpiling of raw materials, and curtailing use of the existing vessel fleet and related facilities.

Dredging is necessary for the maintenance of the existing navigation system. However, the environmental impact of dredging, in terms of degrading the bottom benthic biota, may be significant. Open-lake disposal of dredged polluted sediment disrupts the aquatic environment by increasing the turbidity and smothering benthic organisms. Dredging may resuspend pollutants in the nearshore area, causing a temporary decline in recreational and environmental values. On the other hand, curtailment of dredging activities would have obvious adverse economic consequences. Conflicts exist between Federal and State standards and policies regulating dredging and related disposal activities.

Problem area: Oregon Coast (Pacific Northwest Region, subregion 1705). See Figure II-8.

Dredging for navigation in the Columbia River estuary and several coastal bays conflicts with fishery habitat and water quality. Land disposal of dredged material can affect wildlife habitat. Effects on biological production can be severe in Coos Bay and other bays when oxygen-demanding loads from industrial and commercial waste discharges are freed by construction activities. Toxic products of decomposition are also released occasionally from bottom deposits.

Problem area: Sacramento River (California Region, subregion 1802). See Figure II-8.

Deposits of sediment, debris, and snags interfere with navigation, recreation, and fish spawning areas and make continuing expenditures necessary for dredging and channel clearing on the Sacramento River. Continued bank and channel erosion will cause continued hazards to small boat navigation and require added costs for dredging and channel clearing.

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Problem area: Lower Tombigbee River and Mobile Bay (South Atlantic-Gulf Region, subregion 308). See Figure II-8.

The problem area lies in southwest Alabama in the coastal plain province. Major water resources are: the Tombigbee, Tensaw, Escatawpa, Styx, and Mobile Rivers; Mobile Bay; and the Gulf Intracoastal Waterway. Sediment loads reaching navigation channels reduce navigation depths so that dredging is necessary to remove these materials. As new channels are constructed, it is becoming necessary to build artificial islands in Mobile Bay to dispose of dredged materials. Proper control of material at disposal sites is difficult and presents problems in protecting the water quality of Mobile Bay. In highly developed areas it is difficult to find disposal areas within an economical pumping distance. Competition for land has resulted in the dredging and filling of low areas to develop suitable industrial sites near navigation facilities. The lack of control of these operations results in conflict of land uses and destruction of fish and wildlife habitat.

Options for Resolution

Erosion control on the land and along river banks can lessen the sediment deposition in streams and harbors. Reservoir releases can assist in transporting sediment. Sediment collection systems can help by concentrating the accumulations to limit widespread dredging. Depths of navigation channels could be limited to that needed to safely accommodate the vessels that will regularly use the waterway. Increased flows can reduce the need for dredging.

Disposal sites can be chosen to minimize environmental and fish and wildlife damage. A review of potential sites to evaluate their economic and environmental advantages and disadvantages could lead to an improvement in disposal policies.

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Wet-Soils Drainage and Wetlands

Definition of Problem

Water standing on land can be a problem or a benefit. Such land is usually referred to by agriculturists as wet soils and by fish and wildlife conservationists as wetlands. Agriculturists classify as wet soils those lands that, under natural conditions and without regard to their present status, are permanently or seasonally covered by water or are waterlogged as a result of a high water table. For the agriculturist, to drain the land is to make it available for agriculture. Not to drain it is to permit its continued use by wildlife. However, drainage of land must be considered a long-term process because, if the drainage facilities are not maintained, the land will return to its previous wet condition.

Of the approximately 400 million acres of wet soils, about 100 million acres have been turned into cropland. Another 70 million acres could still be converted, but the remaining 230 million acres offer little potential for cropland. Figure II-9 shows subregions with a potential drainage of 50,000 acres or more for agriculture.

Some water-covered lands provide food and cover for migratory birds, wildlife, sport and commercial fish, and other forms of life, including endangered species. Conservationists refer to such lands as wetlands. Waterfowl depend on wetlands for breeding and wintering habitat, particularly along the four major waterfowl migration routes. In addition to wildlife support, some wetlands store ground and surface water. They control erosion, produce timber, act as fire breaks, improve water quality, absorb flood water's kinetic energy, and provide habitat for minnows, marsh hay, wild rice, blueberries, cranberries, and peat moss.

Estuarine marshes and tidal flats are productive habitats for mammals, birds, small animals, and plants. Marsh habitat includes small creeks and pools where shellfish and finfish thrive. This relationship between the land and major water bodies is critical to the life cycle of commercial and noncommercial fish and wildlife.

At least 127 million acres of wetlands were found in the contiguous States in the early years of this century. By 1954, nearly 40 percent of those wetlands had been drained or filled. Between 1955 and 1975, an additional 6 million wetland acres were drained or filled. About one-half of this 6-million-acre area was of significant value to waterfowl. These lands were drained or filled for agricultural, residential, and industrial uses or for highway, navigation, water supply, or other construction projects.

The principal areas of wetland waterfowl habitat are: breeding areas of Alaska; the glaciated prairie pothole region in the North-Central States; saline and fresh-water marshes of the Great Basin Region; the Mississippi flyway habitat in Michigan, Wisconsin, Minnesota, and Iowa; and the central

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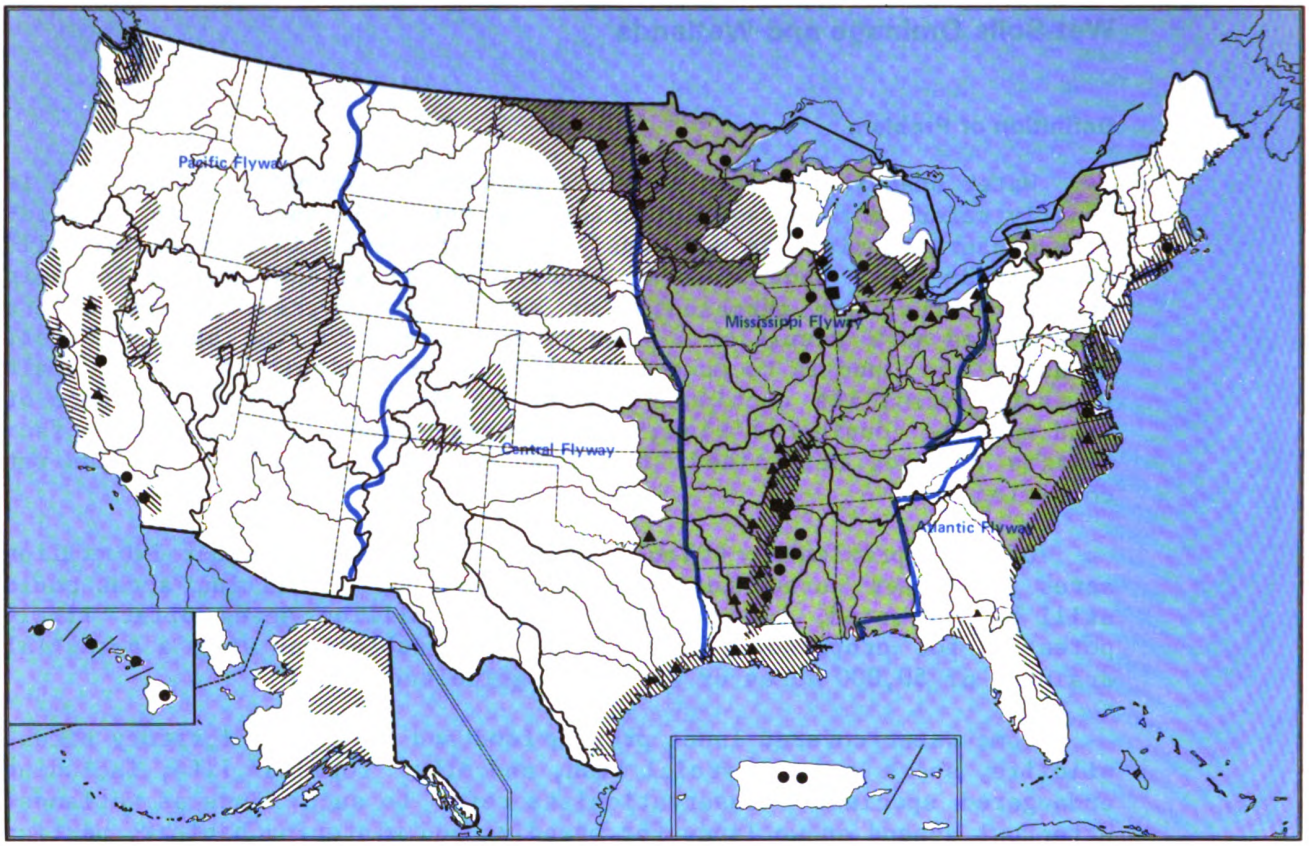

Explanation

Subregion in which 50,000 acres or more of wet-soils are amenable to agriculture if land is drained.

Specific problems ***(as identified by Federal and State/Regional study teams)***

- Wetland waterfowl breeding habitat needing protection
- Wetland waterfowl wintering habitat needing protection
- ▲ Farmland needing drainage
- ■ Urban areas with inadequate drainage
- ● Conflict between wetlands and wet-soils use

Boundaries

- Water resources region
- Subregion
- Flyway of migratory birds

Figure II-9. Wet-soils drainage and wetlands problems

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flyway habitat in Nebraska and Colorado. Important wetlands for wintering birds include the Sacramento and San Joaquin Valleys in California, Atlantic coastal habitat, California coastal habitat, the Mississippi Delta bottomland hardwood area, Texas coastal habitat, Louisiana coastal marshes, and Washington and Oregon coastal habitat. Hawaii's limited wetlands are especially important for endangered species.

The second assessment shows that over 11 million acres of potentially good agricultural land that now has a wet-soil problem would probably be drained and converted to cropland by the year 2000 if projected agricultural levels are attained. About half of this land is now forested. Continuing production of food and fiber for growing domestic consumption and export will make such conversions profitable.

Highway construction on the prairies threatens important potholes that provide breeding and resting areas for migratory waterfowl. Water projects frequently cause the permanent loss of wetlands through flooding, draining, or filling with dredge spoil materials.

Wet soils restrict residential, commercial, transportation, and recreational development. Low, flat land with a wet-soils problem can provide an excellent location for various types of development if drained and protected from flooding. Drainage can increase woodland productivity. Accessibility for harvest, improved species, increased seedling survival, and improved growth rates can result from wetness control.

Inherent conflicts between drainage and the need to preserve wetlands for fish and wildlife (and other social and economic values) require a thorough evaluation of the economic, social, and environmental effects of any proposed change to wet soils or wetlands.

Implications

Wetlands are found in every State. In the North Central, Midwest, Mississippi Delta, and eastern Coastal Plain States some of these lands can be drained and converted to productive cropland. In this assessment, the estimated 11 million acres that could be converted to cropland through drainage are located in 30 of the 106 subregions in 10 of the 21 regions.

The Second National Water Assessment estimates that of 422 million acres of cultivated cropland, 304 million acres are harvested. Some of the 120 million acres of additional land could be cropped if required by the economy. However, every year about 2 million acres of farmland are irreversibly lost to urban and other development while another 1 million acres are inundated by ponds and reservoirs. Although the supply of cropland is currently sufficient, it is finite.

Drainage is an important farm management tool. Drainage of intermittent wetlands that are interspersed with cultivated lands allows farmers to use equipment more efficiently. Large, level, dry fields are less expensive to farm. Land converted from wetlands usually grows high-value crops such as corn, soybeans, cotton, peanuts, tobacco, feed grains, and

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wheat. Drained land gives farmers greater flexibility in the choice of crops to grow and provides a longer growing season by allowing earlier spring planting; moreover, harvesting is not as likely to be delayed or hurried because of wetness. Drainage of wet woodlands also generally increases the wood crop, depending on the species being harvested.

Urgency of drainage needs is primarily related to specific local situations. Drainage can be urgent for the individual farmer who has an opportunity to raise additional crops and make a greater profit or avoid a loss. It can also be urgent in a community faced with residential and commercial damage from high water.

Most land to be drained for crop production is not wetland in the context of fish and wildlife habitat. Most of it is level lowland with high crop production capability and with much already in cultivation. The U.S. Department of Agriculture's Soil Conservation Service has a policy of providing financial assistance for draining some wetlands. However, no Federal financial assistance is provided for draining certain types of wetlands that are excessively wet or rugged, because drainage would be expensive and crop production low per dollar of investment.

Drainage also helps to control health problems such as schistosomiasis and mosquito-borne diseases like encephalitis that result from standing water. Drainage reduces the number of flies and mosquitoes with their health and nuisance problems. It also facilitates on-land disposal of waste materials that require air and bacterial action for their destruction.

However, continued loss of crucial wetlands will reduce the migratory waterfowl population and other wildlife using those areas. Several endangered species and a valuable part of the ecosystem would be lost. Even though wetlands comprise only a small percentage of the United States, their loss would have an effect much greater than their limited size would indicate. For example, Iowa formerly had a million acres of wetlands that produced 3 to 4 million ducks annually; Iowa now has about 50,000 acres of wetlands that produce 50,000 to 100,000 ducks per year.

The urgency to protect wetlands varies with the productiveness, threat of loss, and specific uses of the area. Hawaiian wetlands are crucial to many endangered species, so these must be protected to avoid the loss of this particular wildlife. The U.S. Fish and Wildlife Service has established a priority list of those wetlands most urgently in need of protection.

The potholes region of the North Central States comprises 10 percent of the country's wetlands, but produces 50 percent of the ducks in the contiguous United States. The U.S. Fish and Wildlife Service reports a statistically significant correlation between the number of potholes containing water and the annual continental duck population. Production is significantly reduced in years of below-normal precipitation in the potholes region. As a consequence, there are fewer birds in the fall flight; fewer hunters buy duck-hunting stamps because bag limits are more restricted, and bird watchers see fewer birds.

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Specific Problems

The following representative problems were chosen to illustrate the variety and distribution of drainage and wetland problems. The information was furnished by regional sponsors.

Problem area: Lower Cape Fear (South Atlantic-Gulf Region, subregion 301). See Figure II-9.

In the lower Cape Fear and New River Basins in southeastern North Carolina, the problem is excess surface and ground water that prevents land from being used for production of food and fiber. However, drainage of some of this land may conflict with its use as habitat for wildlife. There is a lack of land use control and management programs.

Substantial acreage already has been drained and made available for agricultural production and other uses. In this area of over 3.5 million acres, approximately 628,000 acres still have a drainage problem. Average annual agricultural production losses are estimated at approximately $1,760,000 in 1967 dollars.

Problem area: Maumee River Basin (Great Lakes Region, subregion 406). See Figure II-9.

The Maumee River stretches 134 miles from Fort Wayne, Indiana, northeast to Maumee Bay on Lake Erie just south of Detroit, Michigan. Soil in the river basin drains poorly and agricultural lands are subject to flood damage and impairment of drainage systems. Poor surface drainage limits use of land for agricultural or urban purposes. Drainage systems and stream channel modification cause wildlife habitat loss, increase surface runoff and erosion, and alter downstream flood stages. It is anticipated that from 1985 to 2000, overloaded tile drains in agricultural land will intensify as a problem.

Problem area: Park River Basin (Souris-Red-Rainy Region, subregion 901). See Figure II-9.

Flood-plain and wetland areas in the Park River Basin, which covers 1,000 square miles in northeastern North Dakota, are being converted to agricultural and urban areas. As a result, crop and livestock production have expanded, but the excess water interferes with farming operations by delaying planting, reducing quantity and quality of crops, and increasing costs. Draining the wetland has reduced the waterfowl habitat. However, the local tax base has expanded from the agricultural and urban development in the flood plain and wetland areas.

Problem area: Lower Minnesota River Basin (Upper Mississippi Region, subregion 701). See Figure II-9.

The lower Minnesota River Basin problem area includes 6,500 square miles in south-central Minnesota southwest of Minneapolis. There has been extensive drainage and filling of wetlands, lakes, and ponds to facilitate

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agricultural development. This has caused a continuing deterioration and reduction of fish and wildlife habitat and wetlands and degradation of streambanks, scenic amenities, and other environmental resources. Consequently, the natural setting of the Minnesota River Basin is being altered. As a result of the drainage and filling of wetlands and the conversion of shoreland, flood-plain, and forest areas to agricultural uses, there has been an expansion of crop and livestock production.

Problem area: Mermentau River Basin (Lower Mississippi Region, subregion 803). See Figure II-9.

The Mermentau River Basin problem area is located in southwest Louisiana and covers the area of the Mermentau River below Iota, Louisiana, an area of 2,335 square miles. The coastal marshes in the area are a valuable environmental resource. However, water levels vary seasonally and do not attain optimum levels for fish and wildlife productivity. High water levels in the problem area during the spring and summer prevent germination of favorable vegetative species for fish and wildlife, and low water depths during other parts of the year reduce the availability of habitat to wintering waterfowl. The production of prime waterfowl food plants such as annual grasses and sedges has decreased substantially. The major cause of this decrease is high water levels in the marsh. These levels are maintained to produce a water supply source for rice irrigation, but they prevent germination of favorable species for wildlife during the growing season. High water levels in the basin have led to the proliferation of water hyacinths that degrade marsh pond habitat and impede commercial and recreation access. High water levels also have reduced the growth of soil-binding plants along lake margins, leaving the shoreline soil exposed and vulnerable to wave erosion. Such erosion has been prominent in the Grand Lake and White Lake areas. During low rainfall months, surface runoff from the Mermentau Basin is inadequate, and supplemental water is needed to manage water levels in the marsh for maximum productivity of fish and wildlife. Water-level management is also needed to maintain vegetative development and water chemistry conducive to high productivity of fish and wildlife.

Limited fish and wildlife productivity due to local water-level management that favors agricultural development adversely affects commercial fishing and trapping and sport fishing and hunting in the area. Without comprehensive water-level management, erosion and poor growth of needed vegetation will ultimately destroy the valuable marshland and fish and wildlife habitat. It is estimated that the annual loss in harvest of white shrimp is about 1.1 million pounds, and blue crabs about 224,000 pounds. Commercial fishing and hunting historically have been significant industries that have strongly influenced the economic and social lives of the residents in the Mermentau River Basin. Deterioration of these industries not only will adversely affect the local economy, but will change the residents' way of life.

In addition, there are 720,000 acres of cropland and pastureland where drainage improvements would increase land values and the net income from agricultural production. This would be accomplished by increased yields

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due to a more favorable plant environment, increased operating efficiencies, and shifts in cropping patterns. The land with inadequate drainage is projected to increase to 770,000 acres by the year 2000 if preventive measures are not implemented.

Problem area: Rio Grande Closed Basin (Rio Grande Region, subregion 1301). See Figure II-9.

The problem area is the Closed Basin of the Rio Grande headwaters in south-central Colorado near the New Mexico border. The area lies north of the Rio Grande, so the surface runoff does not flow into the river. The lower part of the Closed Basin has high water tables that have encroached upon croplands and encouraged the growth of phreatophytes, deep-rooted plants that obtain their water from the water table or layer of soil just above it. There are estimated to be 371,800 acres of phreatophytes which nonbeneficially consume 415 million gallons of water per day. These lands need to be drained in order to return the formerly cropped lands to production and to salvage water that is now being nonbeneficially consumed by the phreatophytes and evaporation.

Drainage and the clearing of phreatophytes, however, will destroy habitat for white-winged doves and songbirds. The most important wildlife habitat areas should be identified and a plan devised to preserve these areas yet still provide a significant improvement for agriculture.

Problem area: Tulare Lake Basin (California Region, subregion 1803). See Figure II-9.

Generally, in the trough of the Tulare Lake Basin, concentrations of salt accumulate in the upper layers of the soil. This accumulation is concentrated because external drainage is poor and because evapotranspiration concentrates the salt in the water as it penetrates the soil profile. Although the 1.6 million tons of salt being added annually is a relatively small amount compared to the total salt load of the basin, this small increment is beginning to cause problems in productive agricultural areas. In addition to the salt problem, as lands are developed, perched water, which is water separated from the main body of ground water by impermeable rock, may inhibit the flows needed to leach salts from the irrgation water unless satisfactory drainage facilities are in operation.

In the mid-1960s, on-farm tile drainage systems became necessary in western Fresno County. In 1975, 6,000 acres were being drained by a tile system. In all, 27,000 acres, including areas with highly saline water, presently require some type of drainage control.

Problem area: San Joaquin River Basin (California Region, subregion 1803). See Figure II-9.

The problem of the San Joaquin River Basin is the salt level in the main stem of the San Joaquin River rather than the salt accumulation within the basin.

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Associated probems in this area include disposal of agricultural waste water, along with salt problems, high water in the root zone, and agriculturists' efforts to drain their land. The total area which is at least partially drained by some type of ground-water control system equals about 280,000 acres. Of this total, approximately 81,000 acres are areas with highly saline water. In 1975, there were 50,000 acres with a tile drain system. New installations are proceeding at the rate of about 4,000 acres per year.

As for the overall problem area in the San Joaquin Valley, the magnitude of the drainage problem in the future can be evaluated by the anticipated increased acreage requiring control measures. In 1975, 600,000 acres suffered some type of productivity loss or required shifting to more salt-tolerant crops. By the year 2000, the total is expected to increase to about 1 million acres.

The greatest economic impact of not providing adequate drainage is loss in land productivity. Counties in this area account for about half of the State's total agricultural production. Preliminary studies have estimated an annual equivalent loss of $37 million. Based on estimates by leading financial institutions that $1 of gross farm income generates an additional $4 of economic activity in California, the $37 million reduction in gross income for the problem area would amount to $148 million loss to the economy.

Lowering shallow ground-water tables would reduce marshy or swampy mosquito breeding areas; this would produce an estimated excess of $3 million in capital savings in mosquito abatement costs at 1967 cost levels.

Other benefits could be derived from the emerging drainage issue in terms of increased wildlife habitat. If land were permitted to revert to natural conditions, additional acres of valuable habitat would be re-established, thereby stemming the now-dwindling total. With or without large-scale drainage and disposal measures, ponding and/or transportation of drain water could be highly beneficial, especially for wild fowl, if the use of insecticides is rigorously controlled.

The seasonal and permanent marshes (wetlands) in the basin are particularly vulnerable to development of urban, industrial, and agricultural land uses. This is a critical problem because this habitat is already in short supply because of reclamation activities. The loss of wetlands will occur on privately-owned lands as economic factors play an increasing role in land-use changes.

Options for Resolution

Since there are many methods of water-level management, the specific method to be applied depends upon the local situation and need. Moderately wet soils can be drained by subsurface tile drains or by surface ditches. Larger areas and those with larger amounts of water to dispose of usually require some type of large canal to collect the water from individual fields and convey it to a disposal area. Low, wet areas also can be

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reclaimed by leveling such an area with the surrounding land. Farm operators accomplish drainage as a normal part of their cropland preparation. Federal and State agencies can assist the process by giving financial and technical aid and by providing major drainage outlets.

A parallel problem is to protect valuable wetlands while providing for the drainage of those agriculturally valuable farmlands. Major steps have recently been taken to protect wetlands from federally supported projects. Executive Order 11990 requires Federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands in carrying out their programs. In addition, Federal purchase of wetlands is being given additional support.

One major problem is the inadvertent drainage of wetlands by the construction of highways with their drainage systems. Adjacent wetlands are frequently drained into these convenient outlets. Prevention of this type of use of highway right-of-way could protect important wetlands. Financial incentives can also be used to encourage private land owners to retain wetlands.

Wetland management should be based on long-range national goals that recognize the tradeoffs needed to balance the environmental and economic objectives. The Federal Government should support State and local decisionmaking by providing national policy objectives and broad guidelines for preserving or draining wetlands and by making available information on the tradeoffs to be considered before reaching a decision. Steps in this direction have already been made. For example, the U.S. Fish and Wildlife Service and the Department of Agriculture are classifying wetlands to identify the wetlands most suitable to support wildlife and natural functions or agricultural use. However, a sharper definition of broad management policy and guidelines at the Federal, State, and local levels is still needed.

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Degradation of Bay, Estuary, and Coastal Water

Definition of Problem

Bays, estuaries, and coastal waters are extremely important to the economy and well-being of the Nation because they contain the major transportation routes for international commerce, the essential habitats for fishery and wildlife resources, and the major recreation sites for more than 80 percent of the Nation's population. Commercial fisheries, sport fishing, waterfowl hunting, and other uses of wildlife all depend heavily on the health of the bays and estuaries. Furthermore, tidal wetlands are valuable for natural waste treatment systems, nursery grounds, and flood absorption. The flushing rates of most bays and estuaries are relatively slow, limiting their capacity to handle large amounts of sediment and domestic and industrial wastes. Pesticides and related industrial wastes as well as heavy metals are readily absorbed on fine suspended sediments that settle out in the bays and estuaries. Unfortunately, these sediment traps also provide a reservoir for toxic substances, which are then available to aquatic life indirectly through the food chain or directly through resuspension of sediments by storms or dredging.

The most significant problem is the discharge of domestic and industrial wastes into the bays and estuaries, particularly in the densely populated New England, Mid-Atlantic, and Great Lakes Regions. Less significant problems are the buildup of sediments in the bays and estuaries from erosion of agricultural and forestry lands, dredging of navigable channels, destruction of sand dunes, shoreline erosion, subaqueous mining of sand and gravel, and decreased fresh-water inflow. Locations in which these problems have been identified are shown in Figure II-10.

Increased nutrient loadings are inseparable from domestic waste discharges, since nutrients result from organic matter decomposition, whether in the natural waters or in waste treatment plants. Some areas have had to resort to expensive tertiary treatment to offset this problem. This will probably become an even more persistent problem as population continues to increase in coastal areas.

Eutrophication of bays, canals, and estuaries causes algal blooms, noxious weed growth, high oxygen demand, odor, and, in the Great Lakes, taste problems in fresh-water supplies. Nutrient additions also come from nonpoint agricultural runoff and from poorly functioning septic systems in urban areas not served by central waste treatment facilities.

Because of a lack of economical onshore disposal sites, dumping of wastes offshore, particularly in the major coastal metropolitan areas of the Northeast, has become a common practice. This has seriously degraded marine and shoreline habitat. Increasing oil and debris have been accumulating on shores, threatening shoreline habitats, valuable fishing grounds, and recreation areas.

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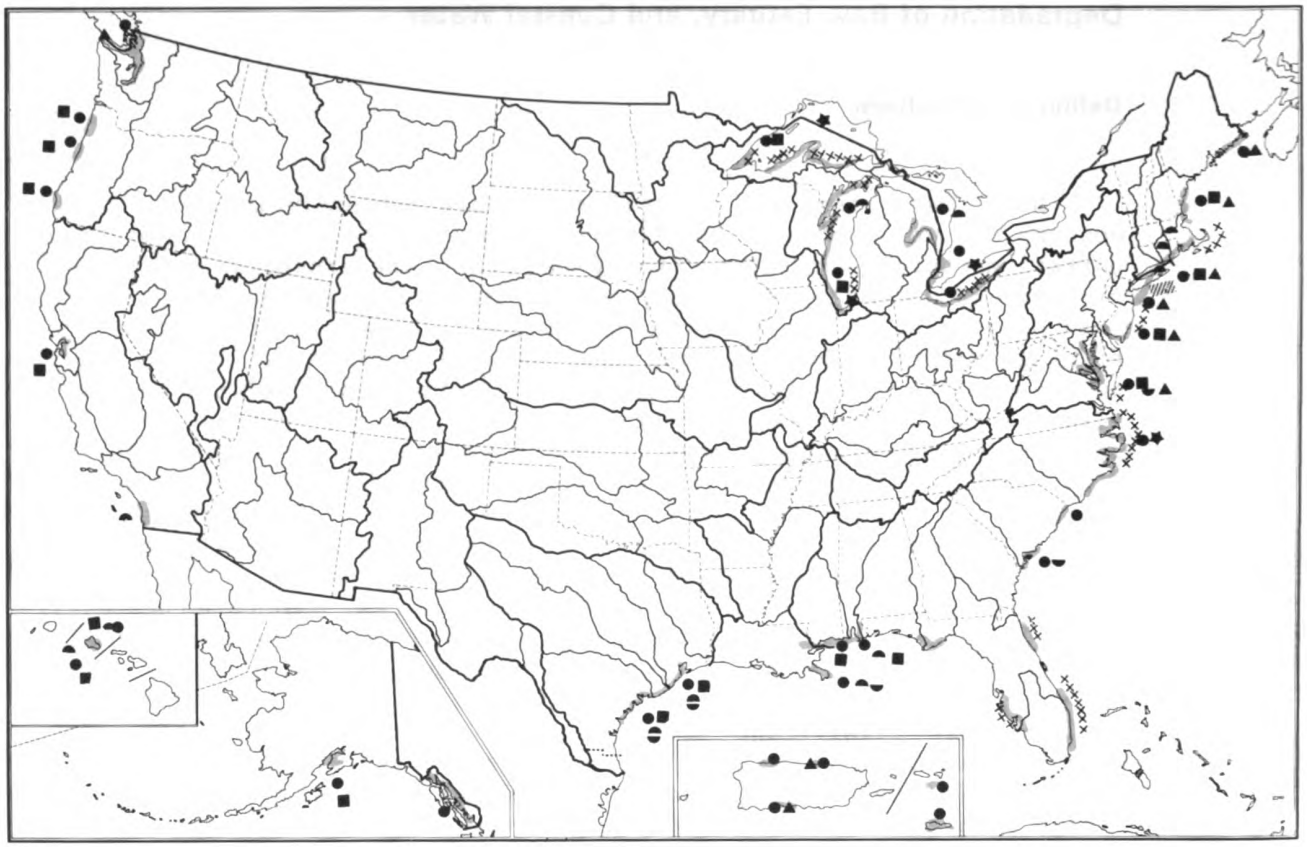

Explanation

Area problem

- Area with major bay or estuarine water-related problems
- Unshaded area may not be problem-free, but the problems were not considered major

Nature of problems

- ● Pollutant loads from upstream or shoreline point sources
- ■ Pollutant loads from nonpoint sources
- ▲ Pollutant loads from commercial and waterborne traffic-related sources
- ★ Increased nutrient loads
- Loss of coastal wetlands
- Loss of fresh-water flow resulting from upstream consumption use or diversion
- xxxx Shoreline erosion
- Offshore dumping

Boundaries

- Water resources region
- Subregion

Figure II-10. Bay, estuary, and coastal water problems (As identified by Federal and State-Regional study teams)

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The next most significant cause of the degradation of bays and estuaries is erosion and the resultant load of suspended sediment carried into the lower reaches of the tributary rivers and into the bays where the suspended solids settle out. Erosion and sedimentation are natural wherever there is flowing water, but poor agricultural and forestry practices and construction that neglects erosion control have greatly exacerbated the problem. Besides the obvious cloudiness of the waters, the sediments cover otherwise productive shellfish beds, affect benthic communities, interfere with spawning grounds of certain fish species, reduce navigation depths, and limit water contact recreation such as swimming and scuba diving.

Dredging of navigable channels is required not only because of sedimentation in the channels, but also because of the requirements of the larger and deeper draft vessels of today's modern fleets. Disposal of the dredged material has become a major problem because toxic substances such as pesticides and heavy metals are also resuspended when the bottom sediments are distributed, and because it is now recognized that marsh and wetlands, traditional repositories for these materials, are extremely valuable for fish and wildlife. Much marshland already has been lost by fill from dredged material. To curtail further loss of wetlands, many States have adopted legislation to prevent such disposal.

Many coastal areas report significant erosion problems. While most of these are related to natural causes, some areas have experienced sand dune destruction from building on beaches and barrier islands. Many barrier islands are valuable wildlife preserves. They also protect coastal areas from storms and erosion.

Stabilization of shorelines is extremely expensive, particularly in dynamic coastal areas. Areas with heavily developed beaches have substantial property to protect. However, with few exceptions, attempts to stabilize sand shifting have not been successful over long periods. Subaqueous sand and gravel mining, now taking place along the New York and New England coasts, are expected to spread farther along the coast. This may compound the difficulty of maintaining the shoreline.

A long-term decrease in fresh-water inflow to the estuaries is characteristic of more arid regions such as the Texas Gulf Coast and the southern part of California, where water diversions, for example, are made to other watersheds or to homesite developments. These modified flows alter the natural salinity regime of the estuaries and change the flushing characteristics of the estuary. When natural estuarine circulation is altered, major changes in wildlife populations, particularly those that are sensitive to specific salinity relations, can be expected.

Increased environmental awareness has caused planners and managers in coastal regions to critically review plans and proposals for new activities in coastal waters, particularly in relation to deep-water ports, floating nuclear powerplants, and other energy-related facilities. With more concern for improved management of this coastal area within the 200-mile limit, appropriate balance between economic development and protection of the limited resource base will receive increasing attention. Should substan-

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tial quantities of oil or natural gas be found, there will be increased demands for offshore port, distribution, and refining facilities.

Implications

Untreated and inadequately treated domestic wastes introduce enteric bacteria and viruses into the bays and estuaries where they pollute fish and shellfish and make some local areas unfit for water contact sports. The threat to public health is avoided only by closing the polluted areas to the taking of fish and shellfish or swimming. Already many thousands of acres of shellfish grounds have been closed, resulting in a loss of livelihood for many watermen and in high prices for the remaining resource.

Industrial wastes such as insecticides, polychlorinated biphenyls (PCB), and heavy metals all have public health implications since they can be concentrated in fish or shellfish far above the concentrations in the water. Public health implications have resulted in closure of many areas, and failure to solve this problem will undoubtedly result in further closures. With the introduction of hundreds of new organic chemicals every year, the cost of monitoring and enforcement of public health laws is likely to increase substantially if contamination of the water is not controlled at the source.

Most bays and estuaries and some barrier beaches and shorelines in populated areas are already under stress from domestic and industrial wastes, sedimentation, dredging, filling of marshland for dredge material disposal or development, or poor management of barrier islands and shorelines. Without marked progress in pollution abatement and land use management, both esthetic and ecological aspects of environmental quality may continue to be degraded.

Continued degradation of bays, estuaries, and coastal waters threaten an approximately 1 billion dollar annual commercial fishery and a recreation fishery of probably greater value. With few exceptions, these fisheries depend upon the quality of water and habitat in bays and estuaries. For the past 20 years the total United States landings of fish and shellfish has remained about constant, but landings of fish for human consumption have decreased. The difference has been made up by increased industrial fish landings.

Severe marine transportation dislocations can occur if major ports and their access channels cannot be dredged deeply enough to accommodate modern deep-draft vessels. However, disposal of dredged material without consideration to potential adverse environmental effects could be deleterious to the sport and commercial fishing industry.

Beach and shore erosion are natural occurrences, but severe economic problems can result from improper coastal development. The cost of beach replenishment along resort areas is enormous but necessary to these popular recreation resorts.

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If substantial quantities of oil or natural gas are found on the Atlantic Outer Continental Shelf, the national dependence on foreign oil and the balance of payments could improve greatly. On the other hand, ports in undeveloped areas have expressed concern over the effects of offshore drilling on the marine and estuarine environment as well as related land issues. The costs of planning, managing, and meeting new demands for facilities are a great concern, particularly to localities that may not possess an adequate tax base to provide investments in anticipation of ultimate economic benefits.

Fish and wildlife resources depend upon quality habitats. Larval and juvenile stages are particularly sensitive. The key to successful fishery and wildlife management is maintenance of appropriate water quality and other environmental factors in spawning, nursery feeding, and transit areas.

There are no major international implications regarding degradation of bays, estuaries, or coastal waters of the United States, with the possible exception of the Great Lakes Region where the United States and Canada must cooperate on water-quality management and pollution abatement. On the other hand, if an international agreement (in context of the U.S. 200 mile fishery zone) guarantees a minimum catch of estuarine- or bay-dependent species, the degraded environments that adversely affect the species' production could lead to problems.

Almost all bays and estuaries in urban, agricultural, or urbanizing areas are affected by point or nonpoint pollution. Almost all coastal States have bay, estuary, or coastal systems that have been subject to dredge and fill operations with resultant loss of fish and wildlife habitat. In many of these regions, the economic gain from increased industrial and commercial development spurred by these activities has outweighed the environmental loss. However, with a reduction in suitable fish and wildlife habitats, the potential benefits of this type of alteration have been severely diminished to the point that most coastal States have active regulatory programs to discourage further wetland alteration.

Fresh-water diversion, with the exception of the Texas-Gulf Region, is not a regional problem. It is, however, a problem between river basins and their associated estuarine systems in many regions since planners and managers attempt to alleviate local fresh-water supply shortages by interbasin transfers.

The degradation of bays and estuaries and the coastal environment is insidious. It has developed over a long time with gradually increasing demands and pressures being exerted by increasing populations, a higher standard of living, increasing conflicts of use, new products in manufacturing and agriculture, and increasing use of pesticides. Whereas populations and demands increase, the carrying capacity of estuaries remains fixed. It is the consensus of the scientific community that the carrying capacity of many major bay and estuarine systems has already been reached.

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Specific Problems

The following representative specific problems illustrate the variety of estuary and coastal problems. Regional sponsors provided information upon which to base the problem analysis.

Problem area: Potomac River (Mid-Atlantic Region, subregion 206). See Figure II-10.

The disposal of domestic and industrial waste is causing problems nearly everywhere along the Potomac. Nutrient loading is common to all areas. For example, the tidal Potomac River is exhibiting signs of eutrophication from metropolitan Washington, D.C., to an area 50 miles downstream.

Problem area: Mid-Atlantic Coast (Mid-Atlantic Region, subregions 202 and 203). See Figure II-10.

The sludge disposal problem in the Mid-Atlantic States is particularly acute. Several localities, including New York City, Philadelphia, and some New Jersey communities, are under Federal regulatory strictures or court injunctions to limit or curtail the disposal of waste in the Atlantic Ocean.

Problem area: James River, Virginia (Mid-Atlantic Region, subregion 205). See Figure II-10.

The most recent and widely publicized problem related to industrial waste discharge is that of Kepone in the James River, Virginia. Present evidence indicates that Kepone (a chlorinated hydrocarbon used in pesticide formulations) was discharged for several years into the James River before regulatory agencies became aware of the problem. As a result, the James River is now closed to fishing some 70 miles below the plant that manufactures Kepone.

Although site-specific problems such as the discharge of Kepone into the James River receive widespread attention, a more pervasive and economically severe problem is the closing of shellfish harvesting grounds because of high fecal or total coliform counts in parts of most bays and estuaries.

Problem area: Northeast Coast (New England Region, subregions 103 and 104). See Figure II-10.

Loss of marshland is an omnipresent problem; however, the major impacts have occurred in areas with heavy populations concentrated in coastal regions such as the Northeast. Since 1900, for example, Connecticut has lost 40 percent and Massachusetts 20 percent of their wetlands. In Long Island, during the 10-year period of 1955-1964, 30 percent of the coastal wetlands were lost. The severity of this problem has been recognized and now almost all coastal States have effective wetlands protective legislation.

Problem area: South Carolina (South Atlantic-Gulf Region, subregion 302). See Figure II-10.

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The problem of decreased fresh-water flow is best exemplified by the situation in South Carolina where severe problems of siltation and the associated costs of dredging have generated a plan to redivert water presently flowing through the Cooper River back to the Santee River.

The principal problem facing South Carolina is that a viable shellfish industry in the mouth of the Santee River may be lost. A more immediate problem is that the fresh-water supplies to industries located along the fresh-water portions of the tidal Cooper River may be contaminated by salt-water intrusion.

Problem area: Hatteras Island (South Atlantic-Gulf Region, subregion 301). See Figure II-10.

Shoreline erosion is a common problem. In many regions the economic magnitude of the problem is underestimated because the impact is borne by small property owners. An example of the difficulty and economic cost of stabilizing shorelines is provided by experience of the Federal Government, which invested over $18 million from 1930 to 1973 in attempting to stabilize the shoreline of Hatteras Island, North Carolina, before the National Park Service adopted a policy of letting nature take its course.

Problem area: Cape Charles, Virginia (Mid-Atlantic Region, subregion 205). See Figure II-10.

Although not quantifiable in precise economic terms, the public cost of onshore actions to support offshore oil and gas development in frontier areas is considered to be substantial, particularly by localities that may have to bear a heavy expenditure of public funds for services before realizing a return of tax dollars from the buildup activities. A prime example of this is the planned establishment of a major offshore structure fabricating facility at Cape Charles, Virginia, an underdeveloped rural area with a severe shortage of skilled labor. Local government is expecting a major influx of skilled workers and a resulting increased demand for local services which will far exceed initial tax returns.

Problem area: Chesapeake Bay (Mid-Atlantic Region, subregion 205). See Figure II-10.

Large quantities of potentially hazardous materials are transported through bays and estuaries; accidental spills are common. A typical example is the sinking of an oil barge in Chesapeake Bay in February 1976 with the spill of 250,000 gallons of No. 6 oil. Some 20,000 waterfowl perished and 20 miles of shoreline were contaminated. Cost of cleaning exceeded $380,000.

Options for Resolution

There are few viable options for dealing with problems of quality degradation of bays, estuaries, or coastal waters that do not include either limitations on development and/or heavy expenditures of funds. Because of the interrelationship of bays, estuaries, and coastal waters with the adjacent areas, the problems cannot be solved without greatly

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increased local, State, and regional interaction.

Specific actions that would delineate options include the establishment of carrying capacities for various river basins based upon desired use of the systems that would constrain nonmanaged growth.

Plans for development of coastal-related resources must consider conflicts that multiple use places on the system and must relate specific resource utilization plans to regional goals and objectives.

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PART III
WATER USES

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CONTENTS

Functional use and flow management ---- 1
Offstream functional uses ---- 2
Regional uses ---- 4
Socioeconomic characteristics and projections ---- 9
Bases for projections ---- 9
Population ---- 9
Population distribution ---- 11
Employment ---- 11
Personal income and earnings ---- 12
Economic activity mix ---- 13
Gross National Product ---- 14
Summary ---- 15
Comparison of National and State-Regional Futures ---- 16
Domestic and commercial use of water ---- 19
Data parameters ---- 19
Overall domestic and commercial water needs ---- 20
Supply systems ---- 22
Water sources ---- 24
Regional domestic use ---- 26
Regional commercial use ---- 26
Regional projections ---- 27
Water quality ---- 29
Water costs ---- 29
Treatment ---- 29
Issues ---- 30
Water for manufacturing ---- 33
Assumptions ---- 33
Applicability of data ---- 33
Definition of terms ---- 34
Background ---- 35
Water source and uses ---- 36
Projections for manufacturing water ---- 41
Summary of overall projections ---- 50
Data and research needs ---- 54
Food and fiber ---- 57
Terminology ---- 58
Land use ---- 58
Water resources ---- 59
Ground water ---- 63
Crop yields ---- 64
Water quality problems ---- 66
National and State-Regional Futures ---- 73
Summary ---- 74
Water for energy production ---- 77
Background ---- 77
Assumptions ---- 78
Definition of terms ---- 78
Sources and reliability of data ---- 78
Energy consumption and production ---- 79
Electric power generation ---- 79
Regional variations in electric power generation ---- 83
Water for energy production ---- 84
Implications of water use for energy production ---- 92
Summary of projections ---- 93
Minerals production ---- 95
Metals mining ---- 95
Nonmetals ---- 97
Fuels ---- 97
Overall regional needs ---- 99
Mining trends and projections ---- 100

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Water for recreation ---- **103**
Participation in water-related recreation ---- 103
Water resources for recreation ---- 104
Water needs for recreation ---- 106
Areas of critical environmental concern ---- 107
Improving water quality for recreation ---- 113
Competition for water ---- 115
Improving the planning process ---- 116
Water requirements for navigation ---- **117**
Navigation and water resources management ---- 117
Instream effects of navigation ---- 117
Nation's waterways ---- 118
Nation's commerce ---- 119
Navigational water requirements ---- 124
Environmental effects and costs ---- 124
Future navigation systems ---- 125
Water for fish and wildlife ---- **127**
Endangered species ---- 127
Riverine ecosystems ---- 128
Wetlands and coastal ecosystems ---- 133
Upland ecosystems ---- 137
Requirements for fish hatcheries ---- 138
Comparison of National and State-Regional Futures ---- 138
Water for natural areas, historic resources, and wilderness areas ---- **141**
Natural areas ---- 141
Historic resources ---- 142
Wilderness areas ---- 147
Flood-plain management ---- **151**
Background ---- 151
Definition of terms ---- 151
Data parameters ---- 152
Consequence of floods ---- 152
Flood-plain management ---- 153
Erosion and sedimentation ---- **161**
Data parameters ---- 161
Background ---- 162
Water-induced erosion and sediment ---- 162
Options for controlling erosion and sedimentation ---- 171
Conclusions ---- 172

TABLES

III-1. Total withdrawals and consumption, by functional use–"1975", 1985, 2000 ---- 3
III-2. Fresh-water withdrawal and consumptive use relations by type of use–"1975" and 2000 ---- 4
III-3. Total fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 5
III-4. Per capita fresh-water withdrawals and consumption for all offstream uses compared with domestic and commercial uses–"1975", 1985, 2000 ---- 6
III-5. Selected economic indicators–1950, "1975", 1985, 2000 ---- 10
III-6. Regional population, personal income, and earnings–"1975", 2000 ---- 12
III-7. Per capita income and earnings–"1975", 1985, 2000 ---- 14
III-8. Comparison of projected population changes between "1975" and 2000 ---- 16
III-9. Typical urban use by a family of four ---- 20
III-10. Comparison of domestic and commercial use projections ---- 21
III-11. Domestic and commercial fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 22
III-12. Commercial fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 23
III-13. Domestic central system fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 27
III-14. Domestic noncentral system fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 28
III-15. Growth in population, earnings, and fresh-water withdrawals and consumption in manufacturing–"1975", 1985, 2000 ---- 36
III-16. Manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 38
III-17. Manufacturing water use by industry, "1975" ---- 45
III-18. Primary metals manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 46
III-19. Chemicals manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 47
III-20. Paper manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 48
III-21. Food and kindred products fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 49
III-22. Petroleum refining fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 51
III-23. Transportation equipment manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 52
III-24. Textile manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 53
III-25. All other manufacturing fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 54
III-26. Fresh-water withdrawal and consumptive use by type of user–"1975" ---- 57
III-27. Production and net exports of selected food and fiber commodities ---- 60
III-28. Surface area and land use–"1975" ---- 61
III-29. Agricultural lands, cropland, and irrigated farmland–"1975", 1985, 2000 ---- 62
III-30. Factors contributing to changes in farmland acreages–"1975" and 2000 ---- 63
III-31. Water availability and use for agriculture in nine western water resources regions, "1975" and 2000 ---- 64
III-32. Irrigated acreage and water-short subregions–"1975" and 2000 ---- 65
III-33. Irrigation fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 66
III-34. Livestock fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 67
III-35. Irrigation and livestock fresh-water, withdrawals and consumption–"1975", 1985, 2000 ---- 68
III-36. Estimated patterns of cropland harvested–"1975", 1985, 2000 ---- 68
III-37. Pesticide and fertilizer applications for major crop production in "1975" ---- 70
III-38. Projected annual soil loss for production of major crops by 2000 ---- 72
III-39. Comparison of National and State-Regional Futures for increases in irrigated farmland, "1975"-2000 ---- 74
III-40. Projected consumption of energy in the United States ---- 80
III-41. Energy consumption by fuel source, 1950-2000 ---- 83
III-42. Total energy consumption and electric power generation by fuel source–"1975", 1985, 2000 ---- 84

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III-43. Electric power generation by fuel source–"1975", 1985, 2000 ---- 86
III-44. Typical unit water requirements for energy production ---- 87
III-45. Withdrawal and consumption factors for steam electric plant process ---- 88
III-46. Fresh-water withdrawals for energy production--"1975", 1985, 2000 ---- 89
III-47. Fresh-water consumption for energy production--"1975", 1985, 2000 ---- 90
III-48. Fresh-water withdrawals for total energy consumption and electric power generation by fuel source ---- 90
III-49. Fresh-water withdrawals and consumption for steam electric generation–"1975", 1985, 2000 ---- 91
III-50. Saline water withdrawals for steam electric power generation–"1975", 1985, 2000 ---- 91
III-51. Minerals industry fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 96
III-52. Metals mining fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 96
III-53. Nonmetal mining industry fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 98
III-54. Fuels production fresh-water withdrawals and consumption–"1975", 1985, 2000 ---- 99
III-55. Outdoor recreation activity occasions--"1975", 1985, 2000 - 104
III-56. Total surface-water supply and surface-water area usable for outdoor recreation--"1975" ---- 105
III-57. Needs for surface-water area for water-dependent recreation activities–"1975", 1985, 2000 ---- 107
III-58. Attributes of areas of environmental concern, "1975" ---- 109
III-59. Critical environmental concerns--"1975" ---- 110
III-60. Intercity freight traffic by modes and waterborne freight traffic by type of waterway, 1949-1974 ---- 119
III-61. Total, foreign, and domestic waterborne commerce by major commodity groups, conterminous United States, 1974 ---- 120
III-62. Domestic waterborne traffic by commodity group for the Mississippi River and tributaries and Gulf intracoastal water systems–"1975", 1985, 2000 ---- 121
III-63. Waterborne commerce on the Mississippi River and Gulf intracoastal waterway by commodities and origins–"1975", 1985, 2000 ---- 122
III-64. Selected recreational boating statistics, 1974 ---- 124
III-65. Federal fish hatchery fresh-water withdrawals–"1975", 1985, 2000 ---- 139
III-66. Public lands withdrawals and consumption–"1975", 1985 2000 ---- 146
III-67. Annual losses of life and property from floods in the United States, 1926-1975 ---- 153
III-68. Uses of flood plain regulations ---- 155
III-69. Projected national average annual flood damages for selected management scenarios, 1985 and 2000 ---- 158
III-70. Annual total, urban, agricultural, and other flood damages--"1975", 1985, 2000 ---- 158
III-71. Surface area and land use, "1975" ---- 164
III-72. Selected quantitative effects of man's activities on surface erosion ---- 164
III-73. Susceptibility of harvested cropland to erosion, 1975 ---- 165
III-74. Sheet and rill erosion from harvested cropland, forest and range lands–"1975", 1985, 2000 ---- 167
III-75. Forests and range lands subject to erosion from grazing and exploitative grazing ---- 167
III-76. Projected costs of reclaiming an acre of land in Montana --- 170
III-77. Severity and extent of shore erosion ---- 171

ILLUSTRATIONS

III-1. Sources of earnings for conterminous U.S. ---- 15
III-2. Profile of central supply systems ---- 25
III-3. First and second assessment projections for manufacturing water use ---- 34
III-4. Water sources for manufacturing ---- 37
III-5. Water uses for manufacturing ---- 39
III-6. Manufacturing salt-water withdrawals as percentage of total ---- 40
III-7. Trends in manufacturing water uses ---- 43
III-8. Population and food consumption ---- 59
III-9. Total nitrogen levels in streams ---- 69
III-10. Energy consumption by fuel source, 1950-2000 ---- 81
III-11. Current and projected energy consumption by fuel source–"1975", 1985, 2000 ---- 82
III-12. Energy consumption, 1920-2000 ---- 85
III-13. Additional water surface needed for outdoor recreation by 2000 ---- 108
III-14. Commercially navigable waterways ---- 118
III-15. Number of endangered species, June 1977 ---- 128
III-16. Conflicts in instream vs. offstream use ---- 129
III-17. Methods used in arriving at instream flow approximations (IFA) ---- 131
III-18. Current and proposed increases in wilderness areas from first (1968) to second (1977) assessments ---- 148
III-19. Projected average annual flood damages for selected scenarios ---- 157
III-20. Sheet and rill erosion from water, 1975 ---- 166

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Functional Use and Flow Management

Historically, the Nation's growth, both in location and rate, has been related to an inexpensive and abundant supply of water. The country as a whole still has abundant supplies of water; however, projected population increases and expanded economic development will generate water needs that will outstrip available supplies, if water policy and management practices do not respond to these increased pressures.

To provide an information basis for initiating the water resources actions needed to meet water and related land needs, Part III focuses on future needs for 11 functional use and related management categories. The national perspectives on the 1985 and 2000 requirements are based on "1975" use in three management categories: offstream, instream, and flow management needs. Preceding the sections on these management categories, a section on future socioeconomic characteristics outlines the demographic and economic parameters on which the the "1975" use and the 1985 and 2000 water need projections are based. The following are the 11 functional uses in their respective management categories:

Offstream Uses

Domestic and commercial needs
Manufacturing and related needs
Food and fiber production
Energy production
Minerals production

Instream Uses

Recreation activities
Navigation requirements
Fish and wildlife habitats
Natural areas maintenance

Flow Management

Flood damage management
Erosion and sedimentation management

The functional requirements were developed from a future scenario of the Nation's economic and social needs for basic products, services, and environmental conditions. Once these needs were determined, the estimates for water withdrawals, consumption, reservations, and management needs were projected. Needs analyses include effects of changing technologies, policies, and perceptions that have geographic and/or time-dependent influence on water use and management.

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Offstream Functional Uses

Offstream water use involves two variable components: withdrawal from a watercourse or aquifer and consumption of all or part of the amount withdrawn. Although withdrawals may include saline water, the major concern of the second assessment is with fresh-water withdrawals and consumption. Projections of uses and available water supplies (streamflow, ground water, water imports, and water exports) are analyzed in Part IV to identify the locations of critical water balances. Water use and supply comparisons are also discussed in Part IV.

Withdrawals

For "1975," the total estimated fresh-water withdrawals for all offstream uses for an average-year condition were 338.5 billion gallons per day (bgd). Fresh-water withdrawals are projected to decrease by 10 percent to 306.4 bgd by year 2000 (Table III-1). This projection reflects certain assumptions about water use efficiencies and recycling expected to develop from available technology and conservation efforts. Manufacturing will contribute most to reductions in withdrawals for offstream use. By 2000, the fresh-water withdrawals for manufacturing are projected to decline from 51.2 bgd to 19.7 bgd or from 15 to only 6 percent of the offstream total. Smaller reductions in withdrawals will be made in other sectors; however, the proportion of withdrawals represented by irrigation and steam electric generation will remain essentially unchanged at about one-half for irrigation and one-fourth for steam electric generation (Table III-1). All other offstream users will increase both withdrawals and their share of total withdrawals. The largest fresh-water withdrawals are made by agriculture and steam electric generation--almost three-fourths of the total offstream uses.

Consumption

The Nation's consumption of water generally is more critical than withdrawals. The total offstream consumptive use was 106.6 bgd in "1975," but is projected to increase by 27 percent to 135.1 bgd by the year 2000 (Table III-1). Consumption is not proportionate to withdrawals among the functional use categories. Agriculture (irrigation and livestock watering) is the highest consumptive user, accounting for 83 percent of the total water consumed in "1975." Steam electric generation has the lowest, with only 1 percent consumed. The overall consumption will increase from 31 to 44 percent of withdrawals by 2000, primarily because steam electric is projected to increase consumption from 1.4 to 10.5 bgd while actually decreasing withdrawals 11 percent (Table III-2).

The Nation's overall consumption-to-withdrawal ratio is projected to rise from 32 percent in "1975" to 44 percent in the year 2000 because substantial increases in recycling rates and use efficiencies should reduce withdrawals and return flows. In steam electric generation, the ratio will increase from 2 percent to 13 percent as plants change from once-through cooling to recycling and/or other methods of cooling. The largest increase

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Table III-1.—Total withdrawals and consumption, by functional use "1975," 1985, 2000
(million gallons per day)

Functional use	Total withdrawals			Total consumption		
	"1975"	1985	2000	"1975"	1985	2000
Fresh water:						
Domestic:						
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699
Agriculture:						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609
Public lands and others[a]	1,866	2,162	2,461	1,236	1,461	1,731
Total fresh water	338,500	330,375	306,397	106,590	120,545	135,080
Total saline water[b]	59,737	91,236	118,815			
Total withdrawals	398,237	421,611	425,212			

[a]Includes water for fish hatcheries and miscellaneous uses.

[b]Saline water is used mainly in manufacturing and steam electric generation.

in the consumption-to-withdrawal ratio will occur in manufacturing, where increases from 12 to 75 percent will reflect advances in reuse and recycling technology. The consumption-to-withdrawal ratio for irrigation will increase from 55 percent to 61 percent by 2000. This 6 percent increase, however, will result from increased requirements, not from increased efficiency.

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Table III-2.—Fresh-water withdrawal and consumptive use relations by type of use—"1975" and 2000
(billion gallons per day)

Type of use	Withdrawals		Consumption		Percentage of withdrawals consumed
	Bgd	Percentage	Bgd	Percentage	
			"1975"		
Agriculture:					
Irrigation and Livestock	160.7	47	88.3	83	55
Steam electric generation	88.9	26	1.4	1	2
Manufacturing	51.2	15	6.1	6	12
Domestic	23.3	7	6.3	6	27
Commercial	5.5	2	1.1	1	20
Minerals industry	7.1	2	2.2	2	31
Other	1.9	1	1.2	1	63
Total, Regions 1-21	338.5	100	106.6	100	32
			2000		
Agriculture:					
Irrigation and Livestock	156.4	51	95.1	70	61
Steam electric generation	79.5	26	10.5	8	13
Manufacturing	19.7	6	14.7	11	75
Domestic	30.3	10	8.1	6	27
Commercial	6.7	2	1.4	1	21
Minerals industry	11.3	4	3.6	3	32
Other	2.5	1	1.7	1	68
Total, Regions 1-21	306.4	100	135.1	100	44

Regional Uses

Withdrawal and consumption of water varies greatly among the 21 regions, depending on variations in population, income, and dominant type of employment. In "1975," the largest withdrawals were made in the Great Lakes, Ohio, Missouri, Pacific Northwest, and California Regions, with substantial amounts in the South Atlantic-Gulf, Texas-Gulf, and Lower Mississippi Regions (Table III-3).

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Table III-3.—Total fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	5,098	3,939	3,230	481	647	1,063
Mid-Atlantic (2)	18,300	15,857	13,873	1,843	2,472	3,548
South Atlantic-Gulf (3)	24,510	25,457	28,340	4,867	6,772	10,053
Great Lakes (4)	42,813	32,666	25,623	2,598	3,300	4,693
Ohio (5)	34,934	27,838	16,925	1,798	2,527	4,332
Tennessee (6)	7,412	7,131	6,013	313	647	1,105
Upper Mississippi (7)	12,401	10,386	7,910	1,145	1,604	2,688
Lower Mississippi (8)	14,567	17,453	24,841	4,027	4,554	5,511
Souris-Red-Rainy (9)	336	329	587	112	204	446
Missouri (10)	38,016	48,037	44,359	15,469	19,206	19,913
Arkansas-White-Red(11)	12,868	13,799	13,337	8,064	8,769	8,887
Texas-Gulf (12)	16,925	15,932	14,991	11,259	10,227	10,529
Rio Grande (13)	6,321	6,204	5,633	4,240	4,320	4,016
Upper Colorado (14)	6,869	7,841	7,519	2,440	3,018	3,232
Lower Colorado (15)	8,917	8,528	7,857	4,595	4,754	4,708
Great Basin (16)	7,991	7,316	7,258	3,779	3,765	4,036
Pacific Northwest (17)	37,495	38,098	33,852	11,913	14,610	15,196
California (18)	39,636	40,549	41,265	26,641	27,932	29,699
Total, Regions 1-18	335,409	327,360	303,413	105,584	119,328	133,655
Alaska (19)	305	433	745	58	207	459
Hawaii (20)	1,879	1,619	1,349	605	636	666
Caribbean (21)	907	963	890	343	374	300
Total, Regions 1-21	338,500	330,375	306,397	106,590	120,545	135,080

In "1975," the largest consumption occurred in the Missouri, Texas-Gulf, Pacific Northwest, and California Regions, due largely to agriculture. By 2000, these four regions should still have the largest consumption, but the South Atlantic-Gulf Region is projected to more than double its consumption, moving to the fifth highest consumption region.

Per capita withdrawals and consumption for each of the 21 regions are listed in Table III-4. Included in the table are the per capita withdrawals to compare the degree of variation in total offstream uses. In "1975" the Nation had a per capita withdrawal rate of 1,564 gpd (gallons per day) and

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Table III-4. – Per capita fresh-water withdrawals and consumption for all offstream uses compared with domestic and commercial uses – "1975", 1985, 2000
(gallons per day)

Region	All offstream uses						Domestic and commercial per capita withdrawals		
	Per capita withdrawals			Per capita consumption					
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
New England (1)	408	289	211	39	48	52	119	119	117
Mid-Atlantic (2)	462	361	278	47	56	71	116	118	120
South Atlantic-Gulf (3)	964	868	817	191	231	290	112	117	123
Great Lakes (4)	1,409	994	705	85	100	129	141	143	145
Ohio (5)	1,651	1,225	683	85	111	175	110	114	118
Tennessee (6)	2,079	1,768	1,303	88	160	239	99	104	108
Upper Mississippi (7)	926	721	500	86	111	170	147	150	152
Lower Mississippi (8)	2,270	2,579	3,478	628	673	772	125	130	134
Souris-Red-Rainy (9)	518	526	987	173	326	750	105	114	118
Missouri (10)	4,304	5,166	4,416	1,751	2,066	1,983	141	145	149
Arkansas-White-Red (10)	1,880	1,899	1,707	1,178	1,207	1,137	138	141	145
Texas-Gulf (12)	1,708	1,427	1,161	1,136	916	816	150	152	149
Rio Grande (13)	3,729	3,485	3,004	2,501	2,427	2,142	193	198	203
Upper Colorado (14)	19,968	21,964	20,432	7,093	8,454	8,783	233	241	255
Lower Colorado (15)	3,697	2,926	2,165	1,905	1,631	1,297	206	210	213
Great Basin (16)	6,332	4,997	4,174	2,994	2,572	2,321	300	303	305
Pacific Northwest (17)	5,594	5,450	4,461	1,777	2,090	2,002	161	164	167
California (18)	1,873	1,711	1,523	1,259	1,178	1,096	160	161	161
Total, Regions 1-18	1,580	1,404	1,157	497	512	510	133	136	138
Alaska (19)	993	1,199	1,701	189	573	1,048	296	316	336
Hawaii (20)	2,388	1,777	1,243	769	698	614	225	228	235
Caribbean (21)	297	266	210	112	103	71	116	118	121
Total, Regions 1-21	1,564	1,338	1,143	493	506	504	133	136	138

a consumption rate of 493 gpd. By year 2000, the per capita withdrawal rate should decline by 37 percent to 1,143 gpd, but the per capita consumption rate will remain almost unchanged at 504 gpd. The highest per capita withdrawals are made in the Upper Colorado Region at a rate of about 20,000 gallons per capita per day--a rate nearly 50 times greater than that in the New England and Mid-Atlantic Regions. It is significant that in the Upper Colorado and other western regions, the overall withdrawals are not projected to decline by 2000, even though in some regions the rates will be reduced substantially. In fact, by 2000 the Upper Colorado per capita daily withdrawal rate will be nearly 100 times greater than the rates in the Northeast.

Consumption in the Upper Colorado Region should also increase. Per capita consumption rates are projected to be 125 to 140 times more than those in the Northeast. Most western regions will consume water at per capita rates of about 1,000 gpd. This is more than twice the national average of 493 gpd. These high consumption rates result largely from the concentration of irrigated agriculture, minerals production, and steam electric generation in the sparsely populated West.

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Fresh-water withdrawals for all offstream uses in "1975" were about 12 times the domestic and commercial withdrawals and about eight times the domestic and commercial withdrawals projected for 2000. All domestic and commercial uses now average about 133 gallons per capita per day with little change estimated by 2000. In summary, most of the Nation's withdrawal and consumption of water supports the production of food and fiber, energy, and manufactured goods and services. The greatest opportunities for effecting more efficient allocations and uses are in these offstream functional areas.

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Socioeconomic Characteristics and Projections

The earnings, incomes, and lifestyles of the people significantly affect priorities on use of the Nation's water resources. For example, a major change in population growth, a shift in its geographical location, or a change in the composition (age, family size, occupation, etc.) will affect the level, distribution, and mix of water requirements both nationally and regionally. Increasing real incomes and leisure time tend to place higher priorities on instream water uses--recreation, fish and wildlife, natural areas--rather than on the traditional offstream uses. Many traditional economic and water-use relationships change substantially as prices, incomes, asset values, and productivities adjust to changing energy and trade relationships.

This section outlines the basic socioeconomic influences on current and future water use and gives projections for these influences for 1985 and 2000. These influences are: (1) population growth and geographic shifts of population densities, (2) employment, income, and earnings as influences on life style, and (3) the Nation's economic health as manifested in the gross national product. Projected changes are given for the regions that will be most affected. The implications of using both National and State-Regional Futures for water planning, development, and use are also discussed.

Bases for Projections

The second assessment is based on two sets of projections for economic activity and population growth, the National Future (NF) and the State-Regional Future (SRF). The economic and demographic projections for the National Future are based primarily on the 1972 OBERS Projections, Series E Population, published by the Water Resources Council. The OBERS projections are a nationally consistent set of data on population and economic growth for the Nation and its geographic regions. The projections are prepared by the Bureau of Economic Analysis, U.S. Department of Commerce, and the Economics, Statistics, and Cooperative Service, U.S. Department of Agriculture. As a starting point, the national population projection used the Census Bureau's "Series E" projection, which is based on a birth rate assumption modified for labor force movement that in time would yield a zero population growth, exclusive of immigration. This has been the approximate birth rate from 1970 to 1975. The State-Regional Futures are projections either prepared by an assessment team in each of the 21 water resources regions or selected from available projections prepared by or for State agencies.

Population

In the 25 years from 1950 to "1975," the population of the United States increased by 62 million, from about 154.5 million to 216.4 million (Table III-5). This is a 40 percent increase, or an annual growth rate of 1.36 percent. However, during the 25-year period from "1975" to 2000, the national population is expected to increase by 52 million, or 24 percent, at an average annual growth rate of only .9 percent.

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Table III-5.—Selected economic indicators—1950, "1975," 1985, 2000

Economic indicator	Regional aggregate	Actual		National Future		
		1950	1975	"1975"	1985	2000
Population, millions	1-18	151.7	213.0	212.3	233.2	262.3
	1-20	152.3	---	213.4	234.4	263.8
	1-21	154.5	---	216.4	238.1	268.1
Employment, millions	1-18	58.9	84.8	87.6	100.5	117.2
	1-20	---	---	88.1	101.1	117.9
	1-21	---	---	88.9	102.1	119.1
Gross national product,	1-18	$533.5	---	$1,223.5[a]	$1,940.4	$3,134.1
1972 dollars, billions	1-20	---	$1,191.7	$1,516.3	---	---
Total personal income:						
1972 dollars, billions	1-20	$377.1	---	$1,048.8	$1,538.1	$2,602.4
	1-18	$226.1[b]	---	$1,323.0	$1,939.4	$3,281.7
1975 dollars, billions	1-20	---	$1,249.7	$1,330.9	$1,951.3	$3,302.3
	1-21	---	---	$1,340.8	---	---
Per capita income, 1975	1-18	$3,164.0	---	$6,233.0	$8,318.0	$12,511.0
dollars per person	1-20	---	$5,832.0	---	---	---
	1-21	---	---	$6,195.0	---	---
Total earnings:						
1972 dollars, billions	1-20	$311.1	---	$827.6	$1,199.2	$2,002.1
1975 dollars, billions	1-18	---	---	$1,043.4	$1,511.4	$2,523.5
	1-20	---	---	---	---	---
	1-21	---	---	---	---	---

[a]The "1975" estimated average gross national product. The actual 1975 gross national product was $1,191.7 billion.
[b]In 1950 dollars.

From 1950 to "1975," population increased the most in the California Region, with an increase of 10 million (97 percent). This was closely followed by the Mid-Atlantic and South Atlantic-Gulf Regions, with increases of over 9 million each, 31 and 60 percent, respectively. This reflects population migration to sunbelt areas of the Nation. Although the populations are generally lower in the western regions, some of these also had significant percentage increases. The Upper Colorado Region led with an increase of 203 percent or 1.8 million while the Great Basin increased by 84 percent or 630,000. The Texas-Gulf Region increased by 65 percent or 4.1 million persons.

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In the more recent five-year period from 1970 to "1975," the largest increases in population occurred in the South Atlantic-Gulf Region, with an increase of 2.5 million (11.2 percent), and in the Lower and Upper Colorado Regions, an increase of 500,000 and 82,000, respectively, (24 percent each). The Mid-Atlantic and Great Lakes Regions had the lowest relative increases of about 300,000 or only a 1 percent change.

Population Distribution

The geographic distribution of population has important implications for the Nation's water resources (Table III-6). Projections for the year 2000 indicate that the southern (including the Great Basin Region) and outlying (Alaska, Hawaii, and the Caribbean) regions will have large increases in population. Moderate population growth is also projected for the Tennessee, Mid-Atlantic, New England, Great Lakes, and California Regions.

The density of population is a general index that reflects pressures on the Nation's water resources. Between 1950 and "1975," the average population density increased from 43 to 61 persons per square mile. Given the projected increase in population to 268 million by 2000, the density will increase to about 76 persons per square mile. However, population densities among regions vary from a high of 859 per square mile in the Caribbean to 3 and 1 per square mile in the Upper Colorado and Alaska Regions, respectively (Table III-6).

Generally, regions with large metropolitan areas have population densities in excess of 100 persons per square mile (New England, Mid-Atlantic, Caribbean, Great Lakes, Ohio, California, and Hawaii). The agricultural areas have low population densities of fewer than 75 persons per square mile (Lower Mississippi and all regions west of the Mississippi River except California). The urban nature of the population is evident when one considers that more than one-half of the population of all but four regions (Lower Mississippi, Souris-Red-Rainy, Upper Colorado, and Alaska) are included within designated Standard Metropolitan Statistical Areas (Table III-6).

Employment

Employment is expected to grow from 89 million (41 percent of the population) in "1975" to about 119 million (44 percent of the population) by 2000 (Table III-5). This growth of about 1.2 percent annually is somewhat higher than the projected population growth rate. This projection is based in part on the assumption that there will be more women in the work force, more liberal extension of retirement ages and post-retirement employment, earlier entry of youth into the work force, and other such factors that raise employment.

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Table III-6.—Regional population, personal income, and earnings—"1975," 2000

Region	Population (millions) "1975"	Population (millions) 2000	Percent change	Density[a] "1975"	Personal Income (billions 1975$) "1975"	Personal Income (billions 1975$) 2000	Total Earnings (billions 1975$) "1975"	Total Earnings (billions 1975$) 2000	Percent change
New England (1)	12.49	15.31	23	192	83.3	204.3	63.56	153.45	141
Mid-Atlantic (2)	39.61	49.94	26	395	282.5	692.4	222.64	540.14	148
South Atlantic-Gulf (3)	25.42	34.68	36	98	134.0	380.2	104.88	281.45	168
Great Lakes (4)	30.39	36.35	20	233	205.8	490.6	167.82	386.99	131
Ohio (5)	21.16	24.79	17	133	119.4	290.4	94.99	225.19	187
Tennessee (6)	3.56	4.61	29	86	16.2	45.7	12.87	35.36	175
Upper Mississippi (7)	13.39	15.82	18	76	83.2	198.2	65.30	151.97	133
Lower Mississippi (8)	6.42	7.14	11	64	30.7	72.8	23.88	55.44	132
Souris-Red-Rainy (9)	0.65	0.60	-8	12	3.2	6.2	2.44	4.56	87
Missouri (10)	8.83	10.04	14	17	52.6	121.0	40.96	92.44	126
Arkansas-White-Red (11)	6.85	7.81	14	28	35.8	85.2	26.96	63.16	134
Texas-Gulf (12)	9.91	12.91	30	57	57.5	152.2	45.82	118.19	158
Rio Grande (13)	1.70	1.88	11	12	8.1	18.6	6.35	14.38	125
Upper Colorado (14)	0.34	0.37	7	3	1.7	3.8	1.33	2.87	116
Lower Colorado (15)	2.41	3.63	50	16	14.0	40.5	11.27	31.61	181
Great Basin (16)	1.36	1.74	38	9	7.1	19.9	5.99	16.12	169
Pacific Northwest (17)	6.70	7.66	13	25	39.8	93.1	30.92	70.84	129
California (18)	21.16	27.09	28	130	147.8	366.4	115.39	279.44	142
Total, Regions 1-18	212.26	262.31	24	72	1,323.7	3,281.5	1,043.4	2,523.5	142
Alaska (19)	0.31	0.44		1	2.3	6.3	2.15	5.54	153
Hawaii (20)	0.79	1.08	38	123	5.7	14.7	N/A	N/A	N/A
Caribbean (21)	3.05	4.23		859	9.8[b]	42.8[b]	7.7	N/A	N/A
Total, Regions 1-21	216.40	268.06	24	61	1,340.5	3,345.3	N/A	N/A	N/A

[a]Persons per square mile land area.
[b]Estimated income.

Employment is projected to increase most rapidly in the southern regions (South Atlantic-Gulf, Tennessee, Texas-Gulf, Lower Colorado, and Great Basin) and outlying regions (Alaska, Hawaii, and Caribbean), where employment increases of more than 40 percent are projected by 2000. The national average over this period will increase about 34 percent.

Personal Income and Earnings

For the second assessment, earnings and personal income are used as separate indicators of economic activity. Earnings is that part of total personal income derived from wage and salary disbursements, proprietor's income, and other labor income. This represents about three-fourths of total personal income. Personal income includes those earnings plus other transfer payments (social security and unemployment benefits) and property income (rents, interest, and dividends).

Personal Income

The total personal income for all the 21 water resources regions was $1,341 billion (1975 $) in "1975." Projections for the assessment indicate

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that personal income grew much faster than population, employment, or the gross national product during the 1950 to "1975" period, at an annual rate of 4.2 percent. Growth in personal income for "1975" to 2000 is projected to decline to about 3.7 percent annually. This figure is near the 3.8 percent growth rate expected for GNP and is about the same rate expected for total earnings (Table III-5).

Growth rates in personal income are likely to be faster in the Southeast, Northeast, and West (Table III-6). Growth rates in personal income are projected to exceed substantially the national average (i.e., 4 percent or more annually) in the South Atlantic-Gulf, Tennessee, Lower Colorado, Great Basin, Alaska, and Caribbean Regions. Relatively slower growth in personal income is expected in the Souris-Red-Rainy, Missouri, Rio Grande, and Upper Colorado Regions (less than 3.4 percent annually). Above-average growth in personal income is not necessarily correlated with population growth. For example, New England is projected to have slightly above-average growth in personal income but lower than average growth in population.

Per capita incomes generally are lower in the Southeast and Southwest (Table III-7). Projections of per capita income indicate above-average growth for the South Atlantic-Gulf, Ohio, Tennessee, Lower Mississippi, Souris-Red-Rainy, Arkansas-White-Red, Rio Grande, Upper Colorado, and Pacific Northwest Regions. The latter six regions will be slow growing in population as relative incomes increase, but absolute per capita incomes will still remain below the national average. Water uses will be more difficult to evaluate in regions with mixed economic futures.

Earnings

In this assessment, earnings are the most useful and widely available economic indicators of water uses and emerging water resource management problems. Total earnings and earnings by major industries such as manufacturing, agriculture, and mining are available by regions as an indicator of levels and mixes of economic activities. Total earnings by region are generally consistent with population densities. Exceptions to the population-earnings growth correlations will be in the Alaska and Hawaii Regions where, compared to other regions and the national averages, population growth rates will be higher than earnings growth rates. These disparities generally result from differences in the economic activity mixes in each region. Per capita total earnings are usually consistent with per capita incomes and serve as a useful surrogate in assessing water resource supply, use, and management conditions (Table III-7).

Economic Activity Mix

The mix of economic activity in the United States has been shifting from the resource- and product-oriented industries toward services in both public and private sectors. Agriculture, mining, and manufacturing made up about 40 percent of total earnings in 1950. By 2000 these three are projected to make up only about 25 percent of total earnings. On the

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other hand, services and government, which made up about 27 percent of total earnings in 1950, increased to 40 percent of earnings in "1975." The services (e.g., medical and personal services, food, and lodging) and government sectors are projected to make up 47 percent of total earnings in the year 2000 (Figure III-1).

Gross National Product

Gross national product (GNP), the measure of the Nation's production of goods and services, over the long run grows more rapidly than population because of increases in productivity. GNP has fluctuated considerably in the past, with the most recent decline in growth recorded in the mid-1970's (Table III-5). The actual 1975 GNP was only $1,192 billion, while the assumed base year "1975" GNP was about $1,516 billion, both based on 1972 dollars. Projected growth in production is based on the assumption that an economy with essentially full employment and continued increases in productivity will be maintained over the long run, despite intermittent international and domestic problems.

Table III-7.—Per capita income and earnings—"1975," 1985, 2000
(1975 dollars)

Region	Per capita income			Percent change	Per capita earnings			Percent change,
	"1975"	1985	2000	"1975"-2000	"1975"	1985	2000	"1975"-2000
New England (1)	$6,669	$8,925	$13,339	100	$5,088	$6,758	$10,021	97
Mid-Atlantic (2)	7,133	9,399	13,864	94	5,620	7,364	10,816	92
South Atlantic-Gulf (3)	5,269	7,128	10,962	108	4,126	5,446	8,116	97
Great Lakes (4)	6,773	9,049	13,495	99	5,522	7,263	10,646	93
Ohio (5)	5,645	7,633	11,712	108	4,490	6,001	9,084	102
Tennessee (6)	4,548	6,299	9,912	118	3,611	4,937	7,663	112
Upper Mississippi (7)	6,218	8,317	12,529	102	4,878	6,452	9,605	97
Lower Mississippi (8)	4,783	6,500	10,187	113	3,722	5,008	7,763	109
Souris-Red-Rainy (9)	5,001	6,632	10,346	107	3,763	4,950	7,667	104
Missouri (10)	5,954	7,933	12,051	102	4,638	6,122	9,204	98
Arkansas-White-Red (11)	5,237	7,052	10,904	108	3,939	5,265	8,082	105
Texas-Gulf (12)	5,802	7,778	11,792	103	4,624	6,125	9,157	98
Rio Grande (13)	4,761	6,377	9,920	108	3,745	4,958	7,614	103
Upper Colorado (14)	5,044	6,701	10,377	106	3,872	5,092	7,810	102
Lower Colorado (15)	5,819	7,604	11,162	92	4,671	6,022	8,712	87
Great Basin (16)	5,628	7,544	11,465	104	4,747	6,241	9,271	95
Pacific Northwest (17)	5,934	8,110	12,272	107	4,613	6,238	9,335	102
California (18)	6,986	9,144	13,524	94	5,453	7,057	10,314	89
Total, Regions 1-18	$6,223	$8,318	$12,511	101	$4,916	$6,482	$9,621	96
Alaska (19)	7,555	9,719	14,307	89	7,010	8,765	12,450	78
Hawaii (20)	7,208	9,259	13,529	88	N/A	N/A	N/A	N/A
Caribbean (21)	3,225	N/A	N/A	N/A	2,514	N/A	N/A	N/A
Total, Regions 1-21	$ 6,195	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A Not available.

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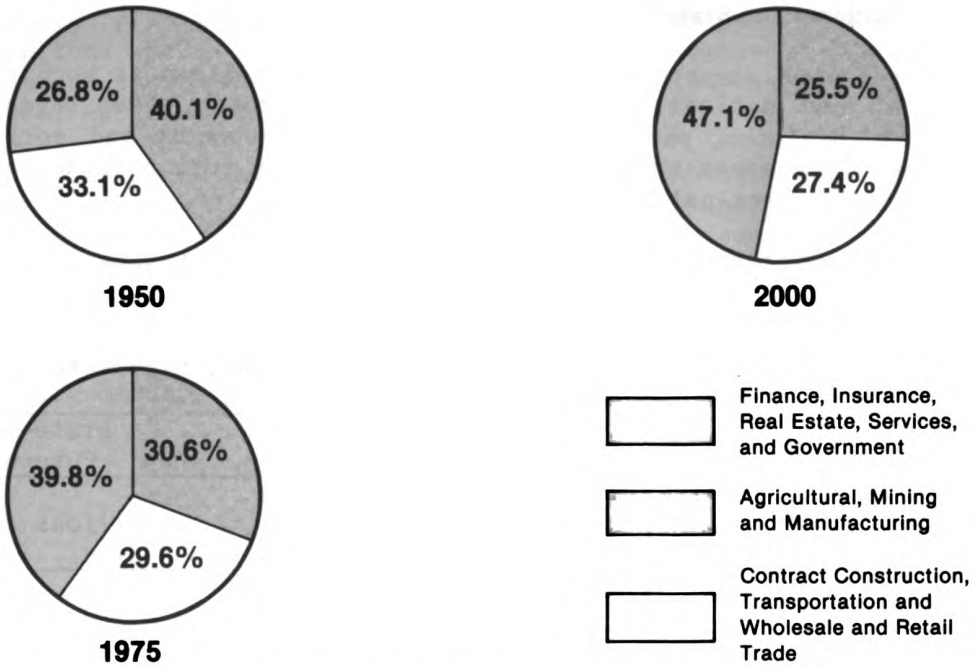

SOURCE: 1972 OBERS Report prepared by the Department of Commerce and the U.S. Department of Agriculture

Figure III-1.—Sources of earnings for conterminous U.S.

The long-run growth in GNP was a 3.4 percent annual rate from 1970 to "1975". This indicator of national economic output is not available on a consistent basis for regional and sector comparisons of economic activity, but surrogate values, such as personal income and earnings, are useful in relating economic activity to emerging water resources supply, demand, and management conditions.

Summary

The social and economic conditions of the Nation affect both the quantity and quality of the Nation's waters. Increasing real incomes, urbanization, regional migration, and shifts in types of employment and sources of earnings all affect the Nation's water supplies and needs. Generally, all these factors tend to concentrate water uses and waste disposal near the urban population centers and to require larger and more accessible reservations of water for instream uses such as recreation and fish and wildlife. Anticipated efficiencies in agriculture and recycling in manufacturing and steam electric power generation will provide opportunities for meeting the changing water use requirements in most of the Nation. However, regions of the Southwest with already critical water conditions may find increasing cost limitations, perhaps even physical limitations, on economic growth expectations as a result of water scarcities. Other regions with less optimistic economic projections may find excess capacities developing in water supply and treatment facilities.

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Comparison of National and State-Regional Futures

The second assessment addresses conditions and problems at both the State-regional and national levels. This dual approach often reveals differences in outlooks, particularly in the basic economic and social data. These differences are valuable for formulating both national and State-regional resource policies and plans.

Table III-8.—Comparison of projected population changes between "1975" and 2000

Region	Population changes, "1975" to 2000			
	National Future (NF)		State-Regional Future (SRF)	
	Millions	Percent	Millions	Percent
New England (1)	2.8	23	2.6	21
Mid-Atlantic (2)	10.3	26	7.8	20
South Atlantic-Gulf (3)	9.3	36	10.6	41
Great Lakes (4)	6.0	20	6.0	20
Ohio (5)	3.6	17	3.6	17
Tennessee (6)	1.1	29	1.1	29
Upper Mississippi (7)	2.4	18	2.5	19
Lower Mississippi (8)	0.7	11	1.7	25
Souris-Red-Rainy (9)	-0.1	-8	-0.1	-8
Missouri (10)	1.2	14	2.7	30
Arkansas-White-Red (11)	1.0	14	2.5	34
Texas-Gulf (12)	3.0	30	5.8	56
Rio Grande (13)	0.2	11	1.8	94
Upper Colorado (14)	0.0	7	0.2	55
Lower Colorado (15)	1.2	50	2.4	89
Great Basin (16)	0.5	38	1.1	78
Pacific Northwest (17)	0.9	13	3.0	44
California (18)	5.9	28	8.2	39
Total, Regions 1-18	50.0	24	63.5	30
Alaska (19)	0.1	43	0.6	143
Hawaii (20)	0.3	38	0.5	57
Caribbean (21)	1.2	39	1.2	39
Total, Regions 1-21	51.6	24	65.8	30

In most instances, the differences between the National and State-Regional Futures can be traced to basic differences in the economic and social indicator projections, especially population earnings, employment, and changing mixes of economic activities. Generally, most regions project

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greater population growth than the National Future (Table III-8); the exceptions are the New England and Mid-Atlantic Regions. States and regions west of the Mississippi River view their population growth prospects with great optimism.

It cannot be expected that any projection will be "right." Because of the inherent uncertainty of projections, any plan for development, management, or uses of water and related land resources should be tested for its sensitivity to changes in economic activity and population. Two courses may be taken to avoid errors in the commitment of resources: first, a more exhaustive analysis should be made to characterize the future more accurately; and second, planning should be kept as flexible as possible to accommodate possible changes in the future course of events.

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Domestic and Commercial Use of Water

Domestic and commercial use of water represents only a small percentage of total withdrawals and consumption; but that small percentage has a high priority that makes proper resource management in this area critical. Increasing demands, rising treatment costs, and deteriorating delivery systems already jeopardize the supply of water for domestic and commercial use in some areas, especially urban areas.

This section covers the supply systems and sources for domestic and commercial water. Although the focus is on domestic water use, commercial uses are included with the discussion of central supply systems. The section also addresses regional variations in use and costs, water resource management problems of conservation strategies, inducements of water pricing, jurisdictional conflicts, and legal rights to surface- and ground-water supplies.

Data Parameters

Commercial use of water includes municipal (e.g., parks, streets, fire protection, public buildings) and commercial (e.g., restaurants, hotels, shops, cleaners, florists) operations. Precise separation of commercial water data from such uses as domestic, manufacturing, or agriculture was not entirely possible. Many central systems either directly or indirectly supply water for small factories, farms, and other uses beyond what is defined as commercial use. However, as far as possible, data on water from central systems used for manufacturing, agriculture, and energy production are included with the discussions of those uses.

The vast majority of commercial water is supplied by a central system. However, some businesses were operating with their own water supply in place before expanding municipalities engulfed them. On a national scale, these and other businesses still outside of municipalities are extremely small. Since there is no accurate way to measure water from such unusual sources, data on commercial water use is given only for that from central supply systems.

Some data for domestic and commercial water uses include losses in the delivery systems. In older cities with ancient and overburdened water supply lines, these losses are often significant. For example, the average household use is about 87 gallons per capita per day (gcd) (Table III-9), yet the average amount sent from a central system is about 118 gcd. Losses in delivery sometimes account for a significant portion of this difference. The tables showing the amount of water that a householder deploys for specific uses are based on water after delivery with no losses included. The tables on withdrawals and consumption by region, however, are based on data from the supply source. Data presented in these tables include delivery losses.

The second assessment projections for domestic and water needs is 31 percent lower for withdrawals and 49 percent lower for consumption than the projections of the first assessment. The two assessments can be compared only for the common target year of 2000. Table III-10 shows both

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assessment projections. Although the data was not separated into identical subcategories for the two assessments, the difference in totals for the year 2000 reflects the changed OBERS Series E projected population growth rate. Population projection for the 25-year period "1975"-2000 is only an annual 0.86 percent increase as contrasted with the 1.4 percent annual increase for previous 25-year period, 1950-"1975."

Table III-9—Typical urban use by a family of four
(gallons per day)

Type of household use	Daily use	
	Per family	Per capita
Drinking and water used in kitchen	8	2.00
Dishwasher (3 loads per day)	15	3.75
Toilet (16 flushes per day)	96	24.00
Bathing (4 baths or showers per day)	80	20.00
Laundering (6 loads per week)	34	8.50
Automobile washing (2 car washes per month)	10	2.50
Lawn watering and swimming pools (180 hours per year)	100	25.00
Garbage disposal unit (1 percent of all other uses)	3	0.75
Total	346	86.50

Assumptions about more increases in efficiencies, reuse, and conservation measures are also factored into the projected decreases, especially for consumption. Increased urbanization, shifts in population densities, and affluent life styles have affected both the supply and the quality of ground- and surface-water resources. Water rights and jurisdictional control and complex institutional arrangements further complicate the supply picture.

Overall Domestic and Commercial Water Needs

Commercial and domestic water requirements are closely related in each region. These uses accounted for 8.5 percent of total fresh-water with-

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Table III-10.—Comparison of domestic and commercial water use projections
(million gallons per day)

Type of system	Second Assessment					
	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
Domestic:						
Central	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral	2,092	2,320	2,400	1,292	1,408	1,436
Total	23,256	26,303	30,318	6,268	7,073	8,074
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Total, domestic and commercial	28,786	32,351	37,050	7,377	8,289	9,443

	First Assessment (1968 estimates)					
	Withdrawals			Consumption		
	1965	1985	2000	1965	1985	2000
Central (includes (commercial)	23,745	33,596	50,724	5,244	10,581	16,478
Noncentral	2,351	2,474	2,852	1,636	1,792	9,427
Total, domestic and commercial	26,096	36,070	53,576	6,880	12,373	18,580

drawals and 6.9 percent of consumption in "1975." This portion represents about 29 billion gallons per day (bgd) for withdrawals and about 7 bgd for consumption. By 2000, withdrawals will rise to 12.1 percent (37 bgd), but consumption will remain about the same at about 7 percent (9 bgd) as shown on Table III-11. Of these totals, water for commercial uses accounts for 5.5 bgd withdrawals and 1.1 of the consumption. These commercial withdrawals and consumption are projected to increase by 22 and 23 percent, respectively, by 2000 (Table III-12). Domestic water use, mainly from central supply systems, accounts for a large portion of withdrawals and consumption. In "1975," about 23 bgd were withdrawn for domestic use and 6 bgd were consumed. By 2000, domestic water withdrawals will increase by 30 percent and consumption by 29 percent (Table III-10).

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Table III-11.—Domestic and commercial fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	1,483	1,616	1,798	212	231	254
Mid-Atlantic (2)	4,604	5,193	5,994	796	891	1,010
South Atlantic-Gulf (3)	2,841	3,433	4,254	998	1,217	1,506
Great Lakes (4)	4,277	4,705	5,283	589	642	703
Ohio (5)	2,337	2,597	2,914	411	456	498
Tennessee (6)	353	421	499	70	81	90
Upper Mississippi (7)	1,965	2,161	2,411	345	369	398
Lower Mississippi (8)	805	880	960	343	370	398
Souris-Red-Rainy (9)	68	71	70	31	31	31
Missouri (10)	1,246	1,351	1,497	331	352	380
Arkansas-White-Red (11)	945	1,028	1,132	348	377	409
Texas-Gulf (12)	1,490	1,697	1,921	507	570	659
Rio Grande (13)	327	352	380	168	181	195
Upper Colorado (14)	80	86	94	28	31	33
Lower Colorado (15)	498	612	772	234	288	364
Great Basin (16)	378	444	530	147	170	200
Pacific Northwest (17)	1,078	1,145	1,264	265	276	298
California (18)	3,388	3,809	4,360	1,434	1,610	1,839
Total, Regions 1-18	28,163	31,601	36,134	7,257	8,143	9,265
Alaska (19)	91	114	147	7	10	12
Hawaii (20)	177	208	255	55	64	78
Caribbean (21)	355	428	514	58	72	88
Total, Regions 1-21	28,786	32,351	37,050	7,377	8,289	9,443

Per capita use of water varies according to: size of community; housing density; climate; water price; income levels of residents; water quality; water pressure; price structure; whether water is metered; outdoor uses such as swimming pools, gardens, lawns, and car washing; and institutional regulations and conservation awareness.

Supply Systems

Approximately 179 million people (83 percent of the Nation's total population) were supplied water for domestic and commercial uses from central systems, that is, from systems that regularly supply water to at least 25 people or have a minimum of 15 service connections. Another 33 million had their own supply system and about 4 million had no piped water supply.

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Table III-12.—Commercial fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	361	393	442	48	52	58
Mid-Atlantic (2)	650	726	826	91	101	114
South Atlantic-Gulf (3)	553	632	769	118	138	161
Great Lakes (4)	1,010	1,091	1,206	113	123	140
Ohio (5)	495	529	571	62	67	74
Tennessee (6)	90	102	116	11	12	14
Upper Mississippi (7)	515	552	603	63	67	74
Lower Mississippi (8)	150	159	170	49	51	54
Souris-Red-Rainy (9)	15	15	14	6	6	6
Missouri (10)	285	306	336	69	72	78
Arkansas-White-Red (11)	210	221	238	69	72	78
Texas-Gulf (12)	283	317	300	94	103	118
Rio Grande (13)	62	65	68	30	31	32
Upper Colorado (14)	10	10	11	3	4	4
Lower Colorado (15)	75	92	114	35	43	54
Great Basin (16)	38	45	55	17	19	22
Pacific Northwest (17)	274	282	307	55	56	60
California (18)	374	414	470	155	174	198
Total, Regions 1-18	5,450	5,951	6,616	1,088	1,191	1,339
Alaska (19)	7	9	10	1	2	2
Hawaii (20)	29	36	46	11	12	15
Caribbean (21)	44	52	60	9	11	13
Total, Regions 1-21	5,530	6,048	6,732	1,109	1,216	1,369

Central Supply System

Most domestic and commercial water supplies come from central systems. For commercial uses, only an extremely small percentage is supplied by non-central systems. Even for domestic uses, noncentral systems account for only about 9 percent of the supplies.

The Nation's 45,760 central supply networks range in size from those serving only a cluster of houses to those serving over a million people. About 200,000 supply units that service the traveling public are included with the central supplies. Publicly-owned central systems (22,000 systems) serve 84 percent of the population, even though they account for only 48 percent of all central systems. Private or investor-owned systems are more numerous (52 percent), but they supply only about 16 percent of the population, generally smaller communities and residential developments

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(Figure III-2). The type of ownership is important for water policy and management decisions, which will be discussed later.

Noncentral Supply System

Noncentral systems, by definition, serve five or fewer households (up to 25 people). Most such systems obtain water from wells, but other sources include springs, creeks, ditches, rivers, lakes, ponds, cisterns, and other catchments from which individual households obtain water. Of the 23 bgd, withdrawn for domestic use in "1975," noncentral systems withdrew only 9 percent and accounted for only 3 percent of the 6 bgd consumed. Noncentral systems are projected to supply an even smaller portion of the population than they currently serve. The population served by such systems should drop from 37 million in "1975" to 26 million in 2000. That is a decrease from 17 percent to 10 percent of the population.

Thus, both the number of people and the percentage of total population with individual water sources are expected to drop in the future. Water usage, however, will tend to rise as more noncentral systems are pressurized. These systems will continue to serve households beyond the central system distribution lines or in small rural areas, on farms, or in new suburban housing, at least until central supply lines are extended.

Water Sources

Although more systems draw from ground-water sources, more surface water is distributed for domestic and commercial purposes. Ground water supplies 75 percent of all systems, but these systems supply only 39 percent of the population. On the other hand, only 13 percent of the systems use surface-water sources, but they supply 49 percent of the population. The 12 percent difference is accounted for by water purchased for retail distribution, which can be supplied by either ground or surface water (Figure III-2). Problems related to both ground- and surface-water withdrawals are discussed later in this section.

Total surface- and ground-water supplies are more than adequate for the Nation's needs--in fact, more than three times the total amount withdrawn for all purposes in "1975" and more than 14 times the amount consumed. Another estimated quadrillion gallons is located just a few feet beneath the surface of the conterminous United States. Only a small fraction of the possible ground-water supplies has been tapped. This overall surplus amount of both surface and ground water, however, is not equally available for all regions.

Surface-water Sources

Only in the Lower Colorado Basin did the amount of surface fresh water consumed exceed the average annual runoff in "1975." Water supply in this

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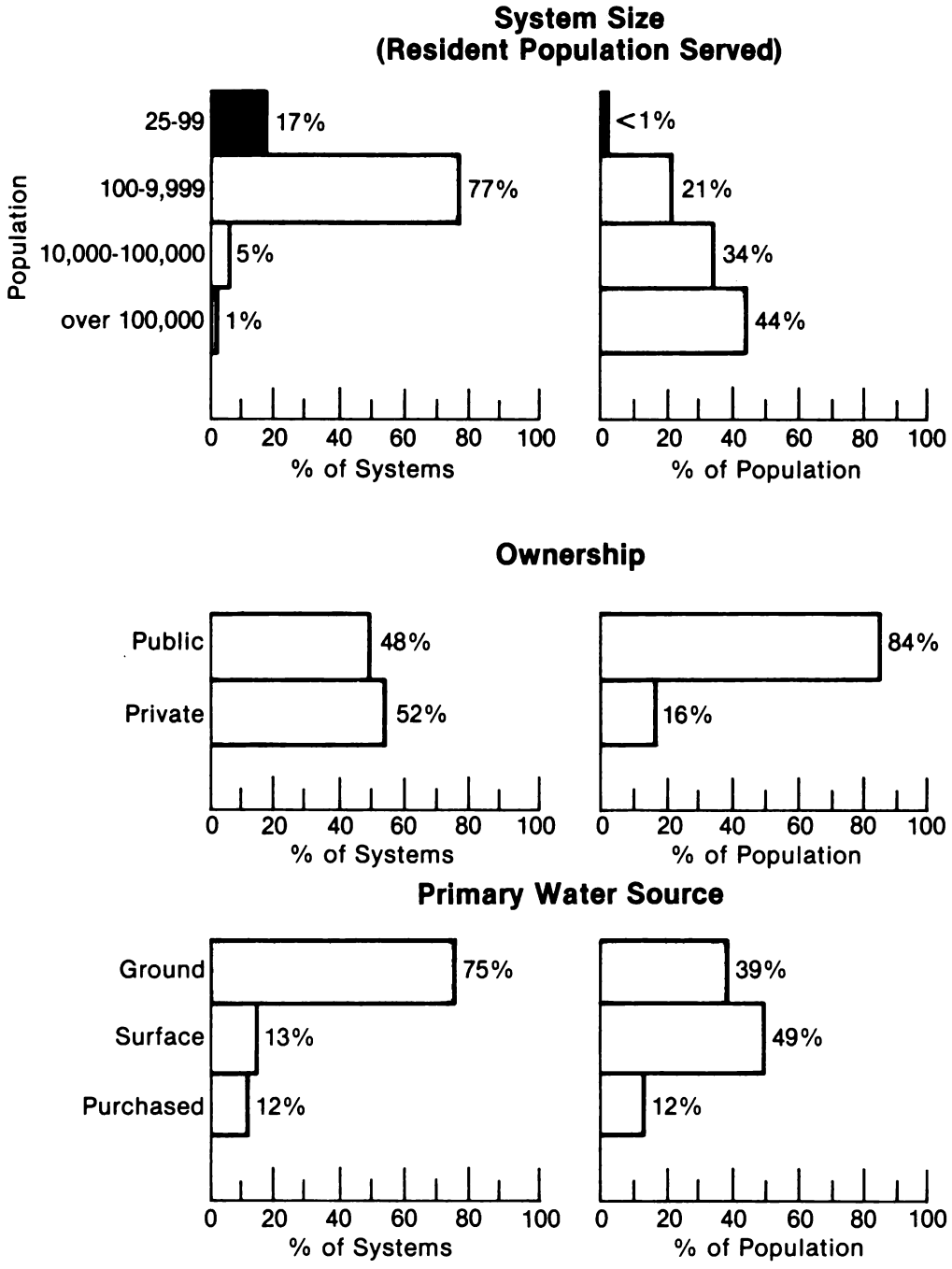

Note: Total Systems = 45,760; Population Served = 179 million;
Total Daily Water Production = 23,240 MGD.

Figure III-2.—Profile of central supply systems

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basin was augmented by inflow from the Upper Colorado Basin, imports of other surface water, and ground-water overdraft. Even though consumption does not exceed natural replenishment, some regions are consuming more than 50 percent of the average annual runoff, namely, the Texas-Gulf, Rio Grande, Upper and Lower Colorado, Great Basin, and California Regions. Such high depletions of streamflows will require more attention to managing the supply and use rates, including those for domestic and commercial purposes.

Ground-water Sources

Because surface supplies are inadequate to meet water needs in the Southwest, those populations depend more on ground-water supplies. Unfortunately, in these areas the recharge rate for many aquifers is very low compared to the total volume in storage, so that withdrawals often exceed replenishment. In the East, ground-water sources are more dependable because the aquifers are adequately replenished annually. Moreover, surface supplies are also more stable in the East, where the average annual flows vary less. This is also true of the Northwest.

Regional Domestic Use

In the western regions (particularly the Texas-Gulf, Great Basin, and Lower Colorado) withdrawals and consumption for domestic uses are projected to increase significantly by 2000. The increase in central system withdrawals from these regions ranges from 36 percent in the Texas-Gulf to 56 percent in the Lower Colorado Region. Similar high growth rates in withdrawals are projected for the South Atlantic Gulf (56 percent) and the Tennessee (54 percent) (Tables III-13 and III-14).

The overall domestic consumption by 2000 is projected to increase by 33 percent. However, regional variations again should range from 12 to 61 percent for the eastern regions and from 20 to 56 percent for the western regions where heavy use of lawn watering in low-density communities, swimming pools, and air conditioning affect the water usage. The Texas-Gulf, Lower Colorado, Great Basin, and California Regions should have the highest increase in consumption, from 28 to 56 percent. These four regions account for almost 30 percent of the Nation's domestic water consumption. California alone accounts for 20 percent.

A large population growth rate is projected for the South Atlantic-Gulf, Texas-Gulf, Lower Colorado, Great Basin, and California Regions by 2000. Problems from water demands in excess of supply can be expected in these regions, particularly in the Lower Colorado and Texas-Gulf Regions.

Regional Commercial Use

The principal determinants of commercial water requirements are similar to those for domestic water use: climate, population density, earn-

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Table III-13.—Domestic central system fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	1,011	1,097	1,222	96	103	114
Mid-Atlantic (2)	3,627	4,095	4,758	505	565	650
South Atlantic-Gulf (3)	1,931	2,369	3,005	657	816	1,057
Great Lakes (4)	2,946	3,264	3,717	280	308	349
Ohio (5)	1,561	1,751	2,013	175	196	227
Tennessee (6)	210	259	323	26	32	39
Upper Mississippi (7)	1,280	1,440	1,653	178	200	231
Lower Mississippi (8)	595	657	729	255	279	307
Souris-Red-Rainy (9)	41	44	47	17	18	19
Missouri (10)	872	959	1,083	207	227	256
Arkansas-White-Red (11)	667	737	830	236	262	293
Texas-Gulf (12)	1,152	1,320	1,565	379	431	508
Rio Grande (13)	254	276	301	132	144	158
Upper Colorado (14)	67	73	80	22	24	27
Lower Colorado (15)	416	512	649	195	240	304
Great Basin (16)	333	391	468	126	146	174
Pacific Northwest (17)	720	776	874	157	168	188
California (18)	2,958	3,338	3,839	1,246	1,403	1,611
Total, Regions 1-18	20,641	23,358	27,156	4,889	5,562	6,512
Alaska (19)	80	101	132	4	5	7
Hawaii (20)	148	172	209	44	52	63
Caribbean (21)	295	352	421	39	46	56
Total, Regions 1-21	21,164	23,983	27,918	4,976	5,665	6,638

ings, and lifestyle. Total commercial withdrawals and consumption are expected to increase in close parallel to the projected population growth (24 percent by 2000). By 2000, withdrawals should increase by 22 percent and consumption by 23 percent. Although nationally commercial water consumption is only about 20 percent of withdrawals, California consumes about 41 percent and is projected to continue having the largest consumption by 2000.

Regional Projections

By 2000, domestic and commercial withdrawals are projected to increase about 30 percent and consumption about 29 percent. In the East, the

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Table III-14.—Domestic noncentral system fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	111	126	134	68	76	82
Mid-Atlantic (2)	327	372	410	200	225	246
South Atlantic-Gulf (3)	357	432	481	223	263	288
Great Lakes (4)	321	350	360	196	211	214
Ohio (5)	281	317	330	174	193	197
Tennessee (6)	53	60	60	33	37	37
Upper Mississippi (7)	170	169	155	104	102	93
Lower Mississippi (8)	60	64	61	39	40	37
Souris-Red-Rainy (9)	12	12	9	8	7	6
Missouri (10)	89	86	78	55	53	46
Arkansas-White-Red (11)	68	70	64	43	43	38
Texas-Gulf (12)	55	60	56	34	36	33
Rio Grande (13)	11	11	11	6	6	5
Upper Colorado (14)	3	3	3	3	3	2
Lower Colorado (15)	7	8	9	4	5	6
Great Basin (16)	7	8	7	4	5	4
Pacific Northwest (17)	84	87	83	53	52	50
California (18)	56	57	51	33	33	30
Total, Regions 1-18	2,072	2,292	2,362	1,280	1,390	1,414
Alaska (19)	4	4	5	2	3	3
Hawaii (20)	<1	<1	<1	<1	<1	<1
Caribbean (21)	16	24	33	10	15	19
Total, Regions 1-21	2,092	2,320	2,400	1,292	1,408	1,436

increases for both central and noncentral systems correlate closely with projected population increases. The western regions--particularly, the Texas-Gulf, Great Basin, and Lower Colorado Regions--are projected to have significant increases in withdrawal and consumption by the year 2000. The increases in central system withdrawals for these regions range from 36 percent in the Texas-Gulf Region to 56 percent in the Lower Colorado Region. Similar high increases in withdrawals are projected for the South Atlantic-Gulf (56 percent) and the Tennessee Regions (54 percent). Consumption above 33 percent of withdrawals results from several factors in all western regions except the Pacific Northwest: heavy lawn watering in low density residential communities with naturally arid climates and extensive use of air conditioning and swimming pools.

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Water Quality

Water quality is particularly critical for domestic and commercial systems. Since supplies for all domestic and commercial requirements generally come from the same system, the quality of water supplied by these systems must meet the most stringent use demand--namely potable drinking water--even though only 1 to 3 percent is used strictly for drinking. The maintenance of potable drinking water frequently has attendant problems of cost, competition with other water uses, and conflicts of water rights.

Ironically, the domestic and commercial sectors frequently contribute to deteriorated quality of downstream reaches by discharging water that is not adequately treated before discharge. This cycle of withdrawal and discharge is repeated along the stream. As towns become cities, a megapolis pattern develops, so that the time and distance shorten between discharge point and subsequent withdrawal point.

Water Costs

Although treatment for discharged water is required, regulatory actions are not necessarily efficient or equitable. Federal laws and regulations for water quality management are now directed toward achieving a national goal of "zero discharge," although some moderation of this level may be introduced in recognition of the costs for achieving this goal. Moreover, toxic substances control laws prohibit the manufacture of new chemicals found to be potentially dangerous to the public health or the environment. Very real threats to downstream and ground-water users are posed by runoff and percolation from fields and forests, municipalities, and transportation accidents (truck, rail, and barge); from malfunctions of municipal and industrial waste treatment systems; and from nonpoint sources. These growing threats call for an increase in the numbers, size, and sophistication of both waste water and drinking water treatment facilities. Equally necessary are the monitoring and constant alertness for ways to prevent pollution of water used for domestic and commercial needs.

Treatment

Treatment by water utilities varies from simple disinfection (i.e., usually chlorination, but increased interest is being directed toward ozone and chlorine disinfection) of high quality ground-water supplies to a full range of treatment processes, including aeration, prechlorination, coagulation, sedimentation, filtration, softening, taste and odor control, iron removal, ammoniation, and fluoride adjustment. Generally, ground-water supplies need less treatment than surface-water supplies to provide palatable and esthetically desirable water. Most ground-water systems, however, currently provide no treatment before distribution within a community; most surface-water-dependent systems provide some level of water treatment before community distribution. Noncentral systems are especially

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vulnerable to pollution and attendant health problems caused by inadequate treatment facilities. The typical noncentral suppliers simply lack the financial ability to provide much of any treatment. Moreover, polluted ground water is an especially difficult problem for noncentral systems because owners may not be aware of the poor water quality until health problems arise.

Issues

Generally, the difficulty of obtaining water of good quality and sufficient quantity for domestic and commercial uses will increase. Some of the more important challenges facing water resource management include: (1) overcoming current impediments to use of conservation techniques, (2) repairing aging urban distribution systems and expanding new systems where necessary, and (3) finding other means such as pricing mechanisms to control domestic and commercial demand for water in the future.

The problem of urban water supply was cited specifically in President Carter's water policy message of June 6, 1978. Maintenance of urban domestic and commercial supplies is perhaps the key challenge for water resource management. In older, central cities, the deterioration of aged distribution systems is a key problem for water supply. The cost is very high to repair and replace unsafe and inefficient systems that have lead or wooden pipes, some over 100 years old. Although these systems are generally self-supporting (by user fees), the large capital investments required to repair them are difficult for financially-trapped cities to make.

In contrast, new urban or growth areas require an expansion, not a maintenance of water supply systems, to meet domestic and commercial needs. Suburban uses, such as lawn watering and swimming pools often are more consumptive than central city patterns of use. However, a variety of problems accompany the needed expansion of supply. Conflicting uses may compete for the available water supplies. For example, phosphate mining near the Florida coast has already affected Sarasota's ability to provide water to the city. Although domestic and commercial supply is clearly not the only cause of such overpumping, ground-water overdraft has also already severely stressed aquifers in some areas.

Management of domestic and commercial water supplies is also complicated by a variety of institutional and jurisdictional conflicts that impede strong coordinated resource management and conservation. At present, no one level of government or private enterprise institution is legally obligated to plan for and provide water supplies. Private utilities, municipal and county agencies, and municipal authorities, for example, may operate water supply systems, but (unlike sewage treatment) no one entity has a positive duty to ensure that such services are funded or provided.

The effects of pricing mechanisms on commercial and domestic water use are other factors to be considered in resource management. In private or mixed public and private segments of the economy, price should determine the

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type and scale of water use. Yet, the common property character of water has lessened the impact of price as a means to reduce demand so that water pricing may not be a significant control. Studies of price and income elasticity in residential water use indicate that withdrawals do not change significantly with a change in price. High income households, which are generally the most consumptive households, can afford and generally are willing to pay higher prices for domestic water use.

Domestic and commercial sectors present substantial opportunities for conservation that so far have been untapped. Because increased competition for water from other sectors will make it increasingly difficult to meet rising demands for commercial and domestic water needs, conservation measures are needed to reduce demands. Every effort should be made to encourage and to reduce impediments to its implementation.

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Water for Manufacturing

Manufacturing directly employs about 26 million Americans and provides the economic cornerstone of most urban areas. It contributes 27 percent of the gross national product, and accounts for approximately 39 percent of the total energy consumption in the United States. It is also a significant user of water. Among all functional uses, manufacturing ranked second in consumption and third in withdrawals in "1975." In fact, the estimated water intake for manufacturing averaged 61 billion gallons per day (bgd), about equal to the flow of the Mississippi River above its confluence with the Missouri.

In this section, water for manufacturing is discussed according to volume, use in factory, source, and varying regional needs by type of manufacture. Projections for 1985 and 2000 water needs are based on current usage, socioeconomic trends, assumptions about these trends, and the effects of legislation on water use.

Assumptions

Several specific trends and assumptions were factored into the projections. The shift toward larger manufacturing plants has led to an integration of operations previously carried out in several plants. It is assumed that this trend will continue. While population is projected to increase about 24 percent by the year 2000, earnings for manufacturing should increase more than 100 percent. Projections of withdrawals and assumption ratios assume that legislative incentives to reduce withdrawals will increase the consumption of water that results from water losses in recycling or treatment.

These projections, however, do not include the uncertain effects of environmental concerns, shifts in energy supplies, or fluctuating international monetary exchanges.

Projected growth in overall water requirements is considerably less in the second assessment than it was in the first assessment. In fact, this assessment forecasts a decline in withdrawals for 1985 and 2000 (Figure III-3). Projections for the first assessment predated the water quality legislation that directly affects manufacturing discharges.

Applicability of Data

The forecasts in this section are based on the National Future. While most regions accepted the National Future projections as generally representative of their State-Regional Futures, the following regions project larger withdrawal requirements for manufacturing in their area: Mid-Atlantic, South Atlantic-Gulf, Tennessee, Lower Mississippi, Missouri, and Pacific Northwest. These higher regional projections for withdrawals result in part from larger State-regional forecasts for manufacturing growth and from varying opinions about the degree to which recycled effluents will replace withdrawals. Some regions believe that incentives

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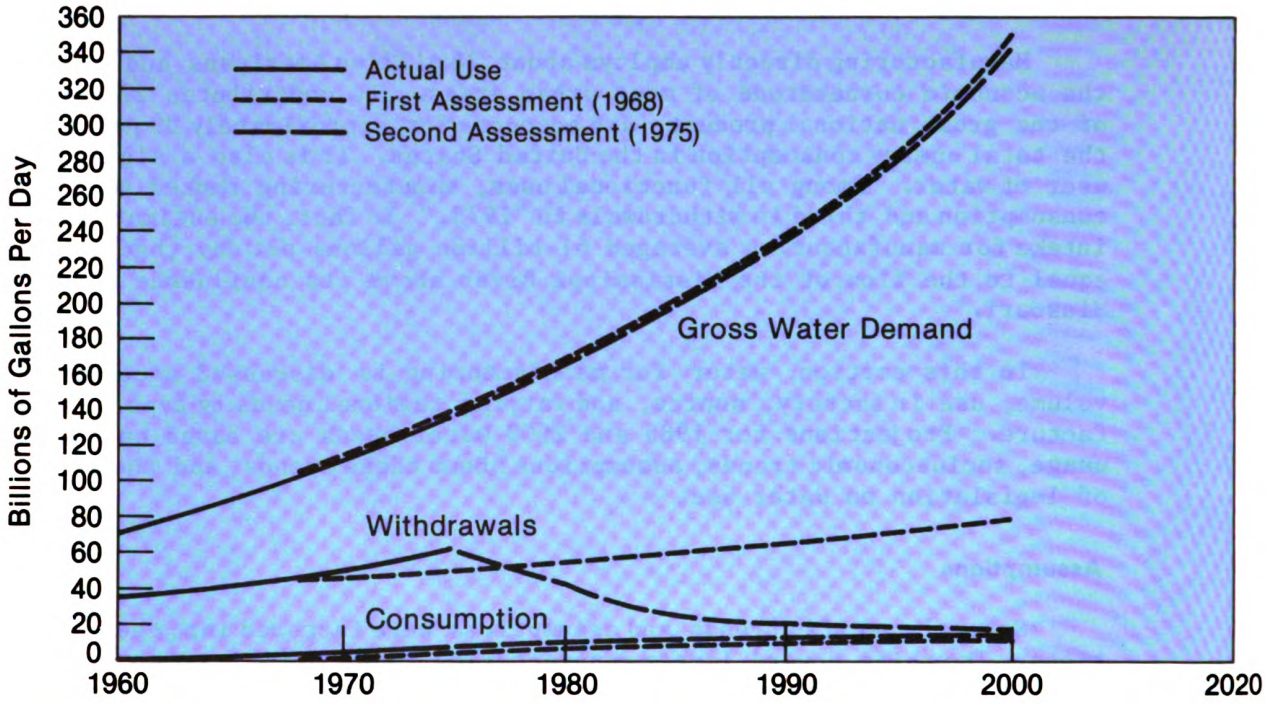

Figure III-3.—First and second assessment projections for manufacturing water use

for recycling will be lacking because they have ample local supplies of water.

While data on industrial water use are generally adequate for assessing and projecting water requirements for the Nation as a whole and for regions with large and diversified manufacturing sectors, they are less adequate for smaller geographic areas and small groups of industries. Information on smaller or less industry-intensive areas and on small industries was not generally available.

Definition of Terms

o Manufacturing is defined as factories, plants, or mills engaged in the mechanical or chemical transformation of materials, components, or substances into new products. Materials processed by manufacturing plants include products of agriculture, forestry, fishing, mining, petroleum extraction, and quarrying, as well as products of other manufacturing establishments.

o Gross water is the volume of water required to run a plant; it is the amount withdrawn plus the amount recycled.

o Withdrawal or intake of water is the volume of water that is

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taken from an outside source, either to satisfy the entire gross water demand if no recycling is practiced, or to make up for the water lost by consumption or discharged from a recycling system.

- Consumption in manufacturing is the loss of water through evaporation, incorporation into products, or leaks and infiltration to the ground.

- In manufacturing, consumption is determined indirectly as the difference between the volumes of water taken in and the volumes that are discharged from the buildings or grounds of the establishment.

- A saline water is water with more than 5,000 parts per million total dissolved solids.

- Process water in manufacturing is the water that comes into direct contact with the materials processed.

Background

The Nation has more than 312,000 manufacturing plants. Although two-thirds are small, with 20 or fewer employees per plant, the trend has been toward larger plants, especially in the more sophisticated process industries. Growth in earnings from manufacturing is expected to continue at a rate of 3.1 percent annually. By the year 2000, earnings from manufacturing are estimated at $595 billion, more than twice those of "1975" (Table III-15). Existing industrialized areas will have the largest increases, but increasing rates of industrial growth in the South, Southwest, and Pacific areas will change the character and extent of water problems in those "sunbelt" areas.

Manufacturing activities are greatly concentrated in urban areas, with nearly 80 percent of the earnings derived from establishments located in areas that surround cities of 50,000 population or more, mainly in the eastern third of the Nation. Nearly 73 percent of the estimated "1975" earnings from manufacturing were realized from activities in the six water resources regions of the East. Industries are also concentrated in areas along both seaboards and the Gulf of Mexico, as well as along the shorelines of the Great Lakes, and the Ohio and Mississippi Rivers.

Many plants such as those engaged in textile manufacture use relatively little water in their operations, while others such as primary metals require vast quantities. To differentiate between establishments with small water requirements and those with large requirements for the national assessment, any establishment with a withdrawal of 10 million gallons per year or more, (28,000 gallons per day) is considered a large water user. Of the 312,000 manufacturing establishments in the Nation, only slightly more than 10,000 (about 3 percent) can be considered large water users, but the manufacturing water demand is so concentrated in

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Table III-15.—Growth in population, earnings, and fresh-water withdrawals and consumption in manufacturing—"1975," 1985, 2000

	"1975"	1985	2000
Population growth:[a]			
Percent change	---	10	23
People (millions)	216	238	268
Total earnings:			
Percent change	---	43	10
Dollars (billion 1975$)	$1,058	$1,521	$2,540
Earnings from manufacturing:			
Percent change	---	38	113
Dollars (billion 1975$)	$280	$388*	$595
Gross water used:[b]			
Percent change	---	49	144
Volume (bgd)	136.6	202.1	330.3
Fresh-water withdrawals:			
Percent change	---	-54	-62
Volume (bgd)	51.2	23.7	19.7
Fresh-water consumption:			
Percent change	---	47	143
Volume (bgd)	6.1	8.9	14.7

[a]Region 21, the Caribbean, is included only in the population data.
[b]Includes saline-water withdrawals, reused water, as well as fresh-water withdrawals.

those 10,000 establishments that they accounted for 99 percent of the total withdrawals for all manufacturing in "1975."

Fresh-water withdrawals for manufacturing by 1985 and 2000 will decline by 54 percent and 62 percent, respectively, from the 51.2 bgd withdrawn in "1975" (Table III-15). However, consumption is expected to increase by 47 percent in 1985 and 143 percent in 2000 as recycling and reuse rates increase (Table III-15). These recirculation rates vary from about 1.5 times in primary metals manufacturing to 5.0 times in petroleum and coal products refining.

Water Source and Uses

The gross water used by manufacturing in "1975" was estimated at 136.6 billion gallons per day (bgd). In order to meet that requirement,

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manufacturing plants withdrew some 37.4 bgd from fresh water lakes and rivers, 6.5 bgd from company wells; about 7.3 bgd from public water systems; and about 10.5 bgd from saline surface sources for a total withdrawal of 61.7 bgd (Figure III-4). The remainder, 74.9 bgd, the largest part of the gross water demand, was satisfied by recycling and reusing water and treated effluents within individual plants.

The difference between the gross water used and the water withdrawn is accounted for by recirculation of the water an average 2.2 times. Because the practice of recycling treated effluents, instead of using additional water withdrawals, is expanding, freshwater withdrawals should drop by 62 percent, from 51.2 bgd in "1975" to 19.7 bgd by 2000 (Table III-16). Three principal uses for water in manufacturing are: cooling (69 percent), processing (27 percent), and inplant steam generation (feed water) and sanitary services (4 percent).

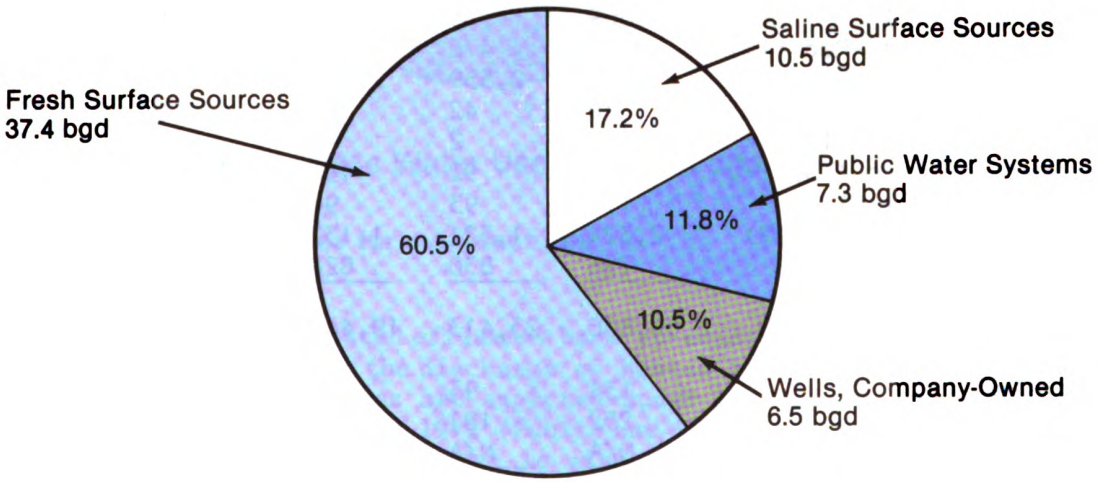

Figure III-4.—Water sources for manufacturing

Water for Cooling

Approximately 69 percent (94.8 bgd) of manufacturing water is used for cooling and condensing (Figure III-5). This large amount of cooling water is needed to manage heat, to maintain operating temperatures within critical ranges, to protect equipment, to air condition, and to speed production processes by reducing cooling times between steps in plant operations. The cooling water is physically separated from materials and products in these manufacturing applications.

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Table III-16.—Manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	2,170	1,022	781	192	332	567
Mid-Atlantic (2)	5,416	2,526	1,942	607	934	1,361
South Atlantic-Gulf (3)	4,103	3,377	3,318	611	1,203	2,532
Great Lakes (4)	13,220	4,106	2,821	1,474	1,719	2,059
Ohio (5)	10,881	3,323	2,341	817	1,095	1,757
Tennessee (6)	2,093	765	671	147	266	514
Upper Mississippi (7)	2,030	886	728	240	309	506
Lower Mississippi (8)	4,163	1,634	1,365	314	552	1,067
Souris-Red-Rainy (9)	102	44	31	13	19	23
Missouri (10)	669	315	292	136	122	202
Arkansas-White-Red (11)	713	476	480	165	232	360
Texas-Gulf (12)	1,932	2,559	2,444	571	1,003	1,917
Rio Grande (13)	19	42	32	5	15	24
Upper Colorado (14)	4	2	2	2	1	2
Lower Colorado (15)	89	92	138	55	54	104
Great Basin (16)	112	93	98	24	42	77
Pacific Northwest (17)	2,324	1,321	1,132	329	501	880
California (18)	796	830	828	257	375	567
Total, Regions 1-18	50,836	23,413	19,444	5,959	8,774	14,519
Alaska (19)	134	93	86	26	41	68
Hawaii (20)	252	181	139	74	88	112
Caribbean (21)	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-21	51,222	23,687	19,669	6,059	8,903	14,699

N/A Not available.

Cooling water temperatures are increased 15 to 25°F through heat exchanger surfaces. The heated waste must be cooled by mechanical heat transfers through evaporation in cooling towers or other heated air exchangers. Direct discharge of heated cooling water to surface waters is increasingly restricted by water pollution control requirements that encourage recycling of cooling waters within the manufacturing facility.

Some manufacturing plants in coastal areas with large cooling water needs are withdrawing large volumes of saline water from bays and estuaries,

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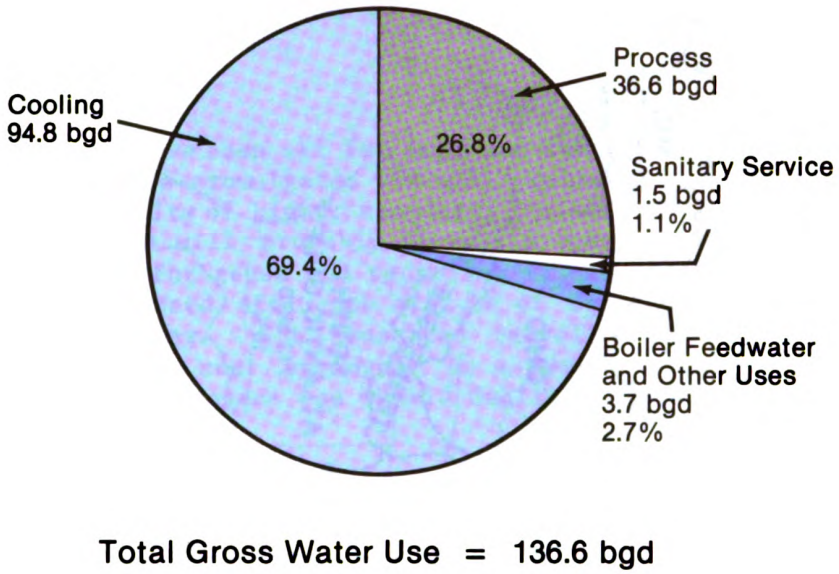

Figure III-5.—Water uses for manufacturing

and discharging the heated effluents back to coastal waters (Figure III-6). Future restrictions on the discharge of heated saline water into ecologically sensitive estuaries are expected under the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). Furthermore, by the year 2000, use of saline water is expected to be totally abandoned in favor of more cost-effective, fresh-water systems that permit recycling at very high rates. Figure III-6 shows the water resources regions in which saline water was used for manufacturing in "1975." The figure shows the total volumes of saline water withdrawn, and the percentage of the total water withdrawal requirement satisfied with saline water. The Texas-Gulf and Mid-Atlantic Regions had the largest saline-water withdrawals--three-fourths of the national total. The Rio Grande Region had the highest ratio of saline water use to total withdrawals in manufacturing (93 percent).

Water for Processing

Process water used directly in manufacturing accounts for 27 percent (36.5 bdg) of the gross water used for manufacturing. Some of the process water that comes into direct contact with the materials may remain in the intermediate and final products. With few exceptions, the processed materials are partially soluble in water.

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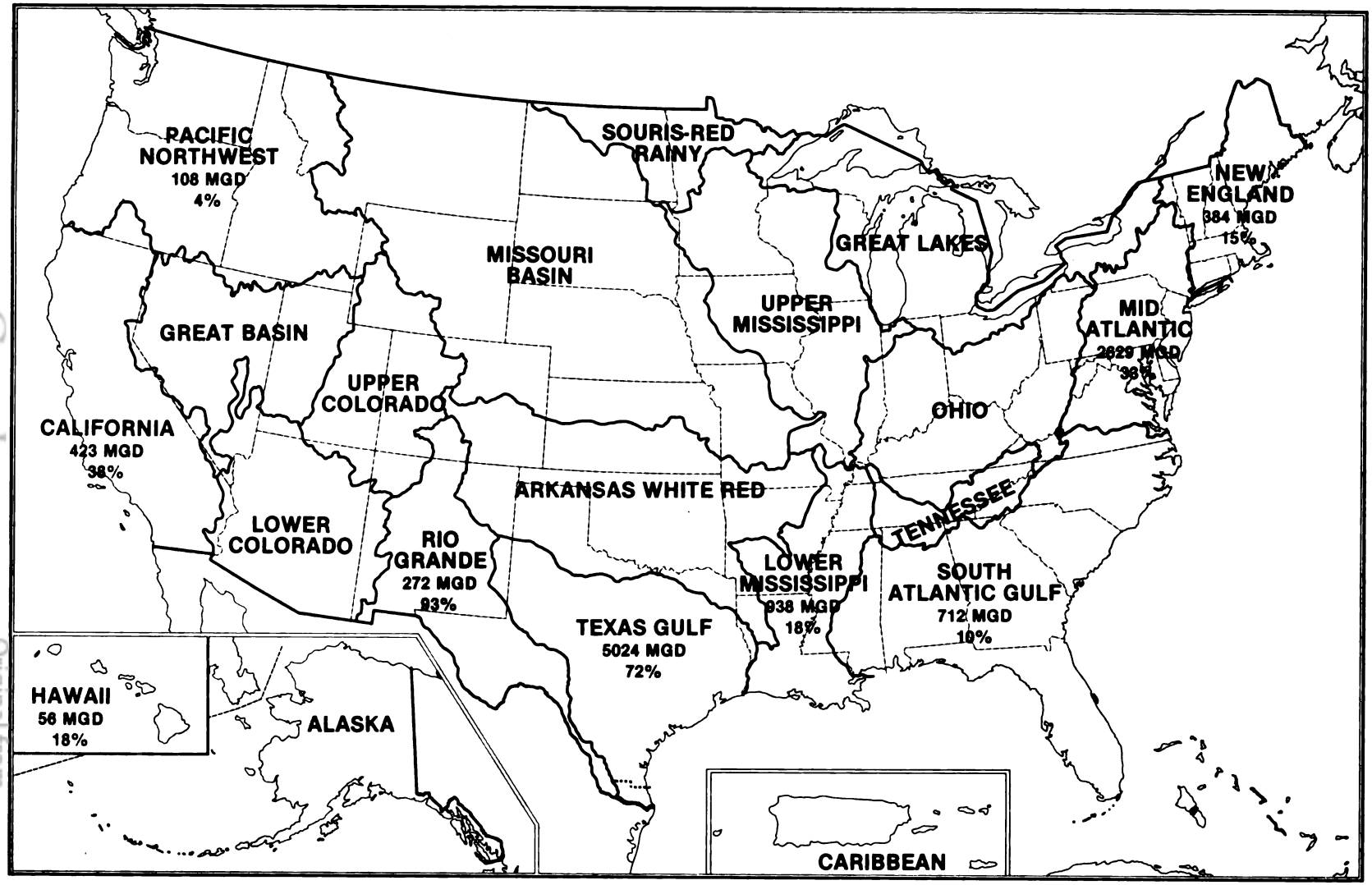

Figure III-8 Manufacturing salt water withdrawals as percentage of total

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The process water often enters the mixture of materials employed in the manufacturing process. In addition, the high density of water combined with turbulence allows for the suspension of nonsoluble solid and liquid materials in the process water. In many operations, process water may be recycled, but eventually the quality is so changed that the water must be removed from the manufacturing operations. At this point the process water becomes the industrial waste effluent that must be treated and improved in quality to meet the standards set by water pollution control agencies.

Standards have been set for most manufacturing effluents; eventually standards will be promulgated for all. Because of the present standards and the probability of higher standards for effluent quality, the treatment technology used will probably cleanse process waste water to a quality level suitable for reuse and recycling in the industrial plant. In many cases, the cleansed effluents will be of equal or better quality than the original water. The reuse and recycling of treated effluents can yield substantial cost savings. As a result, withdrawals of fresh and saline water for process use should decline substantially.

Other Manufacturing Uses—Feedwater and Sanitation

The remaining 4 percent (5.1 bgd) of gross water used for manufacturing is for personal and sanitary uses (about 1.5 bgd), for boiler feedwater to generate steam (2.7 bgd), and for miscellaneous uses such as grounds-keeping and fire protection (0.9 bgd).

Projections for Manufacturing Water

A computerized forecasting model with a comprehensive industrial data base for each region, state, and subregion was used to provide the National Future projections for manufacturing water requirements. The model encompasses economic, engineering, and institutional factors that are considered relevant to the water management decisions of manufacturers.

Gross water (the volume of water withdrawn if no water is reused) is a key projection parameter in the model. Gross water use is projected to increase proportionally with the constant dollar value of the gross product originating in manufacturing. This relationship has existed since 1954, the earliest year for which data are available.

Withdrawals (the volume of water taken into a manufacturing plant from an outside source) are strongly influenced by those internal and external factors that encourage recycling. There has been a long-term trend toward using recycled water for an increasingly greater proportion of gross water use. This trend has been accelerated by the Water Pollution Control Act Amendments of 1972, which were further amended in 1977. A major goal of the Act, as it currently exists, is zero discharge of industrial pollutants to water bodies by the year 2000. Thus, high

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rates of water reuse are projected for the year 2000, with discharges chiefly limited to the control of solids buildup in plant water systems.

To determine the withdrawal needs in 1985 and 2000, the model uses precalculated ratios of withdrawals to gross water use. Only plants withdrawing more than 10 million gallons per year (mgy) are projected to achieve high rates of water reuse. These projections assume that plants using less than 10 mgy, which in the majority are supplied by municipal water systems and account for less than 1 percent of gross water use, will instead use water on a once-through basis and discharge to public sewers.

Consumption is determined indirectly as the difference between the volume of water withdrawn and the volume discharged from the properties or grounds of the establishment. Consumption of water is forecast by using coefficients linked to the gross water demands of the industries that comprise the sector. The coefficients are derived from the individual plant water use information in U.S. Department of Commerce data files (1970 data), but are modified for the year 2000 by judgmental analyses of the increased consumption that should result from advanced waste treatment practices expected to be employed.

Projections of water requirements are based on the assumption that manufacturers will recycle treated effluents, thus reducing withdrawal requirements. However, some water rights laws may deter the introduction of recycling systems. Under these laws, a reduction in withdrawals could mean a reduction of water rights, which would limit plant or company expansion.

The high levels of recycling projected for manufacturing in the year 2000 should approach the limits achievable under the best economically available technology. Futher reductions in withdrawal are unlikely without the development of yet unproven production and cooling technologies. Thus, after the year 2000, total withdrawals must increase again if growth of the sector is to continue. This is illustrated in Figure III-7, in which the analysis of withdrawals and consumption is extended to the year 2020, the most distant year of the OBERS projection.

Regional Distribution of Manufacturing Water Requirements

The estimates and projections of withdrawals and consumption of fresh water by manufacturers are presented for 20 water resources regions in Table III-16. Information for the Caribbean Region was not available. Manufacturing water use is concentrated in five regions that accounted for 74 percent of the total fresh-water withdrawals in "1975." The Great Lakes Region withdrew 26 percent of the total, followed by the Ohio (21 percent), the Mid-Atlantic (11 percent), the Lower Mississippi (8 percent), and the South Atlantic-Gulf (8 percent).

In "1975," the combined Great Lakes and Ohio Regions withdrew an average of 24.1 bgd, about 47 percent of total manufacturing withdrawals

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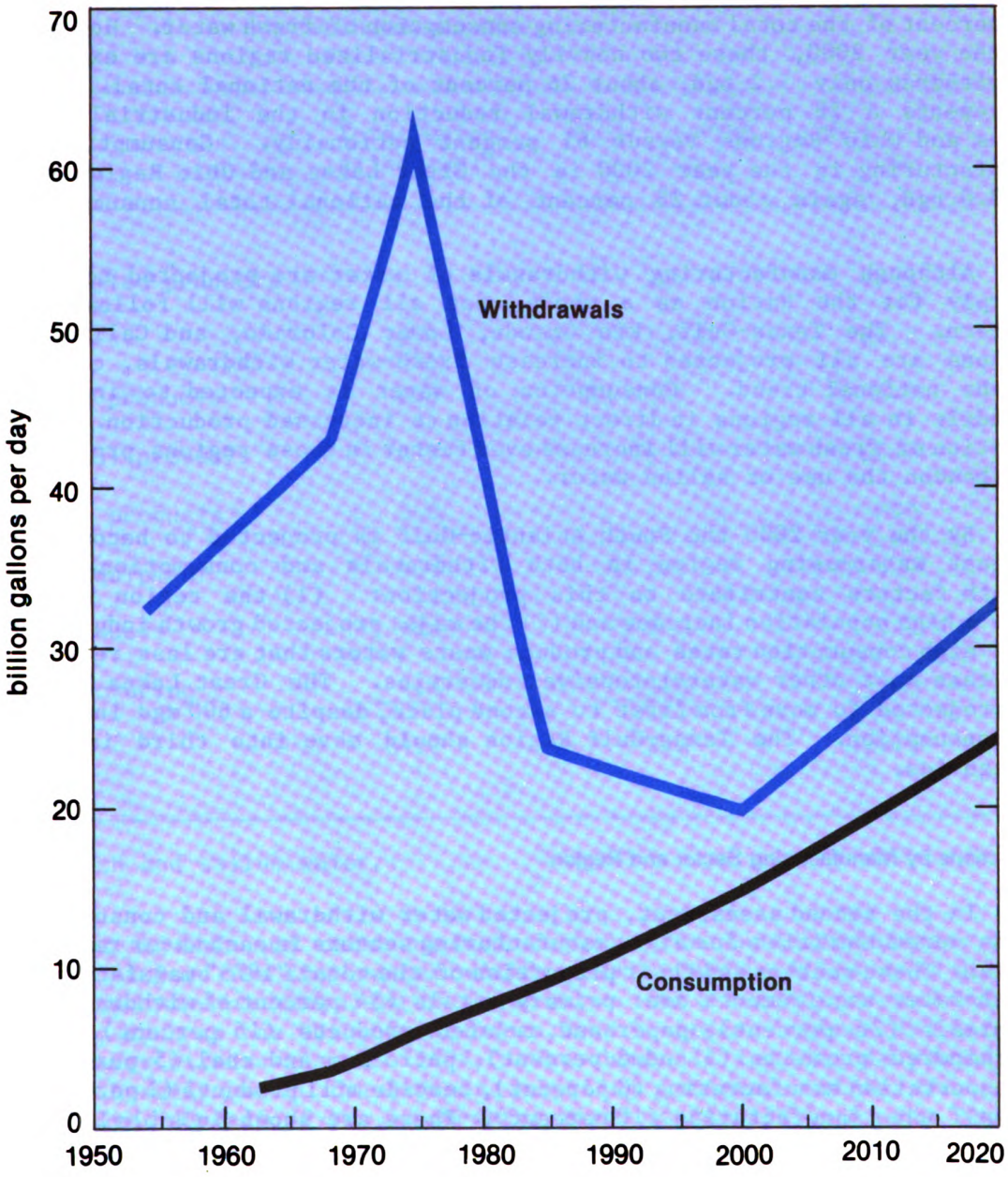

Figure III-7.—Trends in manufacturing water use

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of fresh water. Consumption in these two regions was 2.3 bgd or about 38 percent of the total manufacturing consumption of fresh water. However, by the year 2000, these two heavily industrialized regions are expected to withdraw only 5.2 bgd, about 26 percent of the national total. This represents a 78 percent withdrawal reduction in the industrial Great Lakes and Ohio Regions versus 61 percent nationally. Consumption in manufacturing in the year 2000 in the Great Lakes and Ohio Region will be 3.8 bgd, again about 25 percent of the national total consumption.

Although manufacturing withdrawals of water are projected to drop sharply for the Nation as a whole, not all regions will follow this pattern. The Texas-Gulf, Rio Grande, Lower Colorado, and California Regions are all projected to increase fresh-water withdrawals, counter to the national trend. Consumption of water is expected to increase steadily in all regions in direct relation to increased production. Consumption of fresh water will increase even faster in those regions projected to abandon the use of saline water.

By the year 2000 the South Atlantic-Gulf is projected to become the largest water-using region in both withdrawals and consumption. Two growth factors contribute to this projection: (1) the region should have a high population increase and (2) the major projected growth industries have high consumption rates and produce waste waters that are less recyclable than most other water-intensive industries. The Great Lakes Region is projected to move from first to second place, despite a 600 mgd increase in consumption. The Texas-Gulf Region should move into third in both categories.

Projections by Manufacturing Sector and Region

In the second assessment, projected water withdrawal and consumption needs were identified for eight manufacturing sectors in each water resource region. These sectors and their proportion of the total "1975" manufacturing fresh-water requirements are: primary metals (34 percent of withdrawals), chemicals (26 percent), paper and related products (16 percent), food and kindred products (5 and 6 percent), petroleum and coal (5 percent), transportation manufacturing (3 percent), textile mill products (1 percent), and all other manufacturing (10 percent). These are shown in Table III-17.

Primary metals have a high withdrawal to consumption ratio and a low recirculation ratio. Water requirements for primary metals manufacturing are highest in the Ohio and Great Lakes Regions where 78 percent of the total "1975" withdrawals for this use were estimated. Iron and steel production is concentrated in these two regions and is projected to remain there through the year 2000. Water withdrawals for primary metals are expected to decline sharply as the steel industry adopts intensive recirculation practices (Table III-18).

Chemicals manufacturing is less concentrated geographically than primary metals. The Texas-Gulf petrochemicals sector is by far the largest

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Table III-17.—Manufacturing water use by industry, "1975"
(billion gallons per day)

Industry	Total water withdrawal[a]	Recirculation ratio	Gross water use
Chemicals and allied products	19.4	2.1	40.1
Primary metals	18.9	1.5	28.2
Paper and allied products	8.9	2.9	26.1
Petroleum and coal products	4.7	5.0	23.7
Food and kindred products	2.9	1.6	4.5
Transportation equipment	1.5	2.6	3.7
Textile mill products	0.6	2.8	1.7
All other manufacturing	4.8	1.8	8.6
National average	61.7	2.2	136.6

[a]Includes brackish and saline water.

user, but in this and other coastal regions, the chemical industry has sharply limited its fresh-water withdrawals by large-scale use of saline water and intensive recycling of fresh water. As a result, several inland regions, such as the Ohio, Great Lakes, and Tennessee Regions, had larger fresh-water withdrawals in "1975." The chemicals industry is projected to move heavily toward fresh-water recycling systems, and by the year 2000, more than half of the fresh-water withdrawals will be in the Texas-Gulf, Lower Mississippi, and South Atlantic-Gulf Regions (Table III-19). These five regions withdrew 10.8 bgd (80 percent of the total) for chemicals manufacturing. In "1975," the ratio of consumption to withdrawal requirements in chemicals manufacturing was about the same as primary metals, 10 percent as a national average, except for the Ohio Region where consumption was only 5 percent of the withdrawals.

Paper manufacturing is a heavy user of fresh water in the South Atlantic-Gulf and Pacific Northwest Regions where 2.1 bgd (25 percent) and 1.3 bgd (16 percent), respectively, of the withdrawals are concentrated (Table III-20). The New England, Mid-Atlantic, and Great Lakes Regions also are heavy users of water for paper and allied products manufacturing at rates of 1.0 bgd, 0.7 bgd, and 1.0 bgd, respectively.

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Table III-18.—Primary metals manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	132	36	20	4	8	14
Mid-Atlantic (2)	1,124	616	365	173	239	288
South Atlantic-Gulf (3)	270	189	145	51	73	115
Great Lakes (4)	7,545	2,212	1,282	1,030	1,069	1,017
Ohio (5)	6,346	1,833	1,050	467	607	834
Tennessee (6)	77	43	33	12	16	25
Upper Mississippi (7)	315	135	95	41	41	75
Lower Mississippi (8)	535	101	58	29	36	46
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	89	23	14	8	10	11
Arkansas-White-Red (11)	137	84	62	18	29	49
Texas-Gulf (12)	588	242	162	60	99	129
Rio Grande (13)	10	6	4	1	2	3
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	13	8	6	12	3	5
Great Basin (16)	75	65	68	12	26	54
Pacific Northwest (17)	281	89	55	20	29	43
California (18)	34	32	32	13	18	24
Total, Regions 1-18	17,571	5,714	3,451	1,951	2,305	2,732
Alaska (19)	0	0	0	0	0	0
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	17,571	5,714	3,451	1,951	2,305	2,732
	Saline water use					
New England (1)	2			0		
Mid-Atlantic (2)	931			68		
Texas-Gulf (12)	307			79		
Pacific Northwest (17)	40			2		
California (18)	17			1		
Total, Regions 1-20	1,297			150		

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Table III-19.—Chemicals manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	109	66	55	15	27	42
Mid-Atlantic (2)	1,850	686	568	179	301	429
South Atlantic-Gulf (3)	870	668	748	165	317	589
Great Lakes (4)	1,939	425	335	71	131	255
Ohio (5)	3,261	745	593	168	215	464
Tennessee (6)	1,520	396	336	81	145	262
Upper Mississippi (7)	384	143	131	54	61	99
Lower Mississippi (8)	2,251	734	635	141	264	504
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	188	83	88	68	35	69
Arkansas-White-Red (11)	162	94	102	43	63	81
Texas-Gulf (12)	586	1,490	1,448	271	549	1,151
Rio Grande (13)	1	31	22	0	10	17
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	8	7	13	5	5	9
Great Basin (16)	14	5	5	2	3	4
Pacific Northwest (17)	260	73	65	30	42	49
California (18)	51	69	82	21	37	61
Total, Regions 1-18	13,454	5,715	5,226	1,314	2,205	4,085
Alaska (19)	4	4	5	2	3	4
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	13,458	5,719	5,231	1,316	2,208	4,089
	Saline water use					
New England (1)	184			9		
Mid-Atlantic (2)	634			26		
South Atlantic-Gulf (3)	170			8		
Lower Mississippi (7)	459			12		
Texas-Gulf (12)	4,174			58		
Rio Grande (13)	272			7		
Pacific Northwest (17)	20			1		
California (18)	47			1		
Total, Regions 1-20	5,960			122		

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Table III-20.—Paper manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	962	520	395	86	158	313
Mid-Atlantic (2)	745	460	389	76	146	305
South Atlantic-Gulf (3)	2,111	1,974	1,875	262	614	1,492
Great Lakes (4)	982	534	427	143	213	334
Ohio (5)	224	151	133	23	46	101
Tennessee (6)	381	268	246	41	85	196
Upper Mississippi (7)	348	140	104	20	38	80
Lower Mississippi (8)	517	403	381	46	119	304
Souris-Red-Rainy (9)	86	33	22	9	13	17
Missouri (10)	2	3	5	0	1	4
Arkansas-White-Red (11)	200	125	110	30	50	86
Texas-Gulf (12)	245	200	218	38	79	174
Rio Grande (13)	0	0	0	0	0	0
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	15	18	26	3	8	22
Great Basin (16)	0	0	0	0	0	0
Pacific Northwest (17)	1,326	868	739	197	312	588
California (18)	170	212	228	60	101	178
Total, Regions 1-18	8,314	5,909	5,298	1,034	1,983	4,194
Alaska (19)	124	86	78	24	37	62
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	8,438	5,995	5,376	1,058	2,020	4,256
	Saline water use					
New England (1)	0			0		
Mid-Atlantic (2)	13			0		
South Atlantic-Gulf (3)	464			8		
Pacific Northwest (17)	23			0		
California (18)	39			1		
Total, Regions 1-20	539			9		

These five regions collectively withdrew 5.1 bgd or 62 percent of the water withdrawn by the paper manufacturing sector. By the year 2000,

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Table III-21.—Food and kindred products fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	56	30	23	9	11	15
Mid-Atlantic (2)	271	172	130	45	61	78
South Atlantic-Gulf (3)	142	99	91	15	28	59
Great Lakes (4)	354	153	116	38	48	68
Ohio (5)	124	71	56	17	24	34
Tennessee (6)	19	10	8	1	2	5
Upper Mississippi (7)	506	234	169	62	81	118
Lower Mississippi (8)	209	104	71	17	29	52
Souris-Red-Rainy (9)	15	10	8	4	5	5
Missouri (10)	187	113	92	23	36	65
Arkansas-White-Red (11)	54	28	25	7	9	15
Texas-Gulf (12)	66	55	54	11	21	38
Rio Grande (13)	0	0	0	0	0	0
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	19	10	8	14	4	6
Great Basin (16)	10	9	8	3	5	6
Pacific Northwest (17)	112	68	56	11	19	41
California (18)	189	146	122	41	59	81
Total, Regions 1-18	2,333	1,312	1,037	318	442	686
Alaska (19)	0	0	0	0	0	0
Hawaii (20)	246	174	132	70	83	106
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	2,579	1,486	1,169	388	525	792
		Saline water use				
Total, Regions 1-20	262			5		

the paper industry is projected to be the largest manufacturing water user, in both withdrawals and consumption.

Food and kindred products had the largest withdrawals in "1975" in the Upper Mississippi Region, which withdrew more than 20 percent of the total for this sector (Table III-21). The Mid-Atlantic, Great Lakes, and Hawaii Regions are also relatively large users of water for this

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activity. Generally, withdrawals for food processing are widely dispersed among the regions, with consumption averaging about 15 percent of withdrawals.

Petroleum refining is concentrated in the Texas-Gulf, Lower Mississippi, California, Mid-Atlantic, and Great Lakes Regions. More than 97 percent of the water use in petroleum refining is for cooling. Consumption as a percentage of withdrawals varies from 1 percent for some once-through systems to nearly 100 percent for some of the highest recirculating systems.

The Texas-Gulf Region has the largest concentration of refineries and the largest gross water use for refining, but by substituting saline water for fresh water and by recycling fresh water, the region sharply limited its fresh-water intake in "1975". However, the use of saline water is projected to be phased out by 2000 and replaced with recirculating fresh-water systems. The result is that fresh-water withdrawals for petroleum refining are projected to increase considerably in the Texas-Gulf Region, counter to the national trend. Fresh-water withdrawals for petroleum refining in "1975" were highest in the Great Lakes Region (27 percent of the national total). This was chiefly due to the low degree of water reuse and the absence of saline water use. All refineries in the Great Lakes Region are expected to employ recirculating systems by 2000, resulting in an 86 percent decline in withdrawals (Table III-22).

Transportation equipment manufacturing is concentrated in two regions: the Great Lakes with nearly one-half and New England with one-fourth of the total withdrawals (Table III-23).

Textile finishing and manufacturing is highly concentrated in the South Atlantic-Gulf Region where 76 percent of total withdrawals for this activity occur (Table III-24).

All other industries are concentrated in the industrial areas of the Nation: the Great Lakes (22 percent), the Mid-Atlantic (16 percent), the Ohio (15 percent), and New England (11 percent). Consumption as a proportion of withdrawals for all other manufacturing in "1975" averaged about 12 percent (Table III-25).

Summary of Overall Projections

Figure III-7 shows expected trends in manufacturing withdrawals and consumption. By the year 2000, the National Future analysis indicates that recycling and reuse of water and wastes will have reduced the requirements for water withdrawals to a level beyond which further reductions are unlikely without the development of yet unproven competitive dry manufacturing production technologies.

Water withdrawals by manufacturers in year 2000 will be primarily to replace the water lost in the operations through consumptive uses,

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Table III-22.—Petroleum refining fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	16	8	5	3	4	4
Mid-Atlantic (2)	562	228	137	71	87	109
South Atlantic-Gulf (3)	28	32	25	12	15	20
Great Lakes (4)	687	141	95	51	56	74
Ohio (5)	114	52	48	23	27	38
Tennessee (6)	0	0	0	0	0	0
Upper Mississippi (7)	50	36	33	18	19	26
Lower Mississippi (8)	441	220	150	66	80	119
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	91	36	29	20	19	24
Arkansas-White-Red (11)	74	75	94	44	51	75
Texas-Gulf (12)	312	496	479	170	224	382
Rio Grande (13)	0	0	0	0	0	0
Upper Colorado (14)	4	1	1	2	0	1
Lower Colorado (15)	1	1	0	1	0	0
Great Basin (16)	8	7	7	4	4	6
Pacific Northwest (17)	11	12	15	6	8	13
California (18)	123	147	100	57	64	79
Total, Regions 1-18	2,522	1,492	1,218	548	658	970
Alaska (19)	1	1	1	0	0	1
Hawaii (20)	5	6	6	3	4	5
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	2,528	1,499	1,225	551	662	976
	Saline water use					
Mid-Atlantic (2)	838			22		
South Atlantic-Gulf (3)	30			1		
Lower Mississippi (8)	479			11		
Texas-Gulf (12)	536			10		
Pacific Northwest (17)	1			0		
California (18)	320			9		
Hawaii (20)	4			0		
Total, Regions 1-20	2,208			53		

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Table III-23.—Transportation equipment manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	341	97	61	26	37	48
Mid-Atlantic (2)	67	46	32	6	15	24
South Atlantic-Gulf (3)	19	14	34	4	17	26
Great Lakes (4)	657	273	204	80	111	155
Ohio (5)	89	75	70	21	32	55
Tennessee (6)	0	0	0	0	0	0
Upper Mississippi (7)	26	23	22	5	9	16
Lower Mississippi (8)	3	3	3	1	1	2
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	7	8	9	3	4	7
Arkansas-White-Red (11)	0	0	0	0	0	0
Texas-Gulf (12)	89	24	15	6	9	12
Rio Grande (13)	0	0	0	0	0	0
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	10	8	7	5	6	5
Great Basin (16)	0	0	0	0	0	0
Pacific Northwest (17)	0	0	0	0	0	0
California (18)	25	24	22	4	8	16
Total, Regions 1-18	1,333	595	479	161	249	366
Alaska (19)	0	0	0	0	0	0
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	1,333	595	479	161	249	366
	Saline water use					
Total, Regions 1-20	83			2		

mainly evaporation, with about 72 percent of the withdrawals solely for that purpose. Evaporative losses increase the concentration of dissolved solids in the recirculating waters and treated wastes. This increased concentration requires that varying quantities be discharged and replaced

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Table III-24.—Textile manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	45	12	5	2	4	4
Mid-Atlantic (2)	37	17	12	3	5	7
South Atlantic-Gulf (3)	427	200	157	50	68	107
Great Lakes (4)	0	0	0	0	0	0
Ohio (5)	7	4	3	1	1	2
Tennessee (6)	31	21	19	8	11	14
Upper Mississippi (7)	0	0	0	0	0	0
Lower Mississippi (8)	13	10	11	1	4	8
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	0	0	0	0	0	0
Arkansas-White-Red (11)	1	2	5	1	1	3
Texas-Gulf (12)	0	0	0	0	0	0
Rio Grande (13)	0	0	0	0	0	0
Upper Colorado (14)	0	0	0	0	0	0
Lower Colorado (15)	0	0	0	0	0	0
Great Basin (16)	0	0	0	0	0	0
Pacific Northwest (17)	0	0	0	0	0	0
California (18)	0	0	0	0	0	0
Total, Regions 1-18	561	266	212	66	94	145
Alaska (19)	0	0	0	0	0	0
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	561	266	212	66	94	145
	Saline water use					
Total, Regions 1-20	3			0		

with freshly withdrawn water to maintain quality control. About 18 percent of the year 2000 withdrawal will be for that purpose. The remainder of the withdrawal provides for personnel requirements and for the water that is incorporated in the final manufactured products.

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Table III-25.—All other manufacturing fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	509	253	217	47	83	127
Mid-Atlantic (2)	760	301	309	54	80	121
South Atlantic-Gulf (3)	236	201	243	52	71	124
Great Lakes (4)	1,056	368	362	61	91	156
Ohio (5)	716	392	388	97	143	229
Tennessee (6)	65	27	29	4	7	12
Upper Mississippi (7)	401	175	174	40	60	92
Lower Mississippi (8)	194	59	56	13	19	32
Souris-Red-Rainy (9)	1	1	1	0	1	1
Missouri (10)	105	49	55	14	17	22
Arkansas-White-Red (11)	85	68	82	22	29	51
Texas-Gulf (12)	46	52	68	15	22	31
Rio Grande (13)	8	5	6	4	3	4
Upper Colorado (14)	0	1	1	0	1	1
Lower Colorado (15)	23	40	78	15	28	57
Great Basin (16)	5	7	10	3	4	7
Pacific Northwest (17)	334	211	202	65	91	146
California (18)	204	200	242	61	88	128
Total, Regions 1-18	4,748	2,410	2,523	567	838	1,341
Alaska (19)	5	2	2	0	1	1
Hawaii (20)	1	1	1	1	1	1
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	4,754	2,413	2,526	568	840	1,343
	Saline water use					
Total, Regions 1-20	312			6		

Data and Research Needs

In the first assessment (1968), the assessment process was seriously constrained by lack of data on water uses. In the interim between it and the second assessment, the information base on manufacturing water use was enlarged and broadened by: the addition of the 1968 and 1973

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surveys of water use in manufacturing in the Census of Manufacturers, the completion of a similar survey by the Bureau of Domestic Commerce in 1971, the collection of data on industrial discharges by the Environmental Protection Agency relative to Public Law 92-500, and the surveys and censuses of water use performed by many states. As a result, the analyses and projections of manufacturing water requirements for this assessment were greatly enhanced by the improved data.

However, there are still very serious shortcomings in the data and general information. Legal restrictions against disclosure of information obtained in confidence by Federal and State agencies and severely constrained interchanges of information between user agencies have limited full access to information. Except for the survey data included with the Censuses of Manufacturers collected every five years, much of the information results from single-purpose surveys, which lack historic reference.

Moreover, there is a lack of uniformity in scope and detail among the various surveys of manufacturing water use, particularly on water use in manufacturing processes and productivity.

On the basis of the experiences derived from both assessments and numerous river basin studies, the following improvements in basic data and additional research on manufacturing water use are needed to improve the continuing assessment process:

- Federal, State, and Interstate user agencies should employ a common set of water use parameters
- The inclusion of water-use data under confidentiality clauses of legislation should be re-examined in light of the need for information exchange to support public policy decisions
- Studies of the effect of recycled treated effluents on costs and quality control in major water-using industries should be continued
- Federally supported research and developments, including cost-benefit analyses of alternative energy-efficient production technologies and waste energy recovery from heated effluents, should be considered.

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Food and Fiber

The Nation's food and fiber production in "1975" accounted for 48 percent of all fresh-water withdrawals and 83 percent of consumption (Table III-26). For the nine western regions (Missouri, Arkansas-White-Red, Texas-Gulf, Rio Grande, Upper Colorado, Lower Colorado, California, Pacific Northwest, and Great Basin), where agriculture depends heavily on irrigation, the amount of water used was even more significant. In "1975" these nine regions accounted for 60 percent of the water used for irrigation and by 2000 will use 66 percent. By the year 2000, 17 of the 52 western subregions will have a 70 percent or greater depletion of their potential water supply for the entire year under average and dry year conditions (10 subregions during an average year and 7 during a dry year). Moreover, by 2000, 21 of the 52 western subregions will have a 70 percent streamflow depletion more than 6 months of the year under dry conditions and 46 subregions will have the same depletion at least 1 month of the year. In addition to using the largest amount of water, agriculture also influences the quality and quantity of water for other functions.

Table III-26.—Fresh-water withdrawal and consumptive use by type of user—"1975"

Type of user	Total withdrawals		Total consumption		Consumption as percentage of withdrawals
	bgd	percent	bgd	percent	
Agriculture:					
Irrigation	158.7	47	86.4	81	54
Livestock	1.9	1	1.9	2	100
Steam electric generation	88.9	26	1.4	1	2
Manufacturing	51.2	15	6.1	6	12
Domestic and commercial	28.8	9	7.4	7	26
Minerals industry	7.1	2	2.2	2	31
Other	1.9	1	1.2	1	63
Total, Regions 1-21	338.5	100	106.6	100	32

This section discusses the current and projected uses of water for agriculture, evaluates the adequacy of water supplies to determine where

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supplies will be critical to meet national and/or regional output levels, and points out environmental concerns of using natural resources for agricultural purposes.

Included in the discussion are: problems and conflicts associated with irrigation water use, limited water supplies, ground-water overdraft, water pollution from agriculture, and development of wet soils. Since irrigation uses most of the water for agricultural production and since most irrigated farming is in the West, the discussion will deal primarily with irrigation in the nine Western water resources regions.

Because irrigation is so important to total agricultural production, particularly in specialty crops, estimates for future agricultural needs must include projections on how much irrigation development will be required to support these needs. Future domestic food and fiber requirements are based on historic trends, projected population increases, and per capita disposable income adjusted for certain management and policy assumptions (Figure III-8). The domestic projection is based on a relatively stable growth pattern. Future exports are based on historic trends, including adjustments for the substantial export increases in 1972 and 1973. Since export projections are less predictable, figures are given for high, low, and moderate levels of exports (Table III-27). In general, the Nation's agricultural production has responded to both domestic and international market needs. The $20 to $25 billion annual export of agricultural products in recent years has played an important role in improving the Nation's balance of trade.

Terminology

The information in the discussion and tables of this section frequently applies to specific types of agricultural activities. The following is a description of terms as used in this section.

Agricultural lands is a generic term that includes (1) lands used to raise food for human (food and fiber) and animal consumption; (2) cultivated pasture lands, and (3) native or uncultivated lands used for grazing. Farmland includes both cultivated croplands and uncultivated grazing lands. Cropland refers to acres cultivated for the harvest of crops; on some tables, the term "irrigated farmland" is used instead of "irrigated croplands" because the irrigation water also supports native hay and other uncultivated grazing fodder. A range land is a publicly-owned land, whereas a pastureland (land cultivated for grazing) and a grazing land (native land left uncultivated) are both privately-owned lands. Roughage is fodder for animals.

Land Use

In "1975," of the 2,267 million acres of land available for agricultural uses, 422 million were used for cropland, of which 304 million were harvested (Table III-28); the other 118 million acres were either

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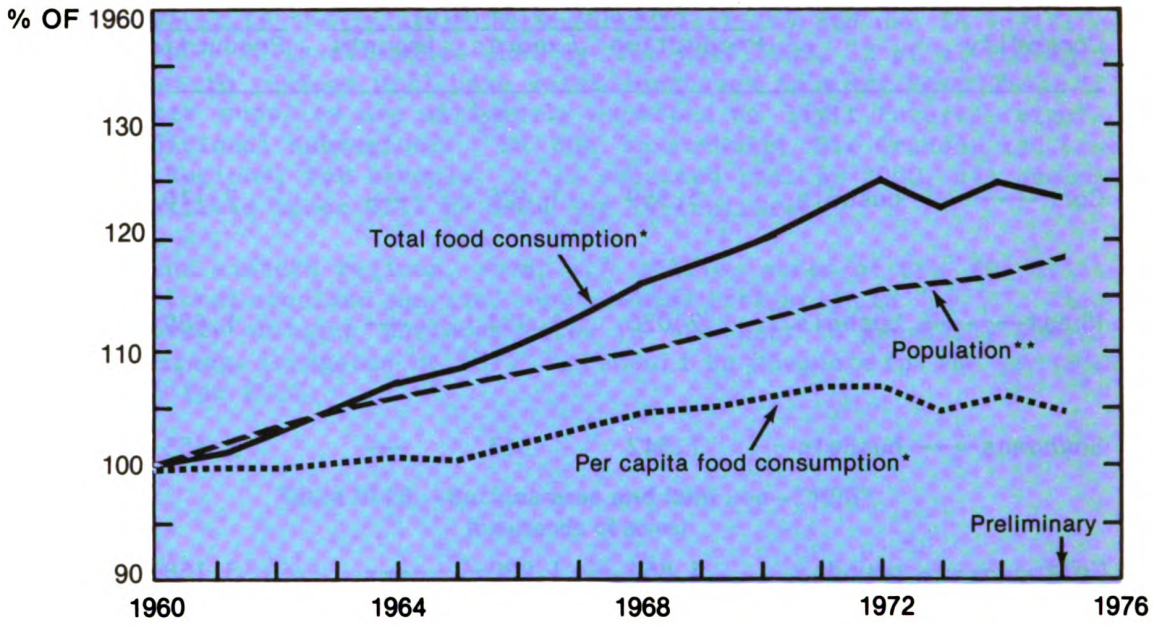
pastured, fallow, or idle. Another 885 million acres were used for forest grazing, permanent pasture, and range land.



* Retail Weight Basis, Using Constant Retail Prices as Index Weights
** Civilian Population July 1; 50 States beginning 1960

Source: Agricultural Handbook No. 491, USDA, p.36.

Figure III-8.—Population and food consumption

By the year 2000, total croplands are projected to increase only slightly, by about 4 million acres (Table III-29); however, the number of harvested acres will increase more significantly, by about 57 million acres, primarily because of improved production technology. Although the cropland acreages should have a net increase through clearing, drainage, and irrigation, the overall agricultural lands will be reduced by special uses such as urban and suburban development, highway construction, recreation and wildlife enlargement, public institutions, and facilities, etc., (Table III-30). This reduction is projected to be about 1.2 million acres annually.

Water Resources

Obviously, land productivity is enhanced by irrigation. Although irrigated cropland makes up only 13 percent of the total cropland, it accounts for 27 percent of the values of all crops produced.

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Table III-27.—Production and net exports of selected food and fiber commodities
(million units)

Commodity	Average 1974-1976			Estimated 2000		
	Production	Exports	Imports	Production	Exports[a]	Imports
Corn-------- bushels	5,559	1,425	---	7,110	1,275 2,067 3,209	---
Wheat------- bushels	2,026	1,054	---	1,689	919 1,479	---
Soybeans---- bushels	1,342	513	---	3,453	1,475 1,700	---
Cotton------ pounds	4,864	1,920	---	5,168	1,680 2,020 2,208	---
Beef, veal, and pork-- pounds	34,642	---	1,809	55,020	---	3,275
Turkeys and broilers-- pounds	10,755	375	---	18,520	333	---

[a]Low and high figures are alternative estimates for low or high levels of export activity, respectively. The center figure represents a moderate level of exports.

In "1975," 45.5 million acres of farmland were irrigated. By 2000, 6.9 million acres will be added to this to total 52.4 million acres under irrigation (Table III-29). This increase in irrigation is significantly greater than the projected increase of 4.0 million acres for total cropland use mentioned above.

In "1975," the nine western conterminous regions contained about 61 percent of the Nation's agricultural land, about 50 percent of the cropland, but about 89 percent of the irrigated farmland. In these nine regions (Missouri, Arkansas-White-Red, Texas-Gulf, Rio Grande, Upper and Lower Colorado, Great Basin, Pacific Northwest, and California), about 19 percent of the cropland is irrigated. By 2000, irrigation in these regions should increase to 21 percent. Other substantial growth rates

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in irrigation can be expected in the South Atlantic-Gulf and Lower Mississippi Regions by 2000.

In "1975," 60 percent of the water available in the nine western regions was used for agriculture; by year the 2000, about 66 percent is projected to be used for that purpose (Table III-31). Not revealed by the data, however,is the relation between availability and use in individual subregions. It is estimated that by the year 2000, 32 of 52 subregions in the western regions will have water shortages in a dry year (Table III-32). Water supplies are ultimately expected to limit future irrigation in 11 additional subregions. In the Texas-Gulf, Rio Grande, and Lower Colorado Regions, for example, it is expected that by 2000, all economically available water will be used for agriculture.

In the eastern regions, about 4.7 million acres of the 207 million acres of total cropland received supplemental irrigation in "1975." Except for temporary drought periods, water in the East is generally adequate for the acreage irrigated in "1975" and should be adequate for the projected increases for 2000.

Table III-28.—Surface area and land use—"1975"
(thousands of acres)

Region	Land use						
	Total surface	Cropland	Pasture & range	Forest & woodland	Other agric.	Urban	Other[a]
New England (1)	41,704	2,769	957	32,582	617	2,705	2,074
Mid-Atlantic (2)	64,162	11,688	4,939	35,466	2,059	4,418	5,592
South Atlantic-Gulf (3)	166,823	25,259	15,344	105,334	4,293	4,747	11,846
Great Lakes (4)	83,345	24,907	3,358	39,152	4,778	4,333	6,817
Ohio (5)	101,493	32,877	13,995	43,143	3,011	3,551	5,116
Tennessee (6)	26,615	4,431	3,532	14,404	908	668	2,672
Upper Mississippi (7)	112,944	64,062	11,644	24,473	3,643	2,151	6,971
Lower Mississippi (8)	64,509	20,409	9,928	27,099	3,828	895	2,350
Souris-Red-Rainy (9)	33,789	20,791	3,376	6,831	681	70	2,040
Missouri (10)	323,734	105,660	161,774	29,937	4,006	1,397	20,960
Arkansas-White-Red (11)	154,308	44,480	66,559	33,545	2,244	1,636	5,844
Texas-Gulf (12)	111,034	25,021	58,632	20,176	2,160	2,485	2,560
Rio Grande (13)	87,222	2,869	63,190	15,048	611	396	5,180
Upper Colorado (14)	65,290	1,951	35,369	17,881	415	47	9,627
Lower Colorado (15)	98,647	1,485	52,243	26,749	2,732	621	14,817
Great Basin (16)	87,421	2,623	61,269	12,251	267	378	10,633
Pacific Northwest (17)	171,037	19,159	51,008	85,041	1,289	1,055	13,485
California (18)	103,890	10,885	28,021	43,227	1,218	3,328	17,211
Total, Regions 1-18	1,897,967	421,326	645,138	612,339	38,760	34,681	145,723
Alaska (19)	362,517	21	238,186	58,635	29	68	65,578
Hawaii (20)	4,095	321	728	1,774	67	21	1,184
Caribbean (21)	2,273	514	880	565	49	126	139
Total, Regions 1-21	2,266,852	422,182	884,932	673,313	38,905	34,896	212,624

[a]Includes recreation parks, wildlife refuges, wilderness areas, public installations and facilities, marshes, etc.

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Table III-29.—Agricultural lands, cropland, and irrigated farmland—"1975," 1985, 2000
(millions of acres)

Region	Total agricultural land[a]	Total cropland			Irrigated farmland		
	"1975"	"1975"	1985	2000	"1975"	1985	2000
New England (1)	3.7	2.8	2.7	2.6	<0.1	<0.1	<0.1
Mid-Atlantic (2)	16.6	11.7	11.6	11.2	0.3	0.4	0.5
South Atlantic-Gulf (3)	40.6	25.3	25.7	27.5	2.0	2.6	3.0
Great Lakes (4)	28.3	24.9	25.4	25.4	0.2	0.2	0.3
Ohio (5)	46.9	32.9	33.0	33.0	0.1	0.1	0.1
Tennessee (6)	8.0	4.4	4.4	4.4	<0.1	<0.1	<0.1
Upper Mississippi (7)	75.7	64.1	64.3	64.7	0.2	0.3	0.4
Lower Mississippi (8)	30.3	20.4	21.9	22.5	2.0	2.5	2.9
Souris-Red-Rainy (9)	24.2	20.8	20.9	20.9	<0.1	0.1	0.3
Missouri (10)	267.4	105.7	105.3	105.1	9.7	11.0	11.5
Arkansas-White-Red (11)	111.0	44.5	44.6	45.1	4.8	5.4	5.5
Texas-Gulf (12)	83.7	25.0	24.9	24.6	4.8	4.2	3.4
Rio Grande (13)	66.1	2.9	2.8	2.8	2.0	1.9	1.9
Upper Colorado (14)	37.3	2.0	2.1	2.1	1.4	1.5	1.6
Lower Colorado (15)	53.7	1.5	1.4	1.4	1.3	1.2	1.1
Great Basin (16)	63.9	2.6	2.8	2.8	1.7	1.5	1.6
Pacific Northwest (17)	70.2	19.2	19.1	18.9	6.2	7.4	7.8
California (18)	38.9	10.9	10.6	10.4	8.7	9.3	10.1
Total, Regions 1-18	1,066.5	421.3	423.6	425.3	45.3	49.6	52.2
Alaska (19)	238.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hawaii (20)	1.0	0.3	0.3	0.3	0.1	0.1	0.2
Caribbean (21)	1.4	0.5	0.5	0.4	0.1	0.1	0.1
Total, Regions 1-21	1,307.1	422.2	424.4	426.1	45.5	49.8	52.4

[a]Includes cropland, pasture, and range land; other agricultural land, forest, and woodland are excluded.

The California Region has the highest rate of water withdrawals and consumption, accounting for about 22 percent of total national agricultural water withdrawals. Irrigation is important to California and the Nation because of the vegetables and valuable tree crops produced in this Region. The Pacific Northwest Region is second in water withdrawals but third in terms of consumption. The Missouri Region is third in withdrawals and second in consumption.

The quantity of water required for livestock production is included in the estimated regional uses in Table III-33. In "1975" water for livestock was only 1 percent of the agricultural water use in the western regions and about 9 percent in the eastern regions. Withdrawals and consumptive use for livestock watering is expected to increase 33 percent by 2000.

Water use for irrigation by region is shown in Table III-33. Livestock water use is shown in Table III-34, and total agricultural water use is summarized in Table III-35.

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Table III-30.—Factors contributing to changes in farmland acreages—"1975" and 2000

Quantified factors contributing to decreased cropland	
Urban land expansion	0.400 acre per capita for all time periods.
Primary highways	40 acres/mile on new highways; 20 acres/mile on expansions.
Secondary highways	16,000 acres/year (1969-1980).
Major airports	5,000 acres each.
Feeder airports	160 acres each.
State recreational land	100,000 acres/year (1969-1980); 75,000 acres/year (1980-2000).
Local and private recreational land	Based on per capita population increase projections: 0.010 to 0.020 acre (1969-1980); 0.035 acre (1980-2020).
Federal recreational land	Estimated by Federal agencies.
Surface mining -- coal, sand, gravel, and other	150,000 acres by 1980; 310,000 acres by 2000; 480,000 acres by 2020 (no account taken for oil shale developments).
Quantified factors contributing to increased cropland	
Clearing and draining	5.6 million acres by 2000.
Clearing pastureland	5.5 million acres by 2000.

Ground Water

Because surface water in many western states is already in short supply, the irrigation expansion in these regions is expected to come primarily from ground-water development by individual farmers. This presents a triple problem: (1) farmers need more information on ground-water sources to amortize investments needed to tap this resource and to assess the returns in crop incomes against costs that must compete with utility companies for the water, (2) since jurisdiction over ground water in many states resides in State and local government, there is no

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Table III-31.—Water availability and use for agriculture in nine western water resources regions, "1975" and 2000
(million gallons per day)

Region	"1975"			2000		
	Available	Used	Percent	Available	Used	Percent
Missouri (10)	23,580	16,620	70	23,580	20,810	88
Arkansas-White-Red (11)	11,930	8,430	71	11,340	8,480	76
Texas-Gulf (12)	13,060	10,730	82	9,420	7,090	75
Rio Grande (13)	4,330	4,350	100	4,170	4,040	97
Upper Colorado (14)	3,060	2,450	80	3,060	3,060	100
Lower Colorado (15)	4,550	4,190	92	3,910	3,890	100
Great Basin (16)	3,720	3,720	100	3,720	3,720	100
Pacific Northwest (17)	53,460	13,990	26	53,460	16,770	31
California (18)	33,060	26,220	79	33,060	28,530	86
Total	150,750	90,700	60	145,520	96,390	66

Source: U.S. Department of Agriculture, "Food and Fiber Production and Related Resource Considerations", 1977, p.32.

adequate method to gage what the public will accept as a depletion rate, and (3) in several western areas, ground water has already been severely depleted and is emerging as a potential problem in other areas.

The most severely depleted aquifers are in the Texas-Gulf, Rio Grande, and Lower Colorado Regions. In addition, ground-water depletion is emerging as a potential problem in the Ogallala aquifer as far north as Wyoming where it is used mostly for irrigation. Ground-water overdraft from irrigation is also generating problems in parts of the Great Basin and California Regions. Moreover, ground-water depletion is causing salt-water intrusion in the California coastal subregions and land subsidence in the Lower Colorado and California Regions.

Moreover, irrigation with ground water ultimately affects streamflows. In closed basins, it depletes ground-water supplies accumulated over centuries. The 1973 National Water Commission report recognized the lack of Federal jurisdiction in ground-water management. According to the Commission, States should regulate ground-water withdrawals in coordination with Federal resource programs. These regulations would take into account both present and future requirements of ground water as well as its affect on surface water.

Crop Yields

Crop yield is the major determinant of land and water use for agricultural production. Improved cultivation practices, better seed varieties,

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Table III-32.—Irrigated acreage and water-short subregions—"1975" and 2000
(thousands of acres)

Region	Irrigated acres "1975"	Irrigated acres 2000	Number of subregions	Number of water-short subregions in 2000[a]
Missouri (10)	9,695	11,505	11	7
Arkansas-White-Red (11)	4,765	5,545	7	4
Texas-Gulf (12)	4,770	3,440	5	2
Rio Grande (13)	1,984	1,865	5	4
Upper Colorado (14)	1,365	1,627	3	3
Lower Colorado (15)	1,283	1,127	3	2
Great Basin (16)	1,739	1,621	4	4
Pacific Northwest (17)	6,186	7,759	7	2
California (18)	8,729	10,079	7	4
Total, nine western regions	40,516	44,568	52	32
Other regions	5,002	7,871	...	...
Total, Regions 1-18	45,302	52,207	...	...
Total, Regions 1-21	45,518	52,439	...	...

[a]Water-short areas in which irrigation and livestock watering would use 90 percent or more of the water supply available to agriculture in a dry year or a critical dry month.

improved fertilizers, use of pesticides, as well as irrigation have increased crop production. From 1954 to 1974, average yields of corn increased by 105 percent, rice and wheat by 65 percent, cotton and soybeans by 35 and 32 percent. By 2000, the additional increases should be about 42, 45, 28, 65 and 57 percent, respectively. In addition to these increased yields, a greater number of acres will be dedicated to these high-yield crops. For example, the acreage for soybeans is projected to increase from 48.2 to 82.5 million acres and for roughage from 72.6 to 106.4 million acres (Table III-36).

In the East, most irrigated crops have high-value yields: vegetables, fruits, tobacco, rice and sugar beets. If commodity market demands continue to expand, additional water supplies may need to be developed to increase production of these crops. However, for the Nation as a whole, most irrigated acreage is in lower-to-medium-value crops such as grains and roughage. The proportion of irrigated acres devoted to these lower-value crops is projected to increase only somewhat, from 45.4 million acres in "1975" to 52.4 million acres by 2000.

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Table III-33.—Irrigation fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Water resources region and No.	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	35	41	46	25	29	33
Mid-Atlantic (2)	265	366	481	196	269	354
South Atlantic-Gulf (3)	3,464	4,008	4,509	2,752	3,184	3,597
Great Lakes (4)	145	211	282	114	169	232
Ohio (5)	47	68	91	37	53	74
Tennessee (6)	14	18	21	11	14	17
Upper Mississippi (7)	192	283	387	153	230	323
Lower Mississippi (8)	4,580	4,559	4,444	3,085	3,204	3,272
Souris-Red-Rainy (9)	46	144	434	37	116	350
Missouri (10)	31,636	39,376	36,236	14,214	17,597	17,607
Arkansas-White-Red (11)	9,980	10,483	9,776	7,048	7,468	7,125
Texas-Gulf (12)	11,538	9,333	7,427	9,347	7,597	6,100
Rio Grande (13)	5,684	5,498	4,873	3,886	3,920	3,570
Upper Colorado (14)	6,400	7,223	6,672	2,194	2,657	2,741
Lower Colorado (15)	7,989	7,299	6,343	4,026	3,962	3,720
Great Basin (16)	6,969	6,120	5,825	3,225	3,082	3,196
Pacific Northwest (17)	33,181	34,639	29,961	11,026	13,362	13,213
California (18)	34,611	34,863	34,764	24,282	25,134	26,311
Total, Regions 1-18	156,776	164,532	152,572	85,638	92,047	91,835
Alaska (19)	4	4	4	3	3	3
Hawaii (20)	1,447	1,226	951	474	481	473
Caribbean (21)	516	490	319	276	289	195
Total, Regions 1-21	158,743	166,252	153,846	86,391	92,820	92,506

Water Quality Problems

Environmental effects of agricultural activities arise from four general sources: (1) chemical applications to increase agricultural production, (2) excessive and/or inefficient use of water, (3) injudicious agricultural practices, and (4) conversion of lands to expand agriculture. Each of these will be discussed briefly below.

Chemical Applications

While advances in chemical applications have led to significant increases in agricultural production, the increases have introduced concomitant problems. Because of technological advances--much of these advances in herbicides, insecticides, fertilizers--yields in crops per acre have increased on the average about 75 percent over the past 20 years. Hand in hand with this quantity increase, however, a quality problem has arisen. The chemicals that aid in such production increases also contribute significant amounts of pollutants to the environment. Combined with other environmentally unhealthy agricultural practices, the pollutants have posed a serious threat to other water uses. The section on water quality in Part IV deals with these problems in detail. The following discussion only highlights some problems that water management must address to maintain a proper balance between agricultural commodities quantity and environmental quality.

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Table III-34. – Livestock fresh-water withdrawals and consumption – "1975", 1985, 2000
(million gallons per day)

Region	Withdrawals and consumption[a]		
	"1975"	1985	2000
New England (1)	18	19	19
Mid-Atlantic (2)	68	69	71
South Atlantic-Gulf (3)	134	166	202
Great Lakes (4)	85	85	87
Ohio (5)	113	127	139
Tennessee (6)	27	32	37
Upper Mississippi (7)	230	283	304
Lower Mississippi (8)	44	54	63
Souris-Red-Rainy (9)	26	33	37
Missouri (10)	450	559	658
Arkansas-White-Red (11)	215	238	279
Texas-Gulf (12)	180	197	228
Rio Grande (13)	38	39	44
Upper Colorado (14)	27	31	34
Lower Colorado (15)	47	52	60
Great Basins (16)	33	34	36
Pacific Northwest (17)	72	86	102
California (18)	98	118	136
Total, Regions 1-18	1,905	2,222	2,536
Alaska (19)	<1	<1	1
Hawaii (20)	2	3	3
Caribbean (21)	5	8	10
Total, Regions 1-21	1,912	2,233	2,551

[a]All water withdrawn is consumed.

The principal determinant of agricultural chemical use is, of course, the particular crop cultivated. An example is corn production, which relies on nitrogen- and herbicide-intensive techniques and accounts for 45 percent of all herbicides used in United States agriculture (Figure III-9). The Corn Belt States are by far the leading users of fertilizers, consuming more than the next three leading regions combined. This is due not only to more acreage in the region, but also to more intensive use of the chemicals.

Cotton production, which is likewise insecticide-intensive, is another example. About 47 percent of all the insecticides used in United States agriculture are applied to cotton. Pesticide use is most prevalent along

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Table III-35.—Irrigation and livestock fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Agricultural water use	Withdrawal			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
Irrigation:						
Regions 1-18	156,776	164,532	152,572	85,638	92,047	91,835
Regions 1-21	158,743	166,252	153,846	86,391	92,820	92,506
Livestock:						
Regions 1-18	1,905	2,222	2,536	1,905	2,222	2,536
Regions 1-21	1,912	2,233	2,551	1,912	2,233	2,551
Total:						
Regions 1-18	158,681	166,754	155,108	87,543	94,269	94,371
Total:						
Regions 1-21	160,655	168,485	156,397	88,303	95,053	95,057

Table III-36.—Estimated patterns of cropland harvested—"1975," 1985, 2000
(millions of acres)

Crop	"1975"[a]	1985	2000
Barley and oats	24.6	32.3	21.4
Corn and sorghum	75.9	68.4	74.0
Cotton	12.1	8.1	6.6
Soybeans	48.2	49.0	82.5
Wheat	47.8	48.6	42.5
Roughage (hay and pasture feeds)	72.6	93.5	106.4
Other	22.8	26.8	27.3
Total	304.0	346.7	360.7

[a]Projection based on average cropland harvested in 1971-1973.

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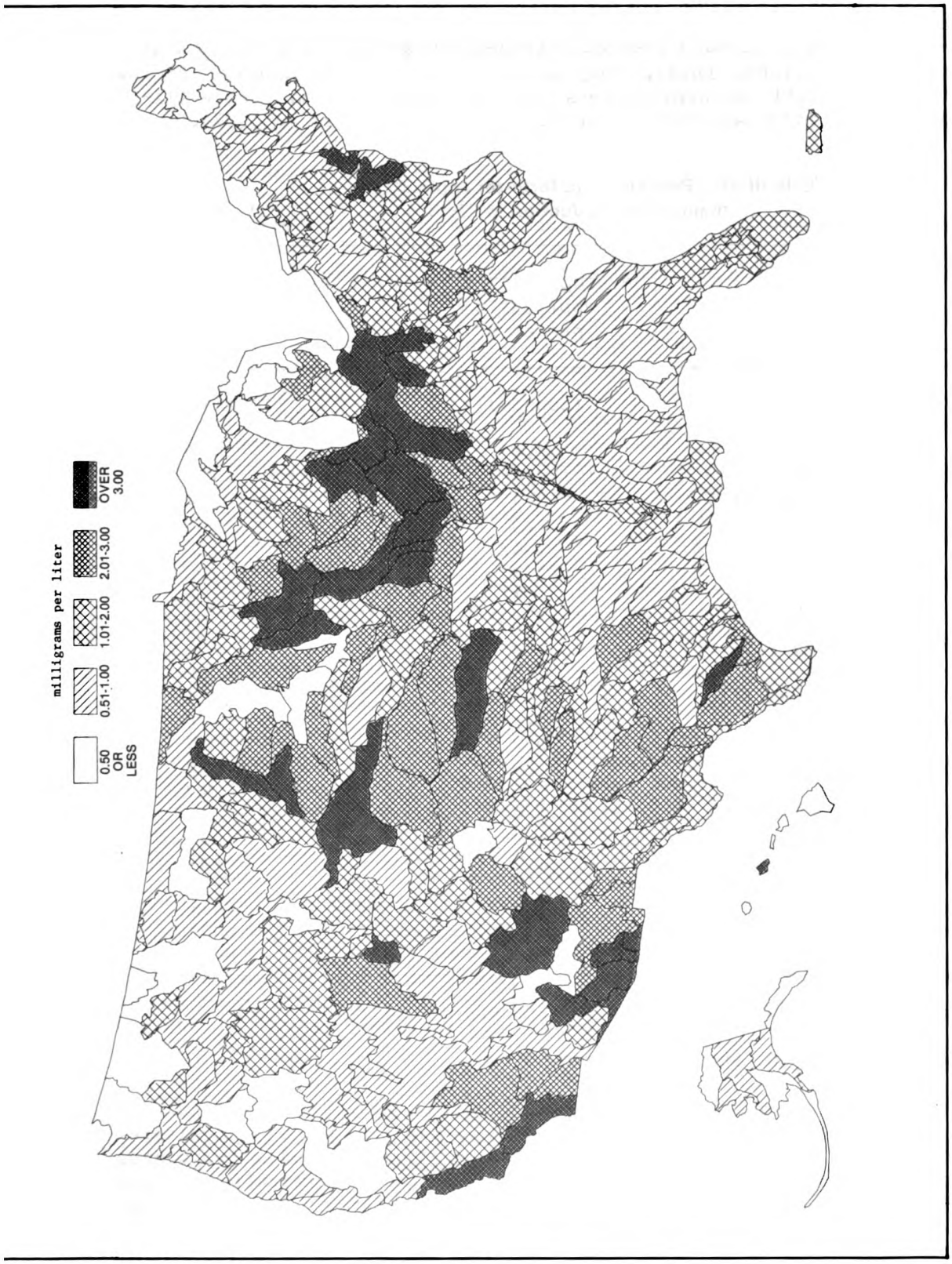

Figure III-9.—Total nitrogen levels in streams

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the Pacific coast and in the Southeast. Use of pesticides in these areas exceeds the national average by multiples of 5.5 and 4.2, respectively. Even though the cropland harvested in these areas accounts for only 9.2 percent of the national total, they account for over 45 percent of the agricultural pesticide applications for the whole Nation. Table III-37 shows the pesticide and fertilizer applications per acre in "1975."

Table III-37.—Pesticide and fertilizer applications for major crop production in "1975"

Region	Average pesticide application per acre[a]	Average fertilizer application per acre[b]
	(pounds)	(pounds)
New England (1)	2.4	129
Mid Atlantic (2)	2.4	129
South Atlantic-Gulf (3)	10.9	234
Great Lakes (4)	1.3	108
Ohio (5)	1.4	138
Tennessee (6)	12.8	160
Upper Mississippi (7)	1.3	138
Lower Mississippi (8)	3.8	93
Souris-Red-Rainy (9)	0.5	50
Missouri (10)	0.5	50
Arkansas-White-Red (11)	3.1	74
Texas-Gulf (12)	3.1	74
Rio Grande (13)	0.9	57
Upper Colorado (14)	0.9	57
Lower Colorado (15)	0.9	57
Great Basin (16)	0.9	57
Pacific Northwest (17)	14.3	143
California (18)	14.3	143
Average Regions 1-18	2.6	105

[a]Includes sulfur and petroleum that are applied as pesticides.

[b]Includes nitrogen, phosphorus, and potash.

The problems arising from use of chemicals for dryland agriculture are frequently compounded by return flows from irrigated agriculture. These return flows generally carry the same chemicals and other wastes of dryland agriculture, and thereby increase the concentration of the toxics already in the stream from other land runoff. In addition to the toxics, the irrigation flows also increase the sediment and salt

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loads in the streams. More efficient methods are needed to control the chemical and physical pollutants from irrigation. For example, computerized irrigation scheduling to determine the precise water and fertilizer applications needed cuts down excessive chemical and water use.

Inefficient Use of Water

In "1975" irrigation consumed 81 percent of all the water in the Nation withdrawn (Table III-26). Such heavy consumption can and frequently does damage instream values such as fish and wildlife, recreation, waste assimilation, sediment transport, and fresh-water inflow to estuaries--all environmentally valuable functions. This heavy consumption that depletes the resource can also curtail continued development of irrigation in the water-short regions of the West.

Irrigation efficiency can be increased by installation and management of irrigation methods suited to site conditions. Proper management, such as timing of irrigation and use of proper flow rates, application times, surface preparation, length of runs, and reuse systems will improve water use efficiencies of gravity methods. Farmers are learning to improve irrigation timing by measuring soil-moisture-using methods, such as the "ball-test," gypsum blocks, and tensionmeters. Water application methods such as sprinkler or drip systems, are generally more efficient than gravity systems. Moreover, reuse of water in gravity irrigation also reduces the needed water diversions. Along the same lines already demonstrated in California, municipal waste water can be reclaimed for use in irrigation.

Injudicious Agricultural Practices

Cultivation of agricultural land increases the potential for topsoil to be carried to streams by rain or irrigation water. The proportion of eroded soil that actually reaches streams depends, of course, on the specific physical characteristics of the land and on the specific cultivation practices used. The best available estimates on the proportion of a ton of soil washed from fields into streams range from 0 to 60 percent.

Because of this variation, the exact relationship between agricultural production and stream sedimentation is not precisely known. However, we do have data on the relationship between cropland use practices and the amount of soil eroded from fields. If all other technical factors vary evenly over different regions of the country, the data on erosion and the data on stream sedimentation closely correspond.

Table III-38 shows projections of total annual soil loss during the production of major crops by the year 2000. Data on current soil erosion are presented in the section on erosion and sedimentation in Part III of this report. The projections assume that farmers will adopt soil conservation practices in response to environmental quality policies to achieve clean water environmental goals by the year 2000.

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Table III-38.—Projected annual soil loss for production of major crops by 2000

Region	Total soil loss	Average soil loss per acre
	(million tons)	(tons)
New England (1)	0.4	1.0
Mid Atlantic (2)	27.0	3.4
South Atlantic-Gulf (3)	105.4	5.8
Great Lakes (4)	33.6	1.6
Ohio (5)	93.6	3.4
Tennessee (6)	9.8	3.9
Upper Mississippi (7)	216.5	3.7
Lower Mississippi (8)	89.6	5.7
Souris-Red-Rainy (9)	19.6	1.1
Missouri (10)	262.9	3.4
Arkansas-White-Red (11)	72.2	2.0
Texas-Gulf (12)	46.6	3.0
Rio Grande (13)	4.0	2.7
Upper Colorado (14)	2.6	2.5
Lower Colorado (15)	0.8	0.6
Great Basin (16)	2.7	1.7
Pacific Northwest (17)	43.6	3.8
California (18)	3.5	0.8
Total and average loss Regions 1-18	1,034.4	3.2

Regional variations result from differences in average soil types and the topography of the land. The Lower Mississippi and South Atlantic Gulf Regions are projected to average 5.7 and 5.8 tons per acre per year by 2000. The California (South Pacific) and Lower Colorado Regions should average less than a ton of soil eroded per acre.

Continued soil erosion at present rates has significant implications for both the long-term productivity of the Nation's agriculture and the quality of its water resources. Whether society should allow its agricultural lands to be "mined" in this manner is a difficult question. However, because this soil depletion reduces water quality, public action is needed to help achieve a more satisfactory economic and environmental situation.

Another agriculture-related water quality problem is livestock waste drainage. Over one fourth of all beef cattle raised in the major producing states were fed in operations that have potential waste drainage problems.

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For example, over 80 percent of the beef in Illinois and more than 50 percent of the beef in Nebraska were produced under such conditions. Moreover about one third of the hogs in the major producing states were fed in operations with significant waste drainage problems. Individual state data are not available for hogs, but the Corn Belt and Lake states, the center of U.S. pork production, fed 35.6 percent of its hogs under circumstances in which drainage of wastes posed a problem to water quality.

Conversion of Other Lands

In the estimated percent increase of land for agriculture that was mentioned earlier, the contribution of acres converted from wet soils is included. Federal laws and policies restrict any Federal involvement in the conversion of wet soils or wetlands to pastureland or cropland. However, private landowners continue to convert such lands to agricultural use. Between 1955 and 1975, 6 million acres of wetlands were lost. These wetlands provide food and cover for waterfowl, wildlife, and sport and commercial fish. They also provide breeding and wintering habitat for waterfowl, especially along migrating routes. They can also retain flood waters and trap pollutants. Uncontrolled conversion of these lands could seriously upset critical ecological balances.

Another type of land-use modification that presents a problem is conversion of forests and pasturelands to croplands. By 2000, this type of conversion is projected to be about 11 million acres. Although this may be offset to some degree by croplands with wet soils being converted to forest or pastureland, careful management of such activities must prevent undue stress on the environment by such shifts.

National and State-Regional Futures

Both futures show essentially equal increases in total cropland harvested, but there are considerable differences in the current and future irrigated farmland (Table III-39). The sum of the available State-Regional Futures shows an increase of about 18 million irrigated acres (33 percent) between "1975" and 2000 whereas the National Future shows an increase of only 7 million irrigated acres (15 percent); both increases assume that the major increases in irrigated acreage will be due primarily to an increase in the number of private projects, not in Federally-funded projects.

As shown in Table III-39, the largest differences between the National and State-Regional Futures are concentrated in the central part of the Nation. The reasons for those differences vary by region. In the Texas-Gulf Region, the primary reason for the difference is that the National Future assumed that by year 2000 ground-water overdraft would significantly reduce the amount of irrigation. The state of Texas, however, estimates that the effect of overdraft will not cause a decline in irrigated acreage until after 2010 or 2020.

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Table III-39.—Comparison of National and State-Regional Futures for increases in irrigated farmland, "1975"-2000
(million acres)

Region	National "1975"	Increase in irrigated farmland, "1975" to 2000			
		National Future (NF)		State-Regional Future (SRF)	
		Absolute increase[a] (decrease)	Increase[a] (percent)	Absolute increase	Increase (percent)
New England (1)	0.04	0.01	33	0.01	33
Mid-Atlantic (2)	0.26	0.21	80	0.27	90
South Atlantic Gulf (3)	2.04	1.00	49	1.27	57
Great Lakes (4)	0.16	0.17	104	0.17	104
Ohio (5)	0.06	0.05	79	0.05	79
Tennessee (6)	0.02	0.008	53	0.005	100
Upper Mississippi (7)	0.20	0.23	112	0.39	161
Lower Mississippi (8)	1.97	0.89	45	0.34	14
Souris-Red-Rainy (9)	0.04	0.28	764	0.42	1,161
Missouri (10)	9.70	1.81	19	5.94	52
Arkansas-White-Red (11)	4.77	0.78	16	N/A	N/A
Texas-Gulf (12)	4.77	(1.33)	(28)	2.83	53
Rio Grande (13)	1.98	(0.12)	(6)	.53	24
Upper Colorado (14)	1.37	0.26	19	0.33	22
Lower Colorado (15)	1.28	(0.16)	(13)	0.03	3
Great Basins (16)	1.74	(0.12)	(7)	0.01	>1
Pacific Northwest (17)	6.19	1.57	25	2.23	30
California (18)	8.73	1.35	15	1.46	16
Alaska (19)	0.004	0	0	N/A	N/A
Hawaii (20)	0.14	0.008	6	0.008	6
Caribbean (21)	0.07	0.008	11	0.008	11
Total, Regions 1-18	45.30	6.91	15	N/A	N/A
Total, Regions 1-21	45.52	6.92	15	N/A	N/A

N/A - Not available.

[a]Decrease shown in parenthesis.

In the Missouri Region, the primary reason for the difference lies in the fact that the SRF estimates that recent trends of installing center-pivot irrigation systems without Federal assistance will continue into the future considerably faster than what is projected in the National Future. Also, in the South-Atlantic Gulf Region indications are that irrigation development may be above the National trend, and in the states of North Carolina, South Carolina, and Georgia, it may be substantially higher.

Summary

Growth in world population and increases in per capita income will substantially raise the demand for United States food and fiber products over the next 25 years. This will require greater productivity of the

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Nation's land resources. At the same time, concern about environmental quality draws attention to the agricultural use of the Nation's water and land resources. These two forces--increased demand for food and fiber products and concern for environmental quality--will lead to more frequent future tradeoffs between the food and fiber demand and the environmental goals.

Food and fiber production currently accounts for nearly one-half of all fresh water withdrawn and 81 percent of the fresh water consumed from surface- and ground-water sources in the United States. Agriculture is projected to maintain its predominant role in the use of United States water resources. In particular, irrigated agriculture is projected to expand from its present base of 45.5 million acres to 52.4 million acres by the end of this century. This in turn will increase consumptive use of irrigation water from 86 bgd to 93 bgd.

In many areas of the United States, available water is fully appropriated, limiting the expansion of agriculture in these areas. Under "dry-year" assumptions, agriculture's water supply will be completely used by 2000 in much of the West. Agriculture in large parts of the Missouri, Arkansas-White-Red, Texas-Gulf, Rio Grande, Upper and Lower Colorado, Great Basin, and California Regions currently uses over 90 percent of the available water, or will do so by 2000. For that reason, any additional water required for other uses--navigation, fish and wildlife maintenance, recreation, waste assimilation, or energy development--would have to come from the allocation for irrigation, which would probably lead to a reduced agricultural production in many of these areas.

Overdraft of ground water in large portions of the Great Plains is expected to reduce substantially the availability of water for agriculture by 2000. Adjustment to the reduction will be a major policy issue in the water resources field.

Agricultural pollutants entering streams present a significant water quality problem in both the humid East and the arid West. Erosion of topsoil, leaching of pesticides and fertilizers, drainage from feed lots, and irrigation-induced stream salinity are the principal forms of agricultural water pollution. Application of more stringent restrictions to reduce agricultural pollutants could reduce the cropland reserve even further.

At present, United States agriculture has a cropland reserve of about 40 to 50 million acres that are low quality lands with high economic costs of crop production. This reserve fluctuates from year to year, depending on world food demand, climatic conditions, and stored grain reserves. The development of wetland areas into productive cropland is projected to affect (an increase of about 24 percent) the supply capability of the food and fiber sector between "1975" and 2000. Improved production technology and the continuing adoption of technological improvements by farmers between now and 2000 are expected to keep pace with the commodity demand to maintain a substantial cropland reserve.

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Water for Energy Production

Energy has become a necessity for man. In "1975," the United States used over 70 quadrillion Btu's of energy. The production of this energy required over 142 billion gallons of water per day from fresh surface- and ground-water and saline sources. The largest amount of water for energy production is used to dispose of waste heat produced by the conversion of heat energy to electricity. In "1975," water withdrawals for steam electric power generation accounted for 96 percent of withdrawals for total energy production and 94 percent of total fresh-water withdrawals for all uses. Although the production of electricity from steam requires large water withdrawals, in "1975" it accounted for less than 2 percent of total fresh-water consumption in the Nation. Water is also needed to mine base energy resources and to refine petroleum. These uses are discussed in the sections on minerals and manufacturing.

This section contains estimates of energy use and production in "1975" and projections for 1985 and 2000, as well as the water requirements associated with energy production. The section also discusses potential changes in water use and the implications associated with such changes.

Some information given in the following "background" paragraphs is also contained in part in other sections dealing with offstream uses (e.g., water for minerals production). However, the total past, current, and future energy consumption by fuel source is presented here to compare the overall consumption of fuels with the specific fuels required to produce steam electric power. Since the offstream use of water for steam electric power generation withdraws such vast quantities of water, this section focuses on that specific water use. The instream use of water for hydroelectric power is discussed in conjunction with other instream uses.

Background

The availability of water resources has been fundamental to the rapid growth in man's dependence on electricity. Development and application of hydroelectric power technologies in the 19th century profoundly affected American industry, transportation, and life styles. The change was continued with the invention of steam turbines to drive electric generators. Condensers require high volumes of water to condense the steam to liquid form after it passes through the turbine.

A series of complex factors involving national energy supply and demand has recently focused attention on the role of water in energy production. These factors include national energy self-sufficiency, national economic activity, labor productivity, new sources of energy, environmental concerns including air and water pollution control, and technological changes. The collective effects of these factors should increase the volume of water required for energy production, both nationally and regionally. Several examples are: (1) the implementation of environmental standards for thermal

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discharges requires installation of evaporative cooling towers which will increase water consumption; (2) initiatives for the water-demanding extraction and processing of oil shale and coal resources in the West put even larger water demands on water-short regions; and (3) development of nuclear powerplants that consume substantially greater quantities of water per unit of electricity produced than fossil fuel plants.

Assumptions

The water-use projections for energy production presented in this section anticipate broad national policy commitments to energy conservation efforts, technological advances in use of renewable energy resources, satisfaction of environmental goals, and maintenance of high levels of economic activity.

Although water supply for energy production may be a critical concern in some areas of the United States, it has not been assumed as a constraint to development, except as may be reflected in utility decisions for proposed powerplants. Continued development of nuclear powerplants is also assumed, but with no bias toward any side of current debates on this subject.

Definition of Terms

The terms used in this section are straightforward or consistent with other sections. The following definitions are provided to aid the reader. Gross water demand is the amount of water needed to run the plant. Withdrawal is the volume of water taken from the water source to meet gross water demands; the amount is equivalent to the sum consumed and the amount discharged as waste water. Consumption is the difference between the amount of water withdrawn and the amount returned as waste water. Consumption results from evaporation (direct or induced) or incorporation of the water into the end product such as in coal liquefaction. Total energy production is the sum of all energy outputs, including those derived from gas and oil, coal and coal gasification, and electric power; for comparison with electric power outputs in gigawatt hours, the energy produced from the various fuels is converted to quads. A gigawatt hour equals 1 million kilowatt hours and requires about 9 billion Btu's of heat energy input, depending on the thermal efficiency of the conversion facility. A quad (quadrillion) equals 10^{15} Btu's.

Sources and Reliability of Data

The projections for the National Future include: (1) fuels production forecasts made by the Bureau of Mines, U.S. Department of the Interior, (2) electric power demand and supply projections made by the Federal Power Commission (reorganized into the present Federal Energy Regulatory Commission), and (3) petroleum refining forecasts made by the U.S. Department of Commerce. The projections predate work recently completed by the Energy Information Administration of the U.S. Department of Energy as part of its responsibilities under the Federal Energy Administration Act of 1974.

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These later sets of projections reflect more up-to-date considerations of rapidly changing conditions such as costs, rates of consumption, fuel mixes, public conservation ethic, and implementation of specific Federal and State regulatory initiatives. They are included with the data in this section for comparative purposes (Table III-40).

Energy Consumption and Production

Water needed for energy production varies with the type of fuel used to produce the energy. To put the water use for electric power generation into a wider perspective, the following discussion first, gives the consumption of fuels for total energy production, then compares these to the fuels consumed for electric power generation, and finally shows regional variations in use of fuels for electric power generation.

The historical and projected consumption by fuel sources are shown on Figures III-10 and III-11 and on Tables III-41 and III-42. These exhibits also show projected changes in the distribution of fuel types. Even though petroleum consumption is expected to increase, its relative share in overall energy produced should decline from 46 percent to 32 percent by 2000. Energy production from natural gas is projected to decrease after 1980; the relative importance of gas as an energy source will decline from 28 percent of total energy consumption in "1975" to only 12 percent in 2000. During that period the output of hydroelectric power from run-of-river and pumped-storage plants will increase by one-third from its present level, but its relative share will decline slightly. Consumption of coal for energy production should increase by over 165 percent, but coal's share of total production will remain fairly constant at about 20 percent. By the year 2000, nuclear energy production is projected to increase dramatically by more than 30 times the "1975" level, with its share increasing from 3 to 28 percent of total energy consumption.

The sources of fuel for power generation provide another perspective on the composition of energy production. Of the fuels consumed for total energy production in "1975," 92 percent came from fossil fuels, 5 percent from hydropower generation, and less than 3 percent from nuclear fuels (Table III-42). On the other hand, 76 percent of electric power generation was derived from fossil fuel, 15 percent from hydropower, and 9 percent from nuclear fuels. In "1975," fossil fuels dominated both total energy production and electric power generation. By the year 2000, however, fossil fuel should be used largely for other types of energy conversion (65 percent of total energy consumption) and nuclear fuels will be the primary source (65 percent of electric power generation). By 2000, electric power generation will consume about 62 percent of the fuels used for total energy production as compared with 21 percent in "1975." (See Figure III-12.)

Electric Power Generation

The two principal methods of electric power generation in the United States are the conversion of heat energy to electricity by steam electric

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Table III-40.—Projected consumption of energy in the United States
(quadrillion Btu)

Base energy resource	1985 Second Assessment[a]	1985 EIA[a,b]	2000 Second Assessment[a]	2000 EIA[a,d]
Coal	21.3	21.2	34.8	32.6
Petroleum	45.6	44.2	51.2	45.7
Natural gas	20.1	19.1	19.6	19.0
Nuclear	11.8	6.2	46.1	28.5
Oil shale, biomass	0.9	0.1	5.7	6.9
Hydropower, geothermal	3.9	4.2	6.1	5.8
TOTAL	103.6	95.0	163.5	138.5
User sector				
Residential and commercial	16.5	15.0	17.0	N/A
Industrial	22.8	26.7	25.3	N/A
Transportation	23.7	21.3	28.8	N/A
Electric generation	39.1	28.7	78.5	N/A
Other	1.5	3.3	13.9	N/A
Total	103.6	95.0	163.5	

N/A - Not abailable.

[a] National Future, Second National Water Assessment; estimates provided by the Federal Power Commission.

[b] Volume 11, 1977, "Projections of Energy Supply and Demand and Their Impacts," Energy Information Administration, U.S. Department of Energy, April 1978.

[c] Medium Demand, Medium Supply Case.

[d] Base case within a study performed by The Brookhaven National Laboratory and Dale Jorgensen Associates.

plants (about 85 percent of the present total national generation) and the conversion of hydraulic energy in falling water by hydroelectric plants (about 15 percent of the present total national generation).

National Future projections of electric power requirements were made for each of the 50 Federal Energy Regulatory Commission power supply areas (PSA's). The PSA projections were grouped into 19 power market areas -- 16 within the conterminous United States and one each for Alaska, Hawaii, and Caribbean Regions.

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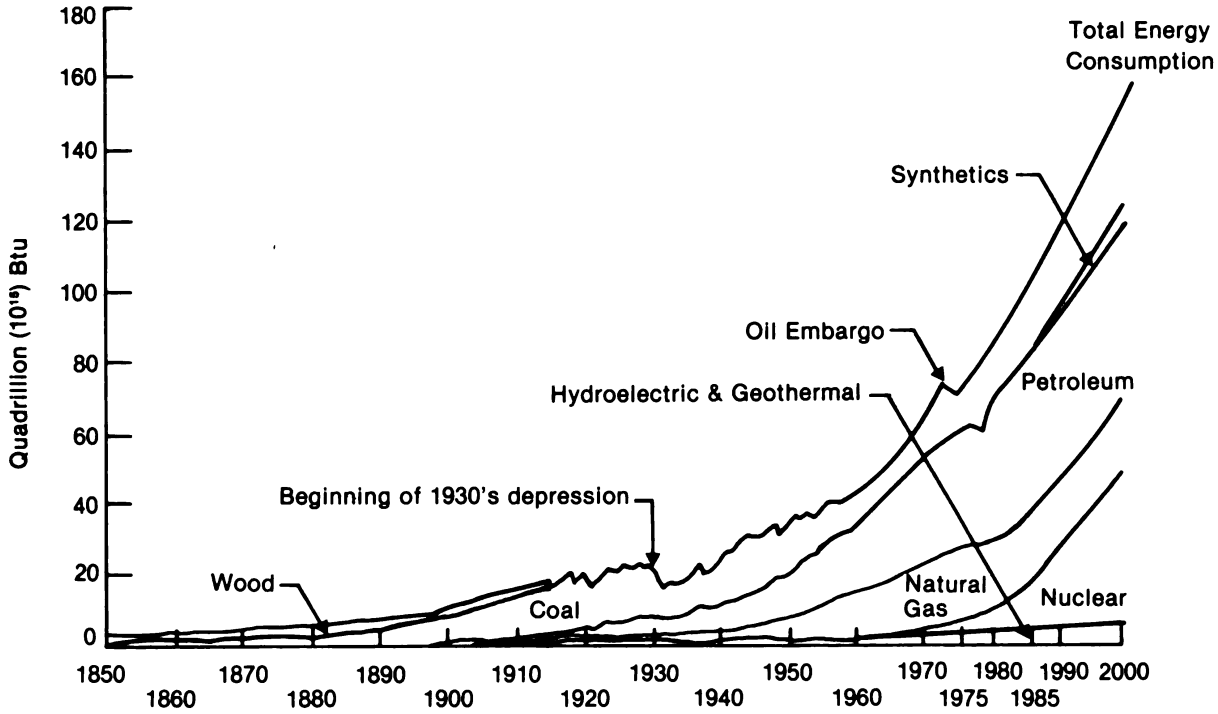

Figure III-10.—Energy consumption by fuel source, 1850-2000

The projections were based on historical trends through 1973 for each PSA. From regression and correlation analyses, extrapolations to 1985 and 2000 were made. The extrapolations were adjusted to make them consistent with the Series E OBERS population and economic projections. These energy requirements were then aggregated on a regional basis, compared with regional and national forecasts, and checked for reasonableness by determining and comparing the per capita use. Additional adjustments were made to account for changes in electric energy use associated with the oil embargo, the 1974-75 recession, and ensuing commitments to more efficient energy use. The National Future projections were separately developed by source of fuels used in generation for each of the target years of "1975," 1985, and 2000.

The generating capacity available in "1975" to supply these power requirements consisted of existing generating units and new units scheduled for operation in "1975." Generation by individual units was based on historical operation modified to reflect load changes and the types of new generation scheduled to be added.

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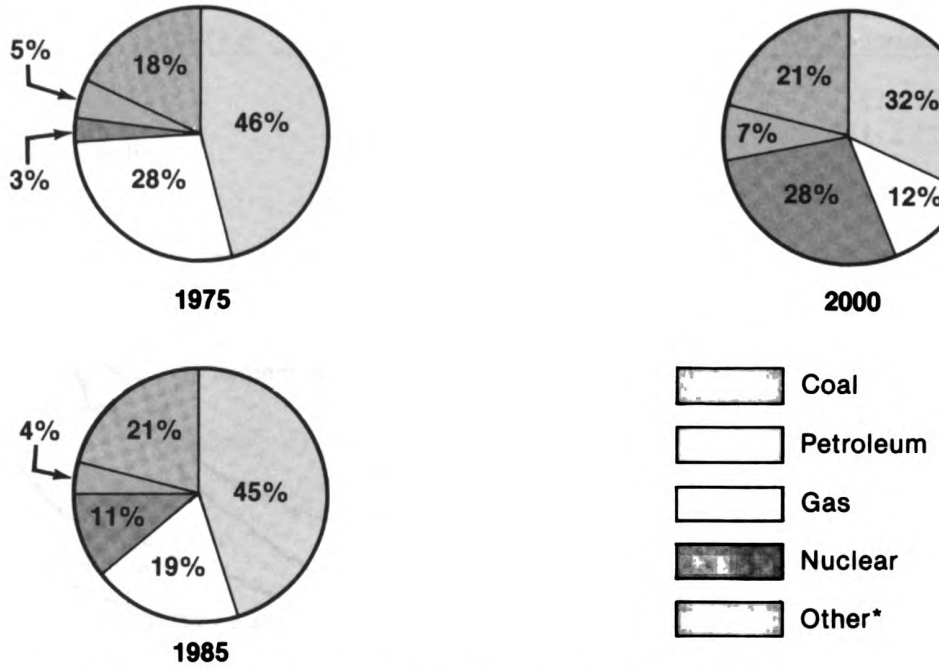

* Other includes hydroelectric, synthetic fuels, geothermal, solar and wind.

Figure III-11.—Current and projected energy consumption by fuel source—"1975," 1985, 2000

Conventional hydroelectric and steam electric (nuclear and fossil-fueled) capacity and generation are projected to increase by about 384 percent from "1975" to 2000. This increase reflects an average annual growth of about 6 percent. The historical increase in electrical generation has been about 7 percent annually for the Nation. This projected increase is not evenly distributed among types of generating plants. Conventional hydroelectric plants are projected to generate about 20 percent more in 2000 than they did in "1975," while nuclear powerplants are projected to generate 5.9 million gWh in 2000, over 30 times their generation in "1975." (See Table III-43.)

Several technological changes could substantially influence future electric load growth. National energy self-sufficiency may involve a significant change from liquid-fueled to electric-powered vehicles, which would increase electric energy requirements. Additionally, sulfur scrubbers for air emission control on more than half of the coal-fired plants will be required to meet existing air quality standards. Once sulfur scrubbers are installed, output from the plants will be reduced by 6 to 8 percent, with a corresponding increase in capacity. Conversely, several

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Table III-41.—Energy consumption by fuel source, 1950-2000
(quadrillion Btu)

	Historical[a]			Projected[b]		
Fuel source	1950	1960	1970	"1975"	1985	2000
Coal	12.9	10.1	12.9	13.1	21.3	34.8
Petroleum	13.5	20.1	29.6	32.7	45.6	51.2
Natural gas[c]	6.2	12.7	22.0	20.4	20.1	19.6
Nuclear[c]	...	0.1	0.2	1.8	11.8	46.1
Hydroelectric	1.4	1.7	2.7	3.3	3.5	4.3
Synthetic fuels	...	...	...	...	0.6	2.5
Geothermal	...	...	...	...	0.2	1.8
Solar	...	...	...	...	...	0.3
Wind and other	...	...	...	0.3	0.2	1.9
Total	34.0	44.6	67.4	71.6	103.1	162.5

Sources:

[a]United States Federal Energy Administration, 1974, "Project Independence," Project Independence Report, Appendix AI, p. 9-16: U.S. Government Printing Office, Washington, D.C. (November 1974).

[b]Estimated for the Second National Water Assessment by the Federal Power Commission (now Federal Energy Regulatory Commission), Bureau of Mines, Federal Energy Administration, and Energy Research and Development Administration.

[c]Includes imports.

emerging technologies such as fluidized-bed boilers, which would eliminate the need for sulfur scrubbers, could reduce electric load growth.

Regional Variations in Electric Power Generation

The largest electric power producing region in "1975" was the Ohio, followed closely by the other industrialized regions--South Atlantic-Gulf,

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Table III-42.—Total energy consumption and electric power generation by fuel source—"1975," 1985, 2000

Type of fuel used	Total energy production						Electric power generation					
	1975		1985		2000		1975		1985		2000	
	Quads	Percent	Quads	Percent	Quads	Percent	1,000 gWh	Percent	1,000 gWh	Percent	1,000 gWh	Percent
Fossil--	66.2	92	87.0	85	105.6	65	1,422	76	2,143	55	2,911	32
Nuclear--	1.8	3	11.8	11	46.1	28	171	9	1,456	38	5,865	65
Hydro--	3.3	5	3.3	3	4.3	3	280	15	261	7	298	3
Other--	0.3	>1	1.0	1	6.5	4	-	-	-	-	-	-
TOTAL	71.6	100	103.1	100	162.5	100	1,873	100	3,861	100	9,074	100

Mid-Atlantic, and Great Lakes (Table III-43). These four regions generated 51 percent of the Nation's electric power in "1975" and will continue to generate one-half of the Nation's electric power through 2000. The fastest rates of growth in electric power generation through 2000 (five times "1975" generation or more) will occur in the South Atlantic-Gulf, Upper and Lower Mississippi, Missouri, Arkansas-White-Red, Texas-Gulf, Great Basin, Alaska, and Caribbean Regions. By 2000, fossil fuel generation will grow more than three times the "1975" levels in the South Atlantic-Gulf, Missouri, Upper Colorado, Great Basin, Pacific Northwest, Alaska, Hawaii, and Caribbean Regions. The fastest growth in nuclear generation by 2000 (more than 50 times the "1975" load) will occur largely in those regions with little or no nuclear generation capacity in "1975," namely the Ohio, Tennessee, Lower Mississippi, Arkansas-White-Red, Texas-Gulf, and Pacific Northwest Regions. Except for New England, Ohio, Upper Colorado, Pacific Northwest, and Alaska, most regions are projected to decline in hydropower generation over the study period.

Water for Energy Production

Water is essential to energy development and production. It is used in extracting base energy resources, processing of these resources into usable fuels, conversion of fuels to more useful forms of energy, and disposal of wastes from all forms of energy production. Water also is used directly for hydroelectric generation, for transportation of base energy resources and fuels, for dissipation of waste heat (cooling) from steam electric generating plants, and for steam to drive steam electric generators.

Water withdrawal and consumption for energy production varies with the type of fuel being extracted, processed, and used. For example, estimates made in Project Independence (November 1974) indicate that mining of coal requires less than 1 gallon of water per million British thermal units (Btu), whereas the extraction of oil and gas requires about 3 gallons of water per million Btu (Table III-44). Oil processing refineries need about 7.6 gallons of water per million Btu; gas processing plants use about 1.7 gallons of water per million Btu; and nuclear fuel mining and

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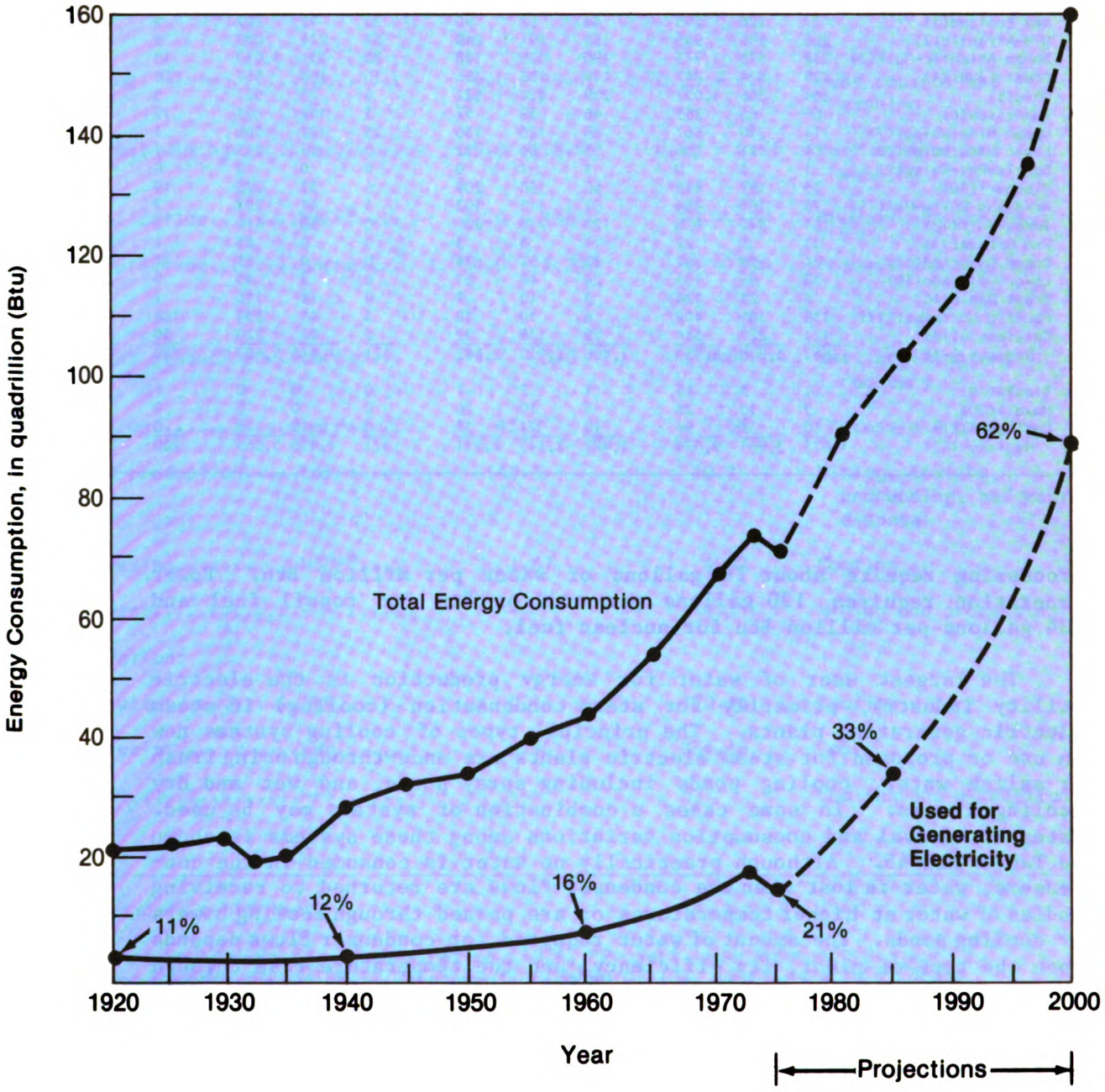

Figure III-12.—Energy consumption, 1920-2000

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Table III-43.—Electric power generation by fuel source—"1975," 1985, 2000
(1,000 gigawatt hours)

Region	Total electric power generation			Fossil fuels			Nuclear fuels			Hydropower		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
New England(1)	67	126	295	44	52	90	20	72	202	2	2	3
Mid-Atlantic(2)	200	406	903	158	191	249	37	211	650	5	4	4
South Atlantic-Gulf(3)	238	675	1,773	190	329	748	30	331	1,010	18	15	15
Great Lakes(4)	209	374	842	148	156	186	35	198	635	26	21	21
Ohio(5)	304	506	1,057	299	424	522	0	75	527	5	6	8
Tennessee(6)	68	163	263	46	39	57	3	109	191	19	15	15
Upper Mississippi(7)	114	250	667	88	126	156	25	122	509	1	1	1
Lower Mississippi(8)	54	121	366	53	80	72	0	40	293	1	1	1
Souris-Red-Rainy(9)	1	1	0	1	1	0	0	0	0	0	0	0
Missouri(10)	75	187	449	50	138	209	6	35	226	19	14	14
Arkansas-White-Red(11)	73	165	404	61	115	102	5	44	297	7	6	6
Texas-Gulf(12)	124	275	825	123	216	205	0	58	618	1	1	1
Rio Grande(13)	11	5	27	11	5	3	0	0	23	1	1	1
Upper Colorado(14)	24	58	91	23	57	74	0	0	13	1	1	3
Lower Colorado(15)	33	65	103	24	48	51	0	7	43	9	9	9
Great Basin(16)	4	25	124	3	10	9	0	14	115	1	1	1
Pacific Northwest(17)	138	189	409	6	10	18	3	45	235	128	134	156
California(18)	121	227	344	79	115	92	6	84	220	36	29	32
Regions 1-18	1,857	3,816	8,939	1,406	2,110	2,842	171	1,446	5,807	280	260	290
Alaska(19)	1	3	15	1	2	7	0	0	0	1	1	8
Hawaii(20)	5	10	26	5	10	26	0	0	0	0	0	0
Caribbean(21)	10	31	94	10	21	35	0	10	58	0	0	0
Regions 1-21	1,873	3,861	9,074	1,422	2,143	2,911	171	1,456	5,865	280	261	298

processing require about 14 gallons of water per million Btu. Power generation requires 120 gallons per million Btu for fossil fuel and 234 gallons per million Btu for nuclear fuel.

The largest user of water for energy production is the electric utility industry, primarily for steam condensation (cooling) in steam electric generating plants. The principal types of cooling systems now in use or proposed for steam electric plants are once-through using fresh or saline water, cooling ponds including spray ponds, and wet and dry cooling towers. In some cases a combination of systems may be used. Water withdrawal and consumption variations among these systems is shown on Table III-45. Although practically no water is consumed in the condensers, water is lost when the condenser flows are returned to receiving bodies of water at higher temperatures or are passed through cooling towers or cooling ponds. The amount of water required for condenser flows depends upon the type of plant, its efficiency, and the temperature rise through the condensers.

The production of steam electric energy accounted for nearly 26 percent of fresh-water withdrawals for all uses, but less than 1 percent of total fresh-water consumption in "1975" (Table III-2). By 2000, fresh-water withdrawals for steam electric energy production will remain about the same for total withdrawals, but consumption will increase to nearly 8 percent of total consumption. Consumptive use will increase from less than 2 percent of "1975" withdrawals for energy production to more than

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Table III-44.—Typical unit water requirements for energy production

Fuel and Process by standard unit	Gallons per standard unit	Gallons per million Btu	Major use
Coal:			
Western coal mining.....ton.....	6.0 - 14.7	0.25 - 0.61	Dust control and washing
Eastern coal mining.....ton.....	15.8 - 18.0	0.66 - 0.75	Dust control and washing
Coal gasification.....MSCF[a]....	72.0 - 158	72 - 158	Process and cooling
Coal liquefaction.....barrel...	1,134.0 - 1,750	31 - 200	Process and cooling
Petroleum:			
Oil and gas production...barrel...	1.7 - 3.0	3.05	Well drilling and recovery
Oil refining.....barrel...	43.0	7.58	Process and cooling
Oil shale production.....barrel...	145.4	30.1	Mining, cooling, processing, and waste disposal
Gas processing.....MSCF[a]....	1.67	1.67	Cooling
Nuclear fuels:.....---.....	---	14.3	Mining and processing
Power generation:			
Fossil fuels.....kWh.....	0.41	120.16	Cooling
Nuclear fuels.....kWh.....	0.80	234.46	Cooling
Geothermal.....---.....	---	527	Cooling and extraction

[a]Million standard cubic feet.

United States Federal Energy Administration, 1974, "Project Independence," Project Independence Report, p. 304: U.S. Government Printing Office, Washington, D.C. 20402.

13 percent of 2000 withdrawals due to installation of cooling towers at existing facilities. Tables III-46 through III-49 show the fresh-water withdrawals and consumption. Saline-water withdrawals are shown for those regions using saline water on Table III-50.

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Table III-45.—Withdrawal and consumption factors for steam electric plant processes

Steam electric plants	Cooling System					
	Once-through		Cooling ponds		Cooling towers	
	Fossil[a]	Nuclear	Fossil[a]	Nuclear	Fossil[a]	Nuclear
Installed before "1975"						
Heat output rate, Btu per kWh	9,800	10,500	9,800	10,500	9,800	10,500
Water withdrawal, gallons per kWh[b]	0.45	0.60	0.54	0.72	0.83	1.11
Water consumption, gallons per kWh	0.28	0.37	0.36	0.48	0.56	0.74
Installed by 1985						
Heat output rate, Btu per kWh	9,700	10,300	9,700	10,300	9,700	10,300
Water withdrawal, gallons per kWh[b]	0.45	0.59	0.53	0.71	0.82	1.08
Water consumption, gallons per kWh	0.27	0.36	0.36	0.47	0.55	0.72
Installed by 2000						
Heat output rate, Btu per kWh	9,600	10,000	9,600	10,000	9,600	10,000
Water withdrawal, gallons per kWh[b]	0.44	0.56	0.53	0.68	0.81	1.03
Water consumption, gallons per kWh	0.27	0.34	0.35	0.45	0.54	0.69

[a] Reflects base load operation (greater than 40 percent plant factor).

[b] Withdrawal for once-through cooling based on condenser temperature rise of 13°F.

Note: Consumption factors reflect assumption that 50, 65, and 100 percent of waste heat from the condenser will be dissipated through evaporative processes for once-through, cooling ponds, and cooling towers, respectively.

In hydroelectric plants, the power produced is directly proportional to the quantity of water passing through the plant and the vertical drop (head) of water through the turbine. Little water is consumed except through surface evaporation. Pumped storage projects also consume little water.

Withdrawal and consumption of water for steam electric power generation are directly related to the efficiency of the conversion of the fuel energy to electricity (Table III-45). A measure of generating plant efficiency is its "heat rate," the amount of fuel energy measured in terms of heat equivalent that is required to produce 1 kilowatt-hour of net electrical energy. Fossil plant efficiencies improved from about 21 percent

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Table III-46. – Fresh-water withdrawals for energy production – "1975", 1985, 2000
(million gallons per day)

Region	Mining fuels			Refining petroleum			Steam electric generation			Total energy production		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
New England(1)	0	0	0	16	8	5	1,263	1,069	375	1,279	1,077	380
Mid-Atlantic(2)	21	19	22	562	228	137	7,463	7,130	4,657	8,046	7,377	4,816
South Atlantic-Gulf(3)	68	85	86	28	32	25	12,768	12,912	13,952	12,864	13,029	14,063
Great Lakes(4)	14	18	21	687	141	95	24,362	22,689	16,061	25,063	22,848	16,177
Ohio(5)	183	288	334	114	52	48	21,022	21,008	10,574	21,319	21,348	10,956
Tennessee(6)	8	14	21	0	0	0	4,799	5,738	4,581	4,807	5,752	4,602
Upper Mississippi(7)	20	33	48	50	36	33	7,644	6,347	3,537	7,714	6,416	3,618
Lower Mississippi(8)	644	841	1,065	441	220	150	4,175	9,313	16,687	5,260	10,374	17,902
Souris-Red-Rainy(9)	4	4	4	0	0	0	82	23	0	86	27	4
Missouri(10)	144	198	236	91	36	29	3,540	5,834	4,938	3,775	6,068	5,203
Arkansas-White-Red(11)	172	190	185	74	75	94	498	1,026	1,012	744	1,291	1,291
Texas-Gulf(12)	837	902	930	312	496	479	724	1,000	1,713	1,873	2,398	3,122
Rio Grande(13)	153	151	147	0	0	0	34	16	10	187	167	157
Upper Colorado(14)	68	97	171	4	1	1	103	157	201	175	255	373
Lower Colorado(15)	7	6	8	1	1	0	68	150	154	76	157	162
Great Basin(16)	1	1	1	8	7	7	33	65	82	42	73	90
Pacific Northwest(17)	3	4	6	11	12	15	260	203	580	274	219	601
California(18)	193	235	217	123	147	100	42	158	367	358	540	684
Regions 1-18	2,540	3,086	3,502	2,522	1,492	1,218	88,880	94,838	79,481	93,942	99,416	84,201
Alaska(19)	12	133	342	1	1	1	36	20	11	49	154	354
Hawaii (20)	0	0	0	5	6	6	0	0	0	5	6	6
Caribbean (21)	0	0	0	0	0	0	0	0	0	0	0	0
Regions 1-21	2,522	3,219	3,844	2,528	1,499	1,225	89,916	94,858	79,492	94,996	99,526	84,561

(16,500 Btu/kWh) in 1938 to 33 percent (9,800 Btu/kWh) in 1965. However, only slight increases in efficiencies are projected through the year 2000. The increase will depend on several factors, including the extent of air pollution control requirements that must be satisfied. Plants that use fossil fuels and require stack emission control equipment would have about 5 percent higher heat rates (and lower efficiencies) than those without such equipment. Heat rates for modern steam electric plants placed in operation before the year 2000 are expected to have heat rates varying between 9,600 and 10,000 Btu per kWh.

Heat rate is influenced by other factors including the temperature and pressure of the steam leaving the boiler. Most modern fossil fuel plants are designed to operate at temperatures of about 1,000 F and at gage pressures of 2,400 to 3,500 pounds per square inch (psi). Because of safety considerations, nuclear plants are designed to operate at temperatures and pressures somewhat lower than fossil fuel plants. Consequently, their thermal efficiencies are lower than fossil fuel plants and the waste heat per unit of generation that must be discharged is about 30 percent greater. Breeder reactors and higher temperature gas-cooled reactors should have efficiencies approaching those of new fossil plants.

The consumptive use of water within a modern 1,000 megawatt coal-fired steam electric plant using wet cooling towers and operating at 70 percent plant factor is estimated at about 9 million gallons per day

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Table III-47. – Fresh-water consumption for energy production – "1975", 1985, 2000
(million gallons per day)

Region	Mining fuels			Refining petroleum			Steam electric generation			Total energy production		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
New England(1)	0	0	0	3	4	4	21	18	167	24	22	171
Mid-Atlantic(2)	12	11	12	71	87	109	103	224	644	186	322	765
South Atlantic-Gulf(3)	55	66	64	12	15	20	153	722	1,857	220	803	1,941
Great Lakes(4)	8	10	11	51	56	74	175	497	1,384	234	563	1,469
Ohio(5)	57	82	96	23	27	38	324	656	1,692	404	765	1,826
Tennessee(6)	1	3	4	0	0	0	42	231	417	43	234	421
Upper Mississippi(7)	4	6	9	18	19	26	129	352	1,079	151	377	1,114
Lower Mississippi(8)	167	212	99	66	80	119	54	118	291	287	410	509
Souris-Red-Rainy(9)	2	2	2	0	0	0	1	0	0	3	2	2
Missouri(10)	96	122	142	20	19	24	68	239	637	184	380	803
Arkansas-White-Red(11)	114	128	130	44	51	75	89	237	457	247	416	662
Texas-Gulf(12)	532	564	598	170	224	382	99	270	991	801	1,058	1,971
Rio Grande(13)	86	90	88	0	0	0	18	9	5	104	99	93
Upper Colorado(14)	38	56	111	2	0	1	39	106	151	79	162	263
Lower Colorado(15)	5	4	5	1	0	0	63	134	126	69	138	131
Great Basin(16)	1	1	1	4	4	6	3	42	52	8	47	59
Pacific Northwest(17)	2	2	4	6	8	13	13	104	344	21	114	361
California(18)	169	210	192	57	64	79	25	101	242	251	375	513
Regions 1-18	1,349	1,569	1,568	548	658	970	1,419	4,060	10,536	3,316	6,287	13,074
Alaska(19)	11	120	308	0	0	1	0	2	5	11	122	314
Hawaii (20)	0	0	0	3	4	5	0	0	0	3	4	5
Caribbean (21)	0	0	0	0	0	0	0	0	0	0	0	0
Regions 1-21	1,360	1,689	1,876	551	662	976	1,419	4,062	10,541	3,330	6,413	13,393

Table III-48. – Fresh-water withdrawals for total energy consumption and electric power generation by fuel source – "1975," 1985, 2000

Type of fuel used	Total energy consumption						Electric power generation					
	"1975"		1985		2000		"1975"		1985		2000	
	Bgd	Percent	Bgd	Percent	Bgd	Percent	Bgd	Percent	Bgd	Percent	Bgd	Percent
Fossil--------	76.9	82	45.0	45	20.8	24	71.8	81	40.2	42	15.9	20
Nuclear--------	17.3	18	54.7	55	64.2	76	17.3	19	54.7	58	64.2	80
Hydro---------	-	-	-	-	-	-	-	-	-	-	-	-
Other---------	-	-	-	-	-	-	-	-	-	-	-	-
Total-------	94.2	100	99.7	100	85.2	100	88.9	100	94.9	100	79.5	100

(mgd) for cooling and about 1 mgd for sulfur removal. Water consumption for sulfur removal will be about 135 billion gallons in the year 2000 or an average of 370 mgd. Most of this water will be evaporated, but some will percolate with the remainder to ground water by seepage from settling ponds.

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Table III-49.—Fresh-water withdrawals and consumption for steam electric generation—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	1,263	1,069	375	21	18	167
Mid-Atlantic (2)	7,463	7,130	4,657	103	224	644
South Atlantic-Gulf (3)	12,768	12,912	13,952	153	722	1,857
Great Lakes (4)	24,362	22,689	16,061	175	497	1,384
Ohio (5)	21,022	21,008	10,574	324	656	1,692
Tennessee (6)	4,799	5,738	4,581	42	231	417
Upper Mississippi (7)	7,644	6,347	3,537	129	352	1,079
Lower Mississippi (8)	4,175	9,313	16,687	54	118	291
Souris-Red-Rainy (9)	82	23	0	1	0	0
Missouri (10)	3,540	5,834	4,938	68	239	637
Arkansas-White-Red (11)	498	1,026	1,012	89	237	457
Texas-Gulf (12)	724	1,000	1,713	99	270	991
Rio Grande (13)	34	16	10	18	9	5
Upper Colorado (14)	103	157	201	39	106	151
Lower Colorado (15)	68	150	154	63	134	126
Great Basin (16)	33	65	82	3	42	52
Pacific Northwest (17)	260	203	580	13	104	344
California (18)	42	158	367	25	101	242
Total, Regions 1-18	88,880	94,838	79,481	1,419	4,060	10,536
Alaska (19)	36	20	11	0	2	5
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	88,916	94,858	79,492	1,419	4,062	10,541

Table III-50.—Saline-water withdrawals for steam electric power generation—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals		
	"1975"	1985	2000
New England (1)	4,831	14,604	10,161
Mid-Atlantic (2)	16,997	28,634	26,208
South Atlantic-Gulf (3)	7,009	14,976	20,239
Lower Mississippi (8)	320	1,590	10,181
Texas-Gulf (12)	4,139	4,950	10,371
Pacific Northwest (17)	131	9	10,652
California (18)	14,088	22,090	24,658
Total, Regions 1-18	47,515	86,853	112,470
Alaska (19)	67	44	420
Hawaii (20)	1,085	2,005	3,637
Caribbean (21)	1,124	2,337	2,288
Total, Regions 1-21	47,791	91,239	118,815

Several emerging technologies could significantly reduce water requirements in steam electric plants. One is fluidized-bed boilers that allow lime to be added to coal in the boiler, thereby eliminating the need for sulfur removal equipment and associated water use. This type of boiler could be developed and placed into production during the next 10 years.

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Implications of Water Use for Energy Production

The use of large volumes of water for energy production in the United States has important implications. The withdrawal and consumption of this water from rivers, streams, and lakes may conflict with other water uses, including environmental purposes. Disposal of wastes, including water-borne wastes, will also be of concern; water quality, air quality, ash disposal, and nuclear wastes will typically deserve considerable attention.

In water-short areas of the Nation, competition for available water supplies is intense and is increasing. Historically, the largest use of water in the West has been for irrigation. With the need for development of energy production facilities in these areas, large amounts of the water need to be converted from agricultural production to energy purposes. This conversion may have undesirable effects upon local economic and social structures. Streamflow regimes might be altered, land use may revert to pre-irrigation conditions, and tax bases will be shifted.

All discharges of heated water contribute to physical and biological changes in the receiving water body. These changes can be beneficial, detrimental, or insignificant, depending upon the ecology of the particular water body and the amount and temperature of the discharges. The addition of heat to water bodies may increase rates of chemical solubility and biochemical reactions, both of which may affect aquatic organisms in the area of higher temperatures. Heat added to a water body may also produce stratification because of the reduced density of the water at the higher temperature. A relatively few degrees difference in temperature is often sufficient to cause the water to separate into distinct layers.

In addition to temperature increases, other water quality parameters could be changed. Salinity of receiving water bodies will be increased by the addition of concentrated boiler water and by evaporation (depletion of streamflow). Production of base energy resource fuels may increase the concentration of heavy metals and toxic substances where adequate controls of runoff from surface mines and waste disposal sites are not practiced and enforced.

Sulfur oxides have been an extensive air pollutant from electric utility installations. Atmospheric sulfur oxides originate during the combustion of sulfur-bearing coal, oil, and, to a much smaller extent, natural gas. The rate at which pollutants are emitted from a powerplant burning fossil fuel depends upon the type and quality of fuel burned, design of the boiler, method of combustion, and other factors. The sulfur, which occurs primarily in organic and pyritic forms, is transformed by the combustion reaction into sulfur dioxide and sulfur trioxide.

The use of low sulfur coal -- coal containing less than 1 percent sulfur by weight -- is the simplest method of reducing sulfur dioxide emissions at coal-burning powerplants; however, the supplies of low sulfur coal are often either committed to steel production and export or are situated in deposits far removed from existing powerplants. Air quality standards can be maintained even with high sulfur coal if devices such as

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flue gas desulfurization systems are used. Because these systems are water-dependent, they pose threats for transforming an air pollution problem into a water pollution problem if not properly controlled.

The disposal of wastes from many energy producing systems must also be considered. Ash from coal-fired plants, spent material from nuclear reactors, residual shale from oil shale operations, sludge from refineries, are only a few of the disposal problems that must be addressed.

Summary of Projections

Water use for energy production in the United States has increased rapidly. In "1975," almost 95 billion gallons of freshwater were being withdrawn daily from fresh-water sources for this production. The following tabulation summarizes water withdrawals and consumption expected for energy production in "1975," 1985, and 2000:

	"1975"	1985	2000
	(billion gallons per day)		
Total fresh-water withdrawals for energy production	95.0	99.5	84.6
Fresh-water withdrawals for steam electric generation	88.9	94.9	79.5
Fresh-water consumption for steam electric generation	1.4	4.1	10.5
Saline-water withdrawals for steam electric generation	47.8	91.2	118.8

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Minerals Production

Minerals production or mining has relatively minor water needs compared to large users such as agriculture. Although the minerals industry withdrew only 2 percent of all fresh-water withdrawals in "1975," the withdrawals are projected to increase about 61 percent by 2000 when they will make up over 3 percent of total withdrawals. Consumption is projected to increase 74 percent by 2000.

Moreover, the consumption rate will grow right along with the increasing demand for minerals with little appreciable improvement expected in efficiencies or recycling. Total offstream withdrawals are expected to decline by 9 percent between "1975" and 2000, with the largest decline of 62 percent in manufacturing. Minerals, on the other hand, are expected to increase withdrawals by as much as 61 percent. This is significant in light of the increasing competition for water among the offstream and instream users, particularly in the western water-short regions.

Minerals production includes the extraction and primary processing of three types of minerals: metals, nonmetals, and fuels. This section discusses current and projected water withdrawals and consumption for all three types of minerals (Table III-51). The data includes water needed for the basic extraction and complementary primary processing needs such as well or brine operations, washing, or crushing to prepare the mined material for use in other industries. Data on water for secondary processing and conversion are included in other offstream uses such as manufacturing and energy production.

Current water use and projected needs for 1985 and 2000 are given for regions with significant production of each minerals type. The final part summarizes the overall regional water needs and points out trends that will influence future needs.

Metals Mining

Metals included in the minerals industry are: iron, lead, zinc, manganese, gold, silver, copper, and molybdenum. The metals mining industry uses the least water of the three mineral categories--about 12 and 13 percent of all withdrawals and consumption, respectively (Table III-51). However, consumption of water for metals mining is about 36 percent of the amount withdrawn compared to 15 percent for nonmetals and about 53 percent for fuels. In metals mining, water is used largely for washing and primary ore processing. In "1975," the Great Lakes, Lower Colorado, and Great Basin Regions each withdrew more than 100 million gallons of water per day (mgd) for metals mining (Table III-52). Alaska is expected to increase withdrawals from 15 to 127 mgd for metals mining by 2000. No significant changes in other regions are expected for 1985 and 2000.

The Great Lakes Region, which includes iron ore production in Minnesota and Michigan, uses the largest amount of water for metals mining (Table III-52). The second and third largest users are the Arizona

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Table III-51.—Minerals industry fresh-water withdrawals and consumption—"1975," 1985, 2000

Mineral Category	Withdrawals						Consumption					
	"1975"		1985		2000		"1975"		1985		2000	
	mgd	%	mgd	%	mgd	%	mgd	%	mgd	%	mgd	%
Metals	817	12	1,053	12	1,361	12	294	13	403	14	513	14
Nonmetals	3,686	52	4,560	52	6,123	54	543	25	686	25	1,021	28
Fuels	2,552	36	3,219	36	3,844	34	1,359	62	1,688	61	2,075	58
Totals	7,055	100	8,832	100	11,328	100	2,196	100	2,777	100	3,609	100

copper mines and the Utah, Nevada, and Idaho silver mines. The Great Lakes Region uses one-third of its total withdrawals for minerals in metals mining. However, the drier Lower Colorado and Great Basin Regions use 83 percent of the total water withdrawals for minerals in metals production. More than 92 percent of the water withdrawn is used consumptively in metals mining in the Lower Colorado Region. In Alaska, one-half of the total minerals withdrawals are for metals mining; this should decline to about one-fourth by 2000, since growth in metals mining is projected to be only eight times the "1975" level in contrast to 28 times for fuels.

Table III-52.—Metals mining fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	3	3	4	<1	<1	<1
Mid-Atlantic (2)	14	15	16	2	2	2
South Atlantic-Gulf (3)	5	7	8	1	1	1
Great Lakes (4)	231	250	289	85	91	101
Ohio (5)	2	2	3	<1	<1	<1
Tennessee (6)	16	18	21	2	3	3
Upper Mississippi (7)	45	50	58	7	7	8
Lower Mississippi (8)	14	12	11	3	3	3
Souris-Red-Rainy (9)	0	0	0	0	0	0
Missouri (10)	34	42	45	5	5	7
Arkansas-White-Red (11)	54	70	97	7	10	15
Texas-Gulf (12)	20	33	40	3	4	5
Rio Grande (13)	9	24	44	3	10	19
Upper Colorado (14)	19	30	57	3	6	13
Lower Colorado (15)	150	206	250	138	194	232
Great Basin (16)	122	169	214	25	37	53
Pacific Northwest (17)	58	62	70	8	8	9
California (18)	6	6	7	1	1	2
Total, Regions 1-18	802	999	1,234	293	382	471
Alaska (19)	15	54	127	1	21	42
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	817	1,053	1,361	294	403	513

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Overall increase in water requirements for metals mining will be about 67 percent in withdrawals and 74 percent in consumption from "1975" to 2000. Stabilized production in the Great Lakes, along with continued competitive foreign supplies of iron, should slow the growth of water needs for mining in that region to less than 25 percent, unless copper resources in Wisconsin and Minnesota are rapidly developed. Basically, anticipated efficiencies and conservation in water uses by the metals mining industries will probably be offset by the need to mine and process lower grade ores.

Nonmetals

Nonmetals consist of lime, clay, barite, phosphate, sulphur, rock salt, rock wool, pumice, sand, gravel, and stone. Construction materials (sand, gravel, and stone) account for the largest proportion of nonmetallic minerals produced in all regions and for most of the water withdrawals in the eastern two-thirds of the conterminous United States. Except in the Lower Mississippi Region, nonmetals production in eastern regions uses about three-fourths of all water withdrawn for minerals production. In the western mining regions and in the Lower Mississippi Region, nonmetals mining withdraws only about one-fifth of the water used in the minerals industry (Table III-53).

The largest water use regions for nonmetallic minerals production are those with large or growing industrial and population centers. Nonmetals mining operations, with few exceptions, are directly related to population and growth. The South Atlantic-Gulf (the largest user) and the Lower Mississippi Regions are growing rapidly. Most of the large nonmetal mining water use in these regions is attributed to phosphate mining in Florida and sulfur mining in Louisiana.

Although the construction industry is expected to grow with population increases, no dramatic shifts in uses or significant water problems appear to be associated with nonmetals mining. Environmental and legal problems with offshore dredging of construction materials and developments on or near such deposits may change local water use, especially in marine and lake coastal areas. Technological improvements in phosphate and sulfur production are expected to meet higher environmental standards, but these improvements will probably have little influence on water use in Florida and the Gulf Coast areas.

Fuels

The fuels included in this assessment are: coal, oil shale, petroleum natural gas liquids, and uranium. The mining and primary processing of fuels is discussed in this section, but secondary processing and conversion to basic energy, direct consumption, and conversion to electricity are included in the sections on manufacturing and energy. Although the conversion function is quite large, other fuels such as nuclear fuel may reduce the conversion function, especially of petroleum. Increasing emphasis on decreasing petroleum imports should substantially increase the use of

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Table III-53.—Nonmetals mining industry fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	87	112	49	11	16	20
Mid-Atlantic (2)	424	514	662	56	69	88
South Atlantic-Gulf (3)	1,105	1,446	1,983	158	207	284
Great Lakes (4)	451	563	734	62	74	99
Ohio (5)	308	372	471	34	50	64
Tennessee (6)	86	108	144	12	15	20
Upper Mississippi (7)	268	334	427	35	45	57
Lower Mississippi (8)	141	157	242	36	38	114
Souris-Red-Rainy (9)	4	5	6	1	1	1
Missouri (10)	91	116	143	10	12	14
Arkansas-White-Red (11)	222	209	289	52	46	73
Texas-Gulf (12)	187	198	275	20	20	29
Rio Grande (13)	28	46	64	14	29	43
Upper Colorado (14)	45	68	127	6	10	20
Lower Colorado (15)	27	40	53	8	19	44
Great Basin (16)	22	36	58	3	7	12
Pacific Northwest (17)	57	75	91	8	9	14
California (18)	98	118	151	13	14	19
Total, Regions 1-18	3,651	4,517	6,069	539	681	1,015
Alaska (19)	3	5	7	0	0	0
Hawaii (20)	1	1	1	0	0	0
Caribbean (21)	31	37	46	4	5	6
Total, Regions 1-21	3,686	4,560	6,123	543	686	1,021

coal for energy conversion with corresponding savings in water requirements vis-a-vis the use of nuclear alternatives.

Fuels production (extraction and primary conversion) accounts for a little over one-third of the total water withdrawn for the minerals industry for "1975," 1985, and 2000 (Table III-51). However, in "1975" the consumption rate for fuels was about 53 percent of withdrawals with the result that total consumption of water for fuels production is 62 percent of that for all minerals--metals, nonmetals, and fuels. The ratio of consumption to withdrawals is highest in the fuels sector, or about 3.5 times that of nonmetals.

The leading water use regions for fuels production are the Texas-Gulf, Lower Mississippi, California, Ohio, Arkansas-White-Red, Rio Grande, and Missouri (Table III-54). Except for the Ohio and Missouri Regions, these regions are the Nation's leading producers of oil and gas. The five oil and gas producing regions withdrew about 2 bgd or 78 percent of all fresh-water withdrawals for fuels production in "1975." The Ohio and Missouri Regions are the leading coal producing regions. In "1975" they withdrew 327 mgd or 13 percent of the total withdrawals for fuels. Altogether these seven regions withdrew 91 percent of all water used in fuels production and accounted for 90 percent of the water consumed.

By the year 2000 some changes are projected. Texas-Gulf withdrawals will grow only 11 percent, while the lower Mississippi will become the largest withdrawal user in oil and gas recovery and processing, especially in the rapidly expanding secondary recovery methods which involve injection of water to flood older wells.

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However, consumptive uses will remain very high in the Texas-Gulf Region (more than double that in the Lower Mississippi Region) at 64 percent of withdrawals for fuels production. The older petroleum fields in the Texas-Gulf Region will increase water consumption in secondary recovery operations. These continued high levels of consumption will also be expected in the Arkansas-White-Red, Rio Grande, and California Regions with a consumption to withdrawal ratio of about 71 percent.

Alaska will be the fastest growing region both in withdrawals and consumption of water for fuels production, primarily petroleum. Water withdrawals and consumption for fuels production in Alaska are expected to increase 27 times from "1975" to 2000.

Table III-54.—Fuels production fresh-water withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	0	0	0	0	0	0
Mid-Atlantic (2)	21	19	22	12	11	12
South Atlantic-Gulf (3)	68	85	86	55	66	64
Great Lakes (4)	14	18	21	8	10	11
Ohio (5)	183	288	334	57	82	96
Tennessee (6)	8	14	21	1	3	4
Upper Mississippi (7)	20	33	48	4	6	9
Lower Mississippi (8)	644	841	1,065	167	212	299
Souris-Red-Rainy (9)	4	4	4	2	2	2
Missouri (10)	144	198	236	96	122	142
Arkansas-White-Red (11)	172	190	185	114	128	130
Texas-Gulf (12)	837	902	930	532	564	598
Rio Grande (13)	153	151	147	86	90	88
Upper Colorado (14)	68	97	171	38	56	111
Lower Colorado (15)	7	6	8	5	4	5
Great Basin (16)	1	1	1	<1	<1	<1
Pacific Northwest (17)	3	4	6	2	2	4
California (18)	193	235	217	169	210	192
Total, Regions 1-18	2,540	3,086	3,502	1,348	1,568	1,767
Alaska (19)	12	133	342	11	120	308
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	2,552	3,219	3,844	1,359	1,688	2,075

Water requirements for coal production in the eastern regions could increase greatly if an expanded policy of energy self-sufficiency includes technical developments to utilize the high-sulfur coals. The western coal regions will face critical water problems with expanding coal production (subject to environmental constraints), especially if the coal is used for conversion to electricity in the region and if there is an oil shale/sands technology breakthrough for extracting these fuels.

Overall Regional Needs

Because quantities and qualities of minerals vary by region, water demands vary accordingly. The largest water-using region for all types of mining is the South Atlantic-Gulf Region, largely for nonmetals such

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as construction materials, clays, and phosphates. The second and third largest water-using regions are the Texas-Gulf and Lower Mississippi where fuels production is the dominant water use. The fourth largest regional user of mining water is the Great Lakes where water uses are largely for metals mining. The most critical water-using regions for mining are the western regions--the Great Basin, Upper and Lower Colorado, portions of the Pacific Northwest, Arkansas-White-Red, and Rio Grande Regions--where minerals are abundant and water supplies are short. These areas will be critically short of water for mining as economic factors such as base metal prices, energy self-sufficiency, and environmental constraints increase water needs for low sulfur coal, oil shale, and uranium.

Regional uses of water in metals and nonmetals mining will not shift geographically as with fuels production (from the Ohio to the Missouri), but both withdrawals and consumption will increase about 1.6 times between "1975" and 2000. No insurmountable water supply problems are foreseen in the minerals industry, except in some local areas in the western regions, especially Missouri, Great Basin, and Upper and Lower Colorado. Much of the increased water requirement in the petroleum industry will be for increased secondary recovery through water flooding procedures, but no severe water shortage is generally foreseen in the petroleum production regions.

However, greater competition for scarce water, the need for water to develop energy resources, the increasing cost of water use, and the environmental requirements that come with such uses will require increased efforts by the minerals industries to conserve water. Water requirements will shift within the industry as supply-demand relationships shift, bringing about substitution of one material for another and greater incentives for more mineral recycling. The greater use of coal for energy production by methods that meet clean air requirements will require more water for coal preparation, transportation, and conversion. Low-sulfur western coal transported to the Midwest through slurry pipelines would effectively displace water from water-deficient areas to water-sufficient areas.

Mining Trends and Projections

A trend toward large-scale minerals operations, brought about by the interrelated factors of mining and processing lower grade ores that require higher capital outlays and longer-term market commitments, generally will require more water per unit of production in the future. Larger quantities of water will also be required to recover additional minerals, especially fuels that require injection or flooding techniques for high recovery operations. Solution mining techniques are needed to recover certain deep minerals not amenable to underground mining. Leaching methods are needed to recover minerals too low in grade for current systems, and newer processes are needed to meet environmental goals. The increased water withdrawals and consumption may be reduced through continued research and applications that will lead to more water recycling and other conservation measures in minerals mining.

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Consumption of water for minerals mining is expected to remain fairly constant at 31 to 32 percent of withdrawals over the 25 years. Nonmetals mining has the largest withdrawal in the minerals industry at 52 percent of the industry total withdrawals in "1975," but consumptive use is only 25 percent of the total withdrawal.

Although fuels mining and processing withdrew about 36 percent of the water withdrawn for minerals mining in "1975," consumption (53 percent of withdrawals) was 62 percent of total minerals mining consumption. Metals mining water withdrawals and consumption are quite stable at about 12 to 13 percent of the total.

The quantity of water used in the minerals industries is directly related to the final consumer activities that each industry supports and depends upon. For example, mining of nonmetals--lime, clay, phosphate, sand, gravel, and stone--depends heavily on the levels and types of construction activities. Fuels production depends on the different types of energy demanded and the variations in supplies available at different times and locations for economic or environmental reasons. These variations also affect the location of energy production facilities and the balance between domestic and import supplies.

All mining activities are projected to use water much more freely than manufacturing, agriculture, and electric generation, both in absolute quantities and in the less-than-average performance of the industry in certain indicator areas like earnings. Projections for increased water uses in mining are also related to the available changing technologies to avert water quality problems and to the changing corporate and industry activity. For example, about 89 percent of all water used in fuels production (2.27 bgd in "1975") was for secondary recovery of petroleum, largely through injection. Typical secondary petroleum operations use about 7.7 barrels of water for each barrel of oil recovered. This ranges from as little as one to as much as 28 barrels of water per barrel of crude oil with the older, more depleted fields that require the heaviest injections of water per barrel of oil. Larger oil imports or larger domestic coal and nuclear fuel sources will tend to reduce water requirements for domestic fuel production--a large part of which will be from secondary recovery processes in the future.

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Water for Recreation

Americans continue to turn to the outdoors for recreation, relaxation, and rewarding use of leisure time. Many activities they enjoy depend on or are enhanced by both the extent and variety of waters available for recreation. In trying to provide sufficient water-related recreation for the public, several issues face recreation planners. These include (1) providing urban recreation opportunities; (2) improving water quality; (3) maintaining streamflows for recreation; (4) providing maximum recreation opportunities at reservoirs; (5) providing public access to recreation waters; (6) protecting flood plains, coastal beaches, wetlands, and other critical areas for recreation; and (7) managing competing uses for water. This section discusses the needs, available resources, and problems involved in planning for water-related recreation. The assessment is concerned largely with two types of water-related outdoor recreation activities: water-dependent (swimming, canoeing, boating, sailing, water skiing, and fishing) and water-enhanced (picnicking and camping).

Participation in Water-related Recreation

The frequency, duration, and type of participation in water-related recreation involves a number of complex economic, social, and personal preference variables. The Outdoor Recreation Resources Review Commission considered leisure time, income, and mobility as the major recreation demand variables. More recent studies, however, indicate that discretionary income, leisure lifestyle, supply of outdoor recreation opportunity, and the sequence of leisure time may be more important in estimating participation and projecting changes in demand for recreation. In addition to these personal factors, increased population, longer life expectancy, population shifts from rural to urban areas, and migration to sunbelt areas also influence present and future recreation patterns.

In "1975," participation in water-dependent recreation was estimated to be 1,359 million activity occasions for the conterminous United States. Water-enhanced recreation activity occasions were 656 million (Table III-55). The total water-related activity occasions were over 2 billion, about 67 percent water dependent and 33 percent water enhanced. The water-dependent activity occasions were heavily weighted by beach swimming (43 percent), fishing (28 percent), and boating (20 percent). The remaining 9 percent of water-dependent occasions consisted of water skiing, sailing, and canoeing. Swimming, boating, and water skiing are more popular in the western regions while fishing, canoeing, boating, and sailing are more popular in the eastern regions. Water-enhanced camping and picnicking activities are more frequent in the West than they are in the East.

By the year 2000, water-dependent activities are projected to increase to 1,824 million activity occasions. With the largest numerical increases in the Great Lakes, South Atlantic-Gulf, and the Mid-Atlantic Regions. The greatest percentage increases will be in the Lower Colorado and Great Basin Regions. Water-enhanced activities of camping and picnicking in the

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Table III-55.—Outdoor recreation activity occasions—"1975," 1985, 2000
(million activity occasions)

Water resources region and no.	Water-dependent			Water-enhanced		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	69.8	77.9	91.0	35.7	40.9	48.4
Mid-Atlantic (2)	217.9	246.6	289.3	115.0	131.0	155.9
South Atlantic-Gulf (3)	160.5	192.0	235.1	57.9	68.4	85.3
Great Lakes (4)	220.4	247.1	295.0	106.6	119.1	138.7
Ohio (5)	142.1	158.3	182.8	58.9	65.5	75.5
Tennessee (6)	22.5	26.4	31.9	8.0	9.4	11.3
Upper Mississippi (7)	97.3	112.0	126.4	47.6	53.0	61.4
Lower Mississippi (8)	40.7	44.3	49.4	14.5	15.8	17.5
Souris-Red-Rainy (9)	4.7	4.7	4.8	2.3	2.3	2.3
Missouri (10)	61.9	67.5	77.2	32.8	35.7	40.8
Arkansas-White-Red (11)	44.5	48.6	55.8	18.0	19.7	22.2
Texas-Gulf (12)	62.6	73.1	89.2	22.3	26.0	31.7
Rio Grande (13)	10.7	11.7	13.1	5.9	6.5	7.3
Upper Colorado (14)	2.2	2.3	2.6	1.4	1.5	1.7
Lower Colorado (15)	15.4	19.2	25.4	9.8	12.3	16.3
Great Basin (16)	8.0	9.7	12.2	5.2	6.2	7.8
Pacific Northwest (17)	42.7	46.1	53.1	27.4	29.6	34.0
California (18)	134.8	156.6	189.5	86.4	100.4	121.3
Total, Regions 1-18	1,358.7	1,544.0	1,832.7	655.7	743.3	879.4
Alaska (19)	2.0	2.4	3.1	1.3	1.5	2.0
Hawaii (20)	18.2	20.8	25.6	5.9	6.6	8.0
Caribbean (21)	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-21	1,378.9	1,567.2	1,852.4	662.9	751.5	889.4

N/A - Not available.

conterminous United States are projected to increase to 879 million occasions by 2000. The largest numerical increases should be in the California, Mid-Atlantic, and South Atlantic-Gulf Regions, but the greatest percentage increases will occur in the Lower Colorado and Great Basin Regions.

Water Resources for Recreation

Recreation surface water is that part of the Nation's waters of suitable quality and accessibility for recreation activities. Although about 85 million acres of total surface water are found in the conterminous United States (about 507 acres per 1,000 people), only 20 million acres or 24 percent are considered usable or accessible for recreation (Table III-56). The surface water usable for recreation varies from a low of about 10 percent of the total surface water in the Great Lakes Region to a high of 86 percent in the Great Basin Region. The Great Lakes, Lower Mississippi, Rio Grande, and Texas-Gulf Regions have relatively low portions of total surface waters available for recreation. Conversely, in the Ohio, Tennessee, Missouri, Upper Colorado, Great Basin, and California Regions, a large portion of total surface water is available for recreation.

Several reasons explain the low percentage of surface water available for recreation in some areas that appear to have abundant surface-water supplies. In very large bodies of water, such as the Great Lakes, only the areas relatively close to shore, a small percentage of the total area, are suitable for recreational uses. This limitation is intensified by lack of adequate harbors, launching facilities, other supporting facili-

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ties, and frequently by unfavorable weather conditions. Deteriorated water quality in urban and rural areas has made large portions of the Nation's streams and lakes unusable for certain types of recreation. Sedimentation, shoreline development, eutrophication, and restricted access often limit inland lakes and reservoirs for recreation. Aquatic vegetation, parasites, and other disease vectors also reduce the recreation use of waterways. In some areas, the full range of recreation activities is limited by competing uses. Altogether, these conditions significantly affect the amount of water available for recreation.

In areas with high density uses but low availability of water, certain problems affecting quality and accessibility can be solved to some extent. A concerted effort to develop additional surface-water acreage or to make existing resources available for public use would significantly enhance recreation possibilities in these regions. For example, improved public access to large water bodies can enlarge opportunities for water-related recreation in many areas.

Table III-56.—Total surface-water supply and surface-water area usable for outdoor recreation—"1975"[a]

Region	Total surface water area		Surface water for recreation		
	Thousand acres[b]	Acres per 1,000 population	Thousand acres[c]	Percent of total	Acres per 1,000 population
New England (1)	4,103	422	1,480	36	152
Mid-Atlantic (2)	4,366	140	1,840	42	59
South Atlantic-Gulf (3)	8,672	433	2,029	23	102
Great Lakes (4)	41,547	1,748	4,253	10	179
Ohio (5)	932	56	519	56	31
Tennessee (6)	660	236	525	80	187
Upper Mississippi (7)	2,716	259	753	28	72
Lower Mississippi (8)	3,433	680	420	12	83
Souris-Red-Rainy (9)	1,232	2,425	333	27	656
Missouri (10)	3,504	504	2,494	71	359
Arkansas-White-Red (11)	1,855	345	634	34	118
Texas-Gulf (12)	2,692	346	387	14	50
Rio Grande (13)	542	402	070	12	52
Upper Colorado (14)	588	2,029	329	59	1,196
Lower Colorado (15)	456	237	209	46	108
Great Basin (16)	1,752	1,735	1,513	86	1,498
Pacific Northwest (17)	3,893	727	1,483	38	277
California (18)	1,674	99	1,091	65	65
Total Regions 1-18	84,557	507	20,326	24	122
Alaska (19)	12,787	52,192	1,937	15	7,906
Hawaii (20)	-	N/A	N/A	N/A	N/A
Caribbean (21)	N/A	N/A	N/A	N/A	N/A
Total Regions 1-21	N/A	N/A	N/A	N/A	N/A

[a]Estimated "1975" population 12 years and older is about 167 million.

[b]Total of inland and other water from Area Measurement Reports, U.S. Department of Commerce Publication GE-20, No. 1, and 1970 update sheet and comprehensive water basin studies.

[c]Water available and useful for recreation. To be available and useful the water must have adequate public access, be free of obstruction to its use, and be of suitable quality for recreation use.

N/A-Not available.

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Water Needs for Recreation

Water resource requirements were projected for the participating age population (12 years and older) for intensive use periods (June, July, and August) in each subregion. These then were aggregated to estimate the water acreage required for "1975," 1985, and 2000 for each region.

In "1975," surface area usable for water-related recreation totaled 20.3 million acres or over 122 acres per thousand of the participating age population. To compare supply and demand, the analysis of each region assumed that the region's population participated in water-related recreation outside the region as frequently as outsiders participated in activities within that region. Once the regional gross surplus or deficit water surface areas were summed, the net surplus or deficit for each region was determined, again considering the balancing of interregional participation (Table III-57).

From the "1975" gross surplus of 10.8 million acres of usable recreation water (regions 1-18), the deficit waters of 8.1 million acres were subtracted for a net supply of 2.7 million acres. In "1975," 54 of the 106 subregions needed more than a thousand acres each of additional recreation surface waters (Figure III-13), with the largest need in the subregion that includes New York City. This had a deficit over 1.68 million acres of which only a small portion could be met through better access or improved water quality. Other regions with gross needs for recreation waters are the Great Lakes, California, New England, and Texas-Gulf Regions, which include the Chicago, Los Angeles, Boston, and Dallas-Fort Worth metropolitan areas, respectively. Virtually all of these urban centers are near major surface-water resources where quality or access is limited, the water body is too large to be effectively utilized, or a significant number of citizens lack mobility.

The Mid-Atlantic, Ohio, Texas-Gulf, Upper Mississippi, South Atlantic-Gulf, California, Lower Mississippi, Rio Grande, and Arkansas-White-Red Regions had net deficit supplies of surface-water area in "1975." Although each region contained enough surface water overall to satisfy recreational demands, assuming that transportation were available, subregions within the region had deficits. Several regions--the Missouri, Alaska, Great Basin, Great Lakes, and Pacific Northwest--have a substantial surplus of water acres in proportion to projected demands (Table III-57).

Needs for recreation waters are projected to increase by the year 2000. Regions with a net deficit in "1975" are projected to increase from 9 to 12 by 2000. Although the Upper and Lower Colorado and New England Regions now enjoy a surplus, their requirements will exceed available supplies of surface water by 2000. The Mid-Atlantic, South Atlantic-Gulf, California, Texas-Gulf, Upper Mississippi, and Arkansas-White-Red Regions will also have increased deficits.

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Table III-57.—Needs for surface-water area for water-dependent recreation activities—"1975," 1985, 2000
(1,000 acres)

Region	"1975"			1985			2000		
	Gross surplus water[a]	Gross deficit water[b]	Net regional surplus or (deficit)[c]	Gross surplus water[a]	Gross deficit water[b]	Net regional surplus or (deficit)[c]	Gross surplus water[a]	Gross deficit water[b]	Net regional surplus or (deficit)
New England (1)	902	560	342	879	681	198	833	929	(96)
Mid-Atlantic (2)	670	1,679	(1,009)	612	2,106	(1,494)	512	2,702	(2,190)
South Atlantic-Gulf (3)	607	958	(351)	446	1,208	(762)	236	1,665	(1,429)
Great Lakes (4)	2,900	1,284	1,616	2,816	1,504	1,312	2,676	1,888	788
Ohio (5)	0	961	(961)	0	(1,129)	(1,129)	0	1,404	(1,404)
Tennessee (6)	192	0	192	140	0	140	111	45	66
Upper Mississippi (7)	84	509	(425)	29	585	(556)	2	783	(781)
Lower Mississippi (8)	3	182	(179)	0	226	(226)	0	292	(292)
Souris-Red-Rainy (9)	211	0	211	212	0	212	210	0	210
Missouri (10)	1,976	6	1,970	1,939	10	1,929	1,880	22	1,858
Arkansas-White-Red (11)	179	250	(71)	174	300	(126)	163	382	(219)
Texas-Gulf(12)	0	539	(539)	0	678	(678)	0	901	(901)
Rio Grande (13)	12	129	(117)	11	142	(131)	10	160	(150)
Upper Colorado (14)	310	0	310	310	0	310	307	0	(307)
Lower Colorado (15)	102	94	8	81	128	(47)	68	185	(117)
Great Basin (16)	1,360	1	1,359	1,334	2	1,332	1,295	5	1,290
Pacific Northwest (17)	818	98	720	807	138	669	791	232	559
California (18)	475	806	(331)	454	977	(523)	419	1,244	(825)
Total, regions 1-18	10,801	8,056	2,745	10,244	9,814	430	9,513	12,839	(3,326)
Alaska (19)	1,901	0	1,901	1,896	0	1,896	1,882	0	1,882
Hawaii (20)	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A
Caribbean (21)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total, regions 1-21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A - Not available.
[a]Total of subregions with surplus water acreage for needs within each subregion.
[b]Total of subregions with deficit water acreage for needs within each subregion.
[c]The algebraic difference between surplus and deficit subregions, i.e., a regional composite view of net needs for the region.

In the conterminous United States, the "1975" net surplus of 2.7 million acres of recreation waters will decline to just better than a break-even basis in 1985, and a 3.3 million acres net deficit by 2000. A majority of the increased needs identified in this assessment could be met through more effective use of total surface waters. In all likelihood, people will travel to other regions with adequate water for recreation, but such travel will be costly in terms of time and energy.

Areas of Critical Environmental Concern

There are many areas of critical environmental concern. Well-known and unique water recreation areas such as Grand Canyon, Yellowstone, and Assateague Island are protected. However, many lesser known natural resources also require special preservation, protection, or enhancement of their recreation values. The assessment identified 2,119 acres of significant value for water related recreation. These areas include coastal shoreline and beach, flood plains and wetlands, lakes, streams, islands,

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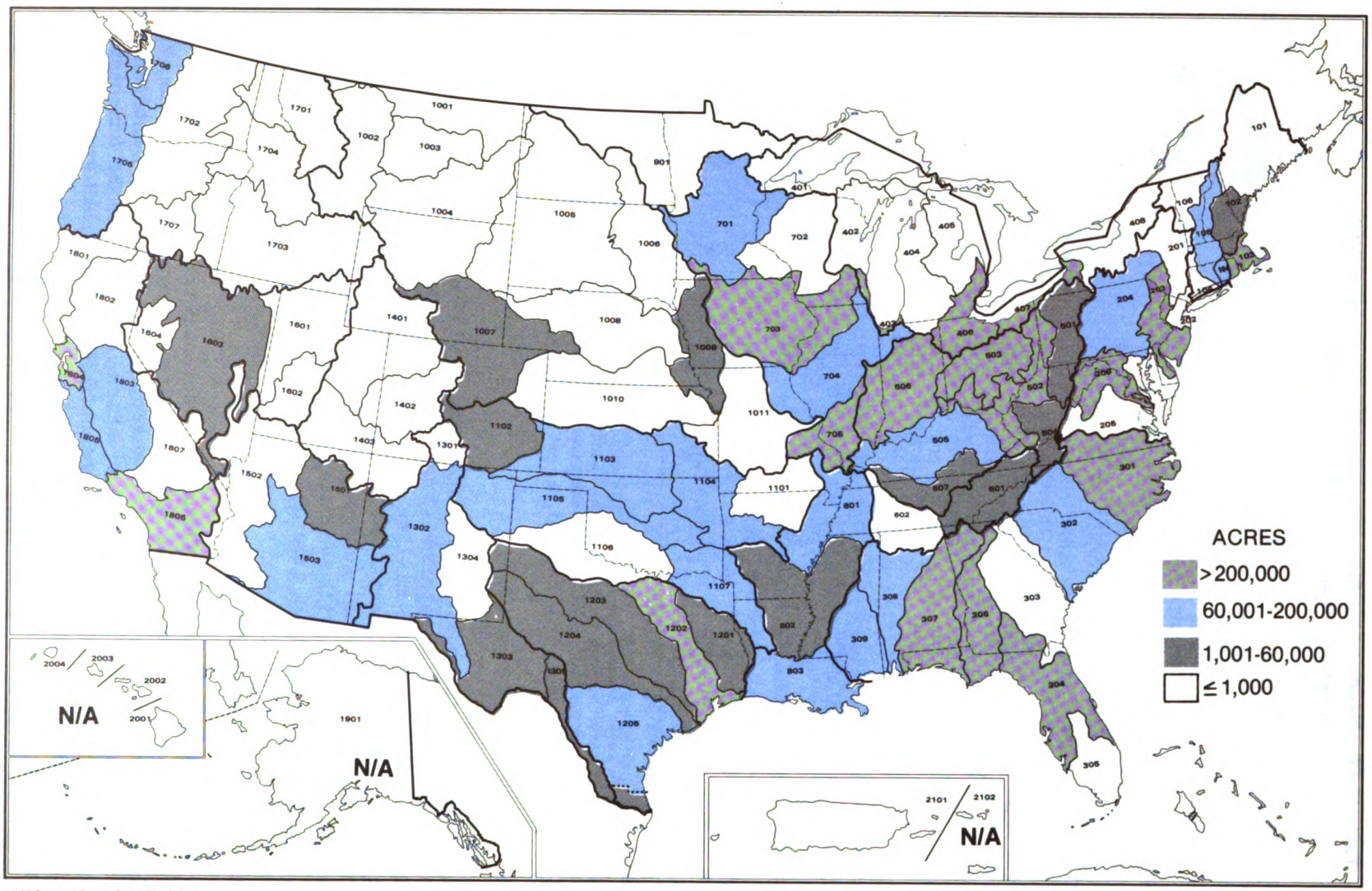

N/A: Not Available

Figure III-13.—Additional water surface needed for outdoor recreation by 2000

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unique natural areas such as waterfalls and areas of significant open space or scenic value. Where data were available, the natural resource attributes for each region are listed in Table III-58.

Table III-58.—Attributes of areas of environmental concern, "1975"

Region	Federal wild and scenic river[a]	State wild and scenic river[b]	Potential wild and scenic river[c]	High value recreation beach or shoreland	Unique water or water-related recreation area[d]	Flood plain recreation area	Open space, scenic, or natural area	High value general recreation area
New England (1)	0	3	45	0	49	1	0	46
Mid-Atlantic (2)	0	22	18	9	54	2	30	69
South Atlantic-Gulf(3)	0	3	42	2	19	1	33	17
Great Lakes(4)	1	15	43	21	126	1	22	38
Ohio(5)	0	17	46	0	77	1	6	11
Tennessee(6)	0	6	0	0	16	4	8	4
Upper Mississippi(7)	1	2	29	1	91	0	83	19
Lower Mississippi(8)	0	2	1	1	26	0	104	6
Souris-Red-Rainy(9)	0	0	7	0	15	0	12	3
Missouri(10)	1	0	8	3	4	3	6	47
Arkansas-White-Red(11)	0	9	3	0	9	1	3	11
Texas-Gulf(12)	0	0	0	1	13	0	19	1
Rio Grande(14)	0	0	1	0	0	0	0	2
Upper Colorado(14)	0	0	16	0	0	0	5	38
Lower Colorado(15)	0	0	21	0	11	0	8	2
Great Basin(16)	0	0	14	0	7	0	14	20
Pacific Northwest(17)	0	7	25	0	23	0	0	213
California(18)	1	7	29	3	24	0	18	20
Total, regions 1-18	4	93	245	41	564	14	371	567
Alaska(19)	0	0	39	0	3	0	0	25
Hawaii(20)	0	0	0	7	12	0	6	0
Caribbean(21)	0	0	0	3	1	0	1	4
Total, regions 1-21	4	93	381	51	580	14	378	596

[a]Pursuant to Section 3(a), Public Law 90-542, as amended by PL 93-261.
[b]Pursuant to State legislation.
[c]Pursuant to Sections 5(a) of 5(d) of PL 90-542, as amended by PL 93-261, SCORP's Framework Level A and River Basin Level B Studies.
[d]Includes water falls, springs, gorges, canyons, wetlands, islands or scientific water-related study areas.

All identified natural resource areas faced some threat that could irreversibly damage the resource. Where data were available, these threats are summarized for each region in Table III-59. However, these totals do not show the relative importance of the threats in any one region.

The assessment process pointed out the desirability for a national program to identify areas of critical environmental concern for water-related recreation and to explore means for their preservation, protection, or enhancement. Because an area is identified as one of critical environmental concern does not imply that no development should be allowed. Rather, the area should be preserved, protected, or enhanced for recreation use as well as for other potential purposes. Proposals for development in these areas should be carefully evaluated until a full analysis is made of all benefits and liabilities.

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Table III-59.—Critical environmental concerns—"1975"

	Residential development	Commercial development	Industrial development	Agricultural development	Mining & related resource development	Dam or irrigation project	Navigation project	Channelization project	Water level fluctuation	Water pollution	Sedimentation	Erosion	Nuisance vegetation	Weed growth	Eutrophication	Adequate public access	Adequate streamflow	Preservation
New England(1)	20	3	2	5	1	5	0	0	1	9	1	0	21	10	1	58	4	(
Mid-Atlantic(2)	21	1	5	4	3	4	1	2	0	13	7	1	22	6	26	44	0	(
South Atlantic-Gulf(3)	13	6	0	0	4	13	5	34	3	8	2	1	8	0	0	1	2	(
Great Lakes(4)	73	4	4	2	6	0	0	3	0	41	8	12	0	0	0	12	0	1
Ohio(5)	18	0	0	3	3	5	2	0	0	2	0	1	0	0	2	14	1	(
Tennessee(6)	6	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	(
Upper Mississippi(7)	126	7	5	35	0	5	14	27	2	100	35	15	2	2	6	32	0	5
Lower Mississippi(8)	2	0	0	22	0	0	0	7	1	0	0	1	0	0	2	57	0	(
Souris-Red-Rainy(9)	3	2	0	1	2	9	0	4	0	16	1	0	0	0	0	3	0	(
Missouri(10)	9	2	3	5	9	21	0	6	8	18	8	6	0	1	3	5	12	(
Arkansas-White-Red(11)	2	4	0	5	0	5	0	1	0	2	0	1	2	0	0	1	0	(
Texas-Gulf(12)	17	19	5	6	0	2	1	5	2	14	6	1	0	0	0	4	1	(
Rio Grande(13)	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	(
Upper Colorado(14)	1	0	0	0	13	21	0	0	0	8	0	3	0	0	2	0	2	(
Lower Colorado(15)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(
Great Basin(16)	4	1	0	0	0	1	0	0	3	2	0	0	0	0	1	6	16	1
Pacific Northwest(17)	5	3	0	1	1	19	1	1	23	31	2	1	0	0	0	20	37	(
California(18)	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	(
Total, regions 1-18	320	52	24	89	42	112	24	91	43	267	71	44	55	19	43	257	76	7
Alaska(19)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(
Hawaii(20)	5	9	1	10	0	10	0	0	0	0	0	0	0	0	0	0	0	3
Caribbean(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total, regions 1-21	325	61	25	99	42	122	24	91	43	267	71	44	55	19	43	258	76	11

Preservation of Free-flowing Streams

The preservation of free-flowing stream values was a high priority problem in 73 of the 106 subregions. The assessment and other reports have highlighted numerous examples of how natural streams have been modified to provide for flood control, navigation, power, and other uses--often without full consideration of the stream's free-flowing values for recreation or fish and wildlife. It is well recognized that such assessments and evaluations should address efforts to enhance stream resources for these uses. The national wild and scenic rivers system supported by the Wild and Scenic

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Rivers Act (Public Law 90-542) now encompasses 1,650 miles of rivers with some 700 miles classified as wild, 460 miles as scenic, and 490 miles as recreational. Twenty-six States have also enacted wild and scenic rivers legislation.

Despite the preservation of a number of streams, the existing Federal and State wild and scenic rivers programs cannot and are generally not intended to preserve every worthy stream in the Nation. Protection of significant stream segments containing natural and recreation values should always be considered as an alternative to development proposals, whether or not a particular stream has been identified under a wild and scenic rivers program. The impetus for formulating free-flowing alternatives to water resources development is contained in the National Environmental Policy Act (Public Law 91-190), the Federal Water Power Act as amended (Public Law 66-280), and the Principles and Standards for Planning Water and Related Land Resources.

In authorizing, funding, and carrying out ongoing and future studies of structural waste developments and free-flowing streams, expertise and funds will be required to formulate and evaluate the alternative plans necessary for sound decisionmaking. Priority should be given to those streams presently being considered for early structural development, those affected by the development of new sources of energy, and those subject to large-scale irrigation developments.

Flood-plain Recreation Areas

Many resources require only some form of protection to be kept available for public enjoyment. Flood plains and wetlands in a natural state are examples. They can provide a significant resource base for meeting high priority recreation needs, a means for reducing or eliminating flood conditions, and, at the same time, a pleasing contrast to intensive urban development.

In most flood-prone areas, the flood plain or wetland area could be preserved by nonstructural solutions that emphasize land uses compatible with occasional inundation. Nonstructural techniques, such as land use regulation or public purchase, leave options open for future generations to decide on the ultimate use of these resources.

Section 73 of the Water Resources Development Act of 1974 (Public Law 93-251) provides for active Federal participation in nonstructural flood damage reduction measures. Where a nonstructural alternative is recommended, "non-Federal participation shall be comparable to the value of lands, easements, and rights-of-way that would have been required of non-Federal interests (under Section 3 of the Act of June 27, 1936, Public Law numbered 738) for structural protection measures." It is in the public interest to emphasize nonstructural measures in Federal programs.

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High Value Beach and Shoreline

Another problem identified concerns coastal and Great Lakes beaches, some of nature's most vulnerable resources. These can erode until they become unusable for recreation. Improper construction of jetties, breakwaters, and other structures can aggravate the natural process of erosion by interfering with the water and circulation patterns that replenish beaches. Unlimited recreation use cannot be accommodated without environmental damage. Indeed, too many people in such fragile areas can destroy the very features that attracted the recreation in the first place.

Urbanizing pressures along coastal and Great Lakes shorelines have generated major environmental and recreation problems. The practice of dredge and fill operations for real estate development continues to destroy resources. Since recreation shorelines are highly desirable for other uses such as industrial and power development, future pressures in many metropolitan areas will intensify. In addition, as populations increase, these shorelines will become increasingly valuable for recreation.

Urban Recreation Water Needs

The United States is an urban nation; 73.6 percent of the population lived in urban areas in 1970. One consequence of this urbanization is that choice water-related recreation land in or near metropolitan areas is almost always under pressure for residential and commercial development. The competing forces make these lands expensive for recreation uses. Moreover, most urban areas have limited water-related recreation opportunities, especially for inner-city residents. Many local jurisdictions lack the financial resources to put together major recreation lands acquisition and development programs and to manage resources for their residents.

Because people are concentrated in urban areas while usable water resources are often at some distance, transportation problems, including energy scarcity, add pressure to make recreation more accessible to urban populations. Virtually every major urban center is located adjacent to major water resources that are often inaccessible or too polluted to enjoy. As water quality improves in urban areas through implementation of the Clean Water Act of 1977 (Public Law 95-217), the recreation opportunities should increase for a substantial public benefit.

Projections for recreation demands demonstrate the pressing need to plan for additional recreation resources for large metropolitan areas either by enhancing existing recreation resources or by establishing new, urban-oriented river and lakefront areas. The urban need has not gone unrecognized at the Federal level. The 1976 Land and Water Conservation Fund Act Amendments (Public Law 94-422) require that a comprehensive review be made and a report prepared on needs, problems, and opportunities associated with urban recreation in highly populated areas. A discussion of resources potentially available for meeting such needs was included in the report. The report also addressed major questions confronting our urban areas such as operation and maintenance costs of recreation areas

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and the appropriate roles of Federal, State, local, and private interests. The report also included definitive urban recreation policy for future action.

Maintaining Streamflows for Recreation

As water is increasingly allocated among competing uses, maintenance of streamflows for recreation is a relatively new but significant concept. Consumptive demands for water in water-short areas are generally favored over recreation demands because of legal constraints and economic interests. Water rights in the West traditionally have been tied to beneficial use of water as defined by State law. Beneficial uses generally include municipal and industrial water supplies, stock watering, agriculture, and mining. Only recently have recreation uses and the esthetics of instream flow been recognized. The necessity for maintaining water in the stream for recreation will become more critical as energy and agricultural developments compete for scarce water resources in many parts of the country.

An acceptable methodology for determining adequate recreation flow now being pursued at Federal and State levels should be encouraged and strengthened by additional funding and personnel. Accurate determinations of instream flow requirements flow for recreation use are essential if multipurpose water resource planning is to be accomplished. Field surveys should be focused initially on streams where energy and agricultural developments are projected. The provision of a comprehensive data bank on instream flows should be a high priority item in future Federal water planning.

Improving Water Quality for Recreation

Man's activities have degraded water quality to the point that water-related recreation opportunities have been diminished or entirely eliminated on some bodies and streams. Water quality is especially critical in the vicinity of cities where needs are greatest and water resources limited. Many urban areas have developed around harbors or along river transportation arteries, but planners in metropolitan areas have often neglected these potential recreation resources because of water quality problems. Increased opportunities for outdoor recreation may be provided in conjunction with the cleanup of waters under the provisions of the Clean Water Act of 1977 (Public Law 95-217), and more specifically, under the areawide waste treatment management planning authorized by Section 208 of that Act.

The planning authorized by Section 208 can integrate environmental and development considerations in solving water quality problems. On the premise that water quality control problems cannot be solved by technology alone, the planning can also coordinate outdoor recreation programs with efforts to clean up the Nation's waters. Since water quality is influenced by patterns of land use, dedication of land to parks and recrea-

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tion should contribute greatly to improved water quality. Park development can help to set the pattern for other types of development that affect water quality.

In support of water quality objectives, adequate public access to clean water will be provided by public acquisition of lands along rivers and lakes. Water-related recreation areas can be enlarged by acquisition of additional lands in conjunction with treatment works. Easements obtained for interceptor sewer lines could include public rights for trails.

Managing Reservoirs for Recreation

Improved use of existing water resources is one means of meeting needs with very little alteration of the environment. Many Federal water resource projects built before 1960 did not provide for recreation. Consequently, present reservoir operations do not allow for meeting or enhancing recreation needs. The Federal Water Project Recreation Act of 1965 (Public Law 89-72) established recreation as a factor in investigating and planning Federal water resource projects. Making recreation equal to other purposes in Federal water resource projects allows for acquisition of land for public recreation use, for control of shoreline development, and for modifying reservoir operating procedures to enhance recreation and related environmental values.

Municipal water supply reservoirs offer additional recreation opportunities. These reservoirs and associated watershed lands are an ideal resource for significant public recreation, often in close proximity to major population centers. Significant use of municipal water supply reservoirs as recreation opportunities was identified in the New England, Ohio, and South Atlantic-Gulf Regions. Historically, recreation use of water supply reservoirs has been restricted to protect public health. Such a policy was essential in the past before water treatment was introduced. Today, improvements in water treatment technology, either widely used or likely to be required, make possible the safe use of reservoirs and associated watershed lands. Under these conditions, recreation becomes not only a compatible use but also a very practical way to ensure the public support necessary for continued long-term protection of the watershed from the encroachment of more intensive uses.

Providing Public Access to Recreation Waters

The great diversity of access rights to waters for recreation can confuse and discourage users. In States where lands beneath the lake or stream are in private ownership, public uses of waters for recreation can be prohibited by the owners of such lands. In many states where public access is a normally guaranteed right, it is not always enforced, so many shorelines are fenced off or otherwise made inaccessible. Excluding the public from shorelines has increased pressures on lake, stream, and ocean frontage that is accessible to the public.

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The importance of public access to surface water cannot be overemphasized. A major effort is necessary to examine public access policies and programs for: existing legal rights of access; tools and techniques for enforcing these rights (e.g., acquiring public access in residential developments); development of access at bridge and road closures; management options for maintenance and liability questions; establishment of new funding programs for access purposes; and mandatory programs for providing access in conjunction with new transportation projects. These issues should be evaluated in appropriate forums to develop incentives to develop greater access to the Nation's waters for recreation.

Any program or consideration of public acquisition of shoreline rights should encourage the private sector, on either a profit or nonprofit basis, to provide access to water. Since public ownership of all the Nation's water and related land resources is neither feasible nor desirable, ways must be found to maintain and increase public access through private lands. Privately-owned waters and related land resources have long played a major role in satisfying public demands for recreation opportunities, so every incentive should be explored for increasing the outdoor recreation opportunities, particularly for water-related activities, on these waters and lands.

Competition for Water

Recreation use of water appears to be on a collision course with energy, municipal, industrial, transportation, and agricultural uses. Two competitors in particular deserve attention--energy and agriculture. Water is essential to all phases of energy development from mining to revegetation of mined lands. Management of reservoirs to maintain minimum reservoir pools during the recreation season and for coordinated water releases to enhance or protect downstream river recreation opportunities could be seriously affected by anticipated water requirements for energy development. Demands for water to support coal and other energy development will undoubtedly lead to consideration of new reservoirs. Various energy development proposals could also affect important recreation streams and eliminate recreation for many miles below the scene of energy developments. Section 13(c) assessments, which was carried out pursuant to Public Law 93-577, Federal Nonnuclear Energy Research and Development Act of 1974, deals with water resources available for nonnuclear energy technologies.

Agricultural development, recreation's second major competitor for scarce water resources, demands and needs water for irrigation. Past Federal policies toward irrigation were based on the need to promote settlement and economic development of the West. While these may no longer be primary goals, there is still an effort to develop rural areas of low growth or depressed economies and to promote agricultural growth by providing water supplies. Agricultural priorities can seriously affect the availability of stream and other surface waters for recreation. Both energy development and irrigation will compete with recreation in areas of limited water resources. Each can significantly affect reservoir recreation management and free-flowing stream values. Adequate consideration of recreation values in all stages of development will be essential to resolving these potential conflicts.

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Improving the Planning Process

A uniform recreation planning system with standardized terminology is a high-priority need. Much of the recreation data developed in the assessment was based on comprehensive water studies and statewide comprehensive outdoor recreation plans. The methodologies and data output by Federal agencies and States varied significantly, even though each had similar guidance. Lack of uniform data led to a number of irreconciliable differences. In the past, recreation information has been lacking or questionable sources have been used. It is now evident that a unified and comprehensive (multi-agency) outdoor recreation planning program is needed.

Throughout the assessment, accurate information on instream flow requirements for recreation were lacking for two reasons. First, an acceptable instream methodology to measure instream flow requirements for recreation has not been developed. The assessment procedure for measuring an entire subregion's instream flow requirements at the outflow point was not considered sound for recreation planning. Secondly, adequate data on recreation uses of streams were not available. Before intelligent decisions can be made on instream flows, information comparable in detail to that developed for other water-planning disciplines (e.g., hydrology, engineering, and economics) is needed. A quantified data base detailing the extent of recreation uses for major streams is essential.

Data in two additional worrisome areas were lacking for the assessment: (1) the nature, magnitude, and importance of the private sector contribution to the water supply for outdoor recreation supply, and (2) the propensity of people to travel for outdoor recreation opportunities. It is often estimated that the private sector provides more than 50 percent of outdoor recreation opportunities. However, there was little information to verify or refute this estimate from a national perspective. Tourism and travel are now significant and are increasing at a rapid rate. However, little information is available to estimate the significance of tourism and travel on a regional base.*

To plan adequately for the increasing need for outdoor, water-related recreation opportunity, greater effort is needed to develop a uniform recreation planning system and a Federal data collection and retrieval system to evaluate the resources available, the developing needs, and the management options to utilize the available waters.

* For a more detailed discussion on the private sector and tourism, see W.H. Honore, et al, The Federal Role In the Private Sector of Outdoor Recreation. (Washington, D.C.: Heritage Conservation and Recreation Service, 1978.)

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Water Requirements for Navigation

Navigation and Water Resources Management

Navigation is a nonconsumptive water use. The streamflows required to support it are generally less than those needed for any other instream purposes. Nevertheless, the development and management of waterways for navigation often conflicts with other water uses. Navigation requires dredging of channels to maintain channel depth, disposal of dredged material, and construction of locks, dams, and impoundments--all of which affect water quality, fish and wildlife habitats, flood-plain functions, recreation, and other competing water-dependent activities.

This section discusses aspects of navigation: (1) the effects of navigation on instream flows and the consequent water-use conflicts, (2) the size, geographic distribution, and traffic load on the existing waterway network, (3) the role of navigation in the Nation's economy, and (4) 1985 and 2000 projections for navigation.

Instream Effects of Navigation

In most water resource regions, the water required for navigation is less than that needed for other instream purposes such as fish and wildlife habitats. For navigation, the required streamflow depends on the degree to which the waterways are channelized, the depth maintained, the number of locks, and the degree to which lockage water is pumped back to upper pools. In general, conflicts between navigation and other instream uses stem less from water supply requirements than from water quality problems.

The environmental effects associated with the building and maintenance of waterway systems most often brings navigation needs into conflict with fish and wildlife needs and other water quality issues. By creating uniform depths and eliminating rapids and shoals, navigation projects can alter the naturally occurring diversity within rivers. Such diversity is needed to maintain large and varied fish and wildlife populations. For example, a study by the Missouri Conservation Department revealed that navigation projects (e.g., wing dikes) on the Missouri River caused a 50-percent reduction in downstream flow. This in turn resulted in the loss of 100 islands critical for fish and wildlife habitat, and finally caused a decrease in the size of the commercial fish catch.

Similar adverse affects associated with navigation result from disposal of dredged material on river banks, dam construction, and the straightening of river curves and bends. Such actions may reduce streamflows, increase siltation, damage adjacent wetlands or prime bottomland habitats, or precipitate erosion of farmland. In Ohio, farmland erosion from construction of high navigation dams and from increased barge traffic resulted in a $140 million damages suit. Thus, while navigation instream flow needs appear small at first, they can have serious effects on other uses. These conflicting instream and offstream demands illustrate some of the issues that must be addressed by water resources management.

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Nation's Waterways

During the past two hundred years, the Nation's navigation system has been continually expanded, largely through Federal actions. It now consists of 26,700 miles of inland and intracoastal waterways, the Great Lakes-St. Lawrence Seaway system, and ports and harbors serving these waterways (Figure III-14). Navigable channels and canals provide direct access to 131 of the nation's largest cities and to almost all parts of the conterminous States. In Alaska, waterways provide access to many parts of the interior not otherwise accessible by highway or railroad.

SOURCE: U.S. Army Corps of Engineers

Figure III-14.—Commercially navigable waterways

The vast geographical distribution of the waterway system indicates how important navigation is to the Nation's economy. On the average, 65 percent of all these waterway channels have 9-foot depth authorization. Exceptions are the Gulf Waterway, which has 50 percent with that authorized depth, and the Atlantic, New York, and New England systems, which have 60 percent. The largest and most improved of the inland systems is

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that formed by the Mississippi River and its tributaries. This waterway spans 9,000 miles of commercial channels, 65 percent of which has depths of nine feet. On the East coast, the Atlantic Intracoastal Waterway and the New York-New England Waterway system provides 7,000 miles of navigable channels. In the south the Gulf Intracoastal Waterway covers 5,400 miles of channels. Farther west, the Columbia-Snake River system and the Central California channels (which extend inland from San Francisco Bay) total about 3,600 miles.

Nation's Commerce

The Nation's waterborne commerce is about one-fourth of the total intercity freight as measured in ton-miles, but only about 17 percent of the net tons carried (Table III-60). Both measures show a steady decline in relative importance to other modes since 1949. Actual ton-miles and net tons carried by water grew steadily, 62 and 88 percent, respectively, from 1949 to 1974. Over the same period, however, nonwaterborne intercity traffic grew faster, at 140 percent in ton-miles and 107 percent in net tons.

Table III-60.—Intercity freight traffic by modes and waterborne freight traffic by type of waterway, 1949-1974

Year	Total intercity freight	All non-waterborne[1] freight		All domestic waterborne freight		Inland waterways		Great lakes		Coastal	
	billion ton miles	billion ton miles	percent	billion ton miles	percent	billion ton miles	percent	billion ton miles	percent	billion ton miles	per cent
1949	1138	777	68	361	32	42	4	98	9	221	19
1954	NA	NA	NA	NA	NA	83	NA	91	NA	NA	NA
1959	1549	1088	70	461	30	117	8	80	5	264	17
1964	1778	1291	73	487	27	114	8	106	5	237	13
1969	2117	1589	75	528	25	188	9	115	5	225	11
1974	2446	1861	76	585	24	247	10	107	4	231	9
	million net tons	million net tons		million net tons		million net tons				million net tons	
1949	2648	2175	82	473	18	166	6	146	6	161	6
1954	3234	2685	83	549	17	217	7	145	5	187	6
1959	3533	2914	82	619	18	282	8	131	4	206	6
1964	4365	3650	84	715	16	358	8	151	4	206	6
1969	4973	4134	83	839	17	461	9	161	3	217	4
1974	5388	4498	83	890	17	511	10	146	3	233	4

[1] Includes railway, truck, airway and oil pipeline frieght (excluding mail and excpress since 1969) for both for-hire and private carriers.

Source: Transportation facts and Trends, Transportation Association of America, Washington, D.C.

Intercity freight traffic on the inland waterways grew faster than other types of waterborne traffic (Great Lakes and coastal traffic) from 1949 to 1974. Inland waterways handled nearly six times more ton-miles

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of traffic in 1974 than in 1949 and about three times more net tons. These data indicate a trend to move commodities over longer and longer distances on the inland waterway system.

Waterborne Commerce - Foreign and Domestic

Commerce handled at United States ports includes both foreign cargoes (both imports and exports) and domestic shipments between United States ports. During 1974 the Nation's total waterborne commerce, including both foreign and domestic cargoes, was 1.7 billion tons, an increase of more than 40 percent since 1964 (Table III-61). Petroleum and related products are the predominant commodity traffic, accounting for about 42 percent of the tonnage in both foreign and domestic waterborne commerce. Petroleum and coal together make up over 55 percent of the total waterborne commerce.

Table III-61.—Total, foreign, and domestic waterborne commerce by major commodity groups, conterminous United States, 1974

	Total		Foreign (imports and exports)		Domestic	
Commodity group	Million tons	percent	Million tons	percent	Million tons	percent
Petroleum and products	735.4	42.1	328.1	43.0	407.3	41.5
Coal and coke	228.8	13.1	81.2	10.6	147.6	15.0
Iron ore, iron and steel	171.2	9.8	79.6	10.4	91.6	9.3
Sand, gravel and stone	127.5	7.3	14.9	2.0	112.6	11.5
Grains	97.8	5.6	70.1	9.1	27.7	2.8
Chemicals	96.1	5.5	40.7	5.3	55.4	5.6
Logs and lumber	52.4	3.0	25.8	3.4	26.6	2.7
Shells	17.5	1.0	0.0	0.0	17.5	1.8
All others	220.1	12.6	123.7	16.2	96.4	9.8
Total	1746.8	100.0	764.1	100.0	982.7	100.0

In 1974, the total foreign waterborne commerce was 764 million tons, with 497 million tons imported and 267 million tons exported. This was an increase of more than 80 percent in total commerce since 1964. Imports and exports through coastal ports were 474 and 239 million tons, respectively, while imports and exports through Great Lakes ports were about 4 and 5 million tons, respectively.

In 1974 domestic waterborne commerce within the conterminous United States was nearly 983 million tons. This represented about 56 percent of the total waterborne commerce for that year and a 20 percent increase over 1964. Of this total, 511 million tons were carried on internal or inland

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waterways; 233 million tons on coastal traffic; 146 million tons on lakes; 88 million tons were local; and 4 million tons were among U.S. territories. Projections for this assessment are based on the navigation and waterborne commerce "1975" figure of 501 million tons of internal traffic on the Mississippi River and the Gulf Intracoastal Waterway systems.

The Mississippi River and the Gulf Intracoastal Waterway systems, which essentially form one system, carry most of the cargo moved on the Nation's waterways. These two systems combined account for about 55 percent of the length, 70 percent of waterborne ton-mileage, and 85 percent of waterborne tonnage in the United States. The lower Mississippi between the mouth of the Ohio River and Baton Rouge carries the largest amount of traffic, more than 90 million tons.

Waterway Commerce, "1975"-2000

Total "1975" domestic waterborne freight traffic on the Mississippi River system and the Gulf Intracoastal Waterway was 501 million tons. This traffic is expected to grow by about 79 percent to 899 million tons in 2000 (Table III-62). Although petroleum and its products comprised 41 percent of the traffic in "1975," this traffic will increase only 46 percent by 2000 when petroleum will make up only about one-third of the freight. Coal and coke products traffic, which will increase by about 112 percent, will make up 29 percent of the traffic in 2000. All other commodity traffic is projected to increase proportionately over this period with the two energy sources retaining together about two-thirds of the Mississippi River-Gulf Intracoastal Waterways traffic.

Table III-62.—Domestic waterborne traffic by commodity group for the Mississippi River and tributaries and Gulf intracoastal water systems—"1975," 1985, 2000

Commodity	"1975"		1985		2000	
	Millions tons	Percent	Millions tons	Percent	Millions tons	Percent
Petroleum and products	207	41	242	37	303	34
Coal and coke	123	25	187	29	261	29
Iron ore, iron and steel	9	2	12	2	16	2
Sand, gravel and stone	27	5	31	5	40	4
Grains	28	6	33	5	47	5
Logs and lumber	1	1	2	<1	3	<1
Chemicals	38	8	56	9	100	11
Shells	13	3	16	3	20	2
All others	55	11	74	12	112	12
Total[a]	501	100	648	100	899	100

[a] Numbers may not total because of rounding.

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The regional characteristics of inland waterway navigation depend on the types of economic activities within the waterway system, activities which originated independently of the system as well as those which originated because the system was available. The Ohio and Upper and Lower Mississippi Regions originated 346 million tons of commerce in "1975," 70 percent of the total traffic (Table III-63). In 2000 these three regions are expected to originate 620 millions tons of waterborne traffic, but at about the same percentage as in "1975." The other major waterway traffic region is the Texas-Gulf with about 100 million tons or one-fifth of the total traffic in "1975." The largest rate of traffic increase is

Table III-63. – Waterborne commerce on the Mississippi River and Gulf intercoastal waterway by commodities and origins – "1975", 1985, 2000
(million tons)

Region	All commodities			Percent of Total			Petroleum			Coal and Coke			Iron ore, Iron, Steel			Sand, Gravel, Stone			Grains			Chemicals			Shells			Other		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
South Atlantic Gulf(3)	31	37	55	6	6	6	15	18	22	6	7	9	3	3	6	2	2	4	<1	<1	1	1	2	5	1	1	2	2	3	4
Great Lakes(4)	13	16	23	3	3	3	3	4	5	1	1	1	1	2	2	2	3	3	1	2	3	1	2	3	0	0	0	3	4	7
Ohio(5)	128	159	219	26	25	24	12	13	16	90	112	156	2	3	3	13	15	18	2	2	4	4	5	9	0	0	0	6	9	13
Tennessee(6)	7	9	30	1	1	3	<1	<1	<1	3	4	21	<1	<1	1	2	2	2	<1	<1	<1	1	1	1	0	0	0	1	1	3
Upper Mississippi(7)	63	110	141	13	17	16	6	8	10	18	57	67	<1	1	1	4	5	7	21	26	34	1	1	3	0	0	0	11	15	23
Lower Mississipi(8)	155	190	260	31	29	29	93	108	135	4	5	6	2	3	3	2	2	3	2	2	3	17	25	43	9	11	13	26	35	53
Missouri(10)	2	2	2	1	1	1	0	0	0	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	1	2	<1	<1	<1	0	0	0	1	1	2
Arkansas-White-Red(11)	1	1	2	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	1	1	<1	<1	<1	<1	<1	<1	0	0	0	1	1	1
Texas-Gulf(12)	100	123	165	20	19	18	78	91	114	1	1	1	1	1	1	1	1	2	1	1	1	13	20	35	3	4	5	4	6	8
Rio Grande(13)	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Total	501	648	899	100	100	100	207	242	303	123	187	261	9	12	16	27	31	40	28	33	47	38	56	100	13	16	20	56	75	115

expected in the Tennessee Region, although the total of 30 million tons by 2000 will represent only 3 percent of all waterway traffic. This increase will result largely from the expected opening of the Tennessee-Tombigbee segment in 1986.

Waterborne cargo on the Mississippi-Gulf waterways in the South Atlantic-Gulf Region consists largely of energy materials, with petroleum and coal making up two-thirds of the traffic. The Ohio Region waterway traffic is 70 percent coal and coke with about equal tonnages of petroleum and sand-gravel-stone (about 10 percent each). The major commodity traffic on the Upper Mississippi Region is grain (one-third of the commerce) followed by coal (29 percent) and petroleum (10 percent). This region originates three-fourths of all the grain traffic on the inland waterway system. Increased agricultural exports would increase this traffic.

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The major traffic commodities on the Lower Mississippi are petroleum (60 percent) and chemicals (11 percent). The chemicals traffic should increase by 250 percent but the petroleum traffic is expected to increase only by about 45 percent by 2000. Likewise, the predominant traffic on the Texas-Gulf waterways is petroleum (78 percent) and chemicals (13 percent). These two regions account for 83 percent of the waterborne petroleum and 79 percent of the waterborne chemicals carried on the domestic waterway system. Small amounts of traffic (about 30 million tons) originate on the Columbia-Snake system (Pacific Northwest Region), but they are not included in the data for the Mississippi River System and Gulf Intracoastal Waterway.

Major navigation improvements are underway in the South Atlantic-Gulf Region to accommodate expected growth above the "1975" level of 230 million tons of total waterborne foreign and domestic tonnage. The new improvements include the Tennessee-Tombigbee Waterway now under construction and significant harbor and port improvements. Maintenance of these waterways to 9-foot channel depths under environmentally acceptable conditions will be a continuing problem for navigation in this region.

The Ohio Region's growth in waterborne commerce, nearly doubling by 2000, will require extensive structural modernization to bring the total system up to modern tow standards with 1200-foot locks. The Texas-Gulf Region will require considerable financing for facilities and maintenance of waterways to accommodate the 65 percent growth in tons of cargo projected by 2000. The Army Corps of Engineers proposes that Locks and Dam 26 be replaced to provide improved locking facilities for commercial navigation.

Noncargo and Passenger Uses of the Inland Waterways

Recreation boating has become an important and rapidly growing activity on the Nation's waterways with an estimated 8.3 million boats in use in 1974 (Table III-64). Recreation boating is giving cargo waterway users increased competition for the use of waterways. The greatest impact is at points of congestion such as locks and fleeting areas. Pleasure boat docking sites also compete with commercial uses of valuable and limited waterfront property. In "1975," noncargo (largely recreation) passages amounted to as many as one-half of all lockages at many locks. This indicates increasing pressures on operating costs for locks and commercial uses as density of traffic and congestion increase.

Compared to other modes, water transportation of passengers is relatively small; however, 1974 records indicate that there were more than 3,800 inspected United States vessels in the passenger trade, mostly small ferry and passenger vessels. While available passenger statistics are not complete, over 20 million persons were carried by these vessels in 1974. An estimated 4,000 other vessels, which carry fewer than seven passengers each, were not required to be inspected. The decline in use of larger passenger vessels appears to have leveled off with tourist cruise ships, mostly foreign, showing an increase in passengers. Local

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Table III-64.—Selected recreational boating statistics, 1974

Area	Total boats all types	Total operators	Total passengers	Boat hours
Great Lakes	2,034,456	3,889,416	5,960,956	256,594,351
Mid-Atlantic	1,364,575	2,692,361	3,848,101	225,256,557
Gulf Coast	1,523,664	2,369,450	4,311,969	287,577,859
New England	1,222,407	2,976,551	3,508,303	186,808,304
West Coast	963,867	2,074,961	3,113,290	86,069,613
Mid-West/Mountains	684,213	1,380,576	2,093,691	59,593,351
East Central	543,161	987,187	3,093,188	59,593,351
Total	8,336,343	16,370,502	14,449,950	1,189,022,661

Source: U.S. Coast Guard

and intercity passenger movements on the waterways are expected to increase between "1975" and 2000, but no special problems relating to the increase in traffic are foreseen.

Navigational Water Requirements

Navigation is a nonconsumptive water user. A body of water of defined depth sufficient to maintain acceptable vessel operations (loads, tows, and speeds) constitutes a navigation system. In open rivers, navigation needs are adjusted to the natural regime of the water flow. Improvements in navigation conditions by dredging and other means, though essential for water transportation, are limited by river hydraulics, cost-benefit expectations, and adverse environmental effects.

Streamflows required to support navigation are generally less than those needed to maintain the quality of water, aquatic habitats, or other instream purposes. During low-flow periods, the lower sections of the Missouri, Mississippi, and Columbia Rivers, which are basically natural river regimes, may be exceptions to this general statement. In the future, increasingly large flows of water will be required to maintain suitable water quality and to meet instream flow needs for fish and wildlife. In most water resource regions, the water required for navigation will be less than that needed for other instream purposes, especially for fish and wildlife. Maintaining adequate instream flows would reduce the amount of needed dredging and channelization.

Environmental Effects and Costs

The principal problem for future waterway transportation will be that of developing and maintaining a viable and efficient transportation system without adversely affecting recreation, fish and wildlife, com-

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mercial fishing, and the environment. The largest factor of uncertainty is that of dredging and the associated spoil disposal. Constraints on ocean dumping, diked wetlands, and other disposal methods have greatly increased the cost of maintaining navigation channels. Such costs may be especially difficult to meet where State and local governments are obligated to provide disposal sites for the material dredged. These environmental and associated cost conditions directly confront the need for channel and port enlargements to meet increased traffic projections for commercial navigation.

Future Navigation Systems

The projected commercial traffic for 1985 and 2000 is based on continued free use of the waterways. It seems likely, however, that some system of charges for the use of the waterways and/or facilities will be adopted and implemented. Study results vary on how the charges will affect navigation traffic.

The waterway system of the United States is essentially complete except for certain connecting links such as the Tennessee-Tombigbee Waterway, the Kaskaskia Rivers and the Red River from Shreveport to the Mississippi waterways. Future improvements will include the completion of several authorized waterways, but efforts will focus mainly on continued modernization. Among the future lock and dam improvements expected to be completed by 2000 are the Vermillion, Seabrook, and Rigolets Locks on the Gulf Intracoastal Waterway; the Smithland Locks and Dam on the Ohio River, and (provided their construction will be authorized soon) Gallipolis Locks and Dam on the Ohio River, and Locks and Dam 26 on the Upper Mississippi River.

A limited number of improvements in harbor approaches may be made. Widening and deepening of coastal harbor and channel dimensions will be limited by the high cost of improvements and environmental concerns. Because they affect maximum tow size and speed, channel and bridge restrictions will continue to constrain system capacity. One-way-only traffic is required now at some of these congested points. Major capacity constraints exist now or will develop before 1990 at various points on the Upper Mississippi, Ohio, Kanawha, and Monongahela Rivers, as well as on the Gulf Intracoastal and Illinois Waterways.

It is uncertain whether several authorized navigation projects can be completed before 2000. These projects include: the Gulf Intracoastal Waterway from St. Marks to Tampa, Florida; the Cross Florida Barge Canal (construction halted in 1971 for environmental concerns); the Coosa River in Alabama; the Yazoo River in Mississippi; the Illinois Waterway Duplicate Locks; the Red River from Shreveport, Louisiana, to Daingerfield, Texas; and the Trinity River in Texas.

Harbor and port facilities for special functions such as petroleum handling will probably be funded and constructed. With the exception of Seattle, no United States port will be accessible to fully loaded superships, very large crude carriers (VLCC) of 140,000 deadweight tons, and

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ultra large crude carriers (ULCC) of 300,000 or more deadweight tons. A "new" domestic trade route will be established between Valdez, Alaska, and West Coast ports to transport oil from the southern terminus of the Trans-Alaskan Pipeline System to refineries in the lower 48 States. Two offshore oil terminals are expected to be built in the Gulf of Mexico. These terminals (LOOP and SEADOCK), the first to be built off the United States coast, will have the capability to handle the largest tankers (ULCC) now afloat, those of 540,000 deadweight tons and 90-foot draft. These offshore terminals will be used primarily to receive foreign oil for transshipment by pipeline ashore.

The continued migration of populations to coastal areas and the considerable nonresident interest in the natural aspects of the coastal and river areas will increase pressures through the noncommercial uses of the system. In addition, construction activities that increase erosion and sedimentation may require even more maintenance dredging or new nonstructural alternatives to solve commercial navigation problems.

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Water for Fish and Wildlife

Since fish and wildlife are highly sensitive to environmental change, their composition and condition can serve as a barometer of the quality of the environment for man. No matter what type of environmental modification occurs--whether one alters stream temperature of flow regime, drains wetlands, channelizes a water course, clears a forest, or changes land uses--it will affect fish and wildlife. Most fish and wildlife species do not adapt easily to changes within their immediate environment. Aquatic and riparian habitats of marshes, rivers, and coastlines are vital for the life cycles of both commercial and noncommercial animal species. This section discusses the water management challenges involved in preserving the natural habitat of wildlife species.

Endangered Species

Since the First National Water Assessment in 1968, concern about the long-term viability of the Nation's environment has resulted in several legislative measures designed to preserve adequate habitat for fish and wildlife resources. Notable among these is the Endangered Species Act of 1973 (Public Law 93-205). The purpose of the Endangered Species Act is to preserve the ecosystems and habitats on which endangered and threatened species depend for existence. In most cases, the danger of extinction is attributable, either directly or indirectly, to human influences.

Protection of endangered species is important not merely because of their esthetic value or their medical and pharmaceutical potential, but because of their unique function within their own ecosystems, which in turn are linked to the functioning of the overall environment. More than 150 species of higher animals in the United States (mammals, birds, reptiles, amphibians, and fish) have been officially listed as endangered (Figure III-15).

The U.S. Fish and Wildlife Service is evaluating data for designating as critical the habitats of these endangered higher animal species in order to protect them. Similar protective measures are being evaluated for insects, crustaceans, mollusks, and a large number of plants that may be endangered or threatened in the near future. The critical habitat of any species is a specific area of land, air, or water, characterized by certain contained biological and physical elements that are essential for that species' survival. The Act affects only those actions that would jeopardize the species' continued existence (as determined by the Fish and Wildlife Service).

The Act requires all Federal departments and agencies to avoid actions that would adversely affect the survival of endangered or threatened species or their critical habitat. Furthermore, Federal agencies are encouraged to conduct programs for the conservation and recovery of listed species. The large number and broad geographical dispersal of the species whose preservation is mandated by Congress may delay and limit the scope of

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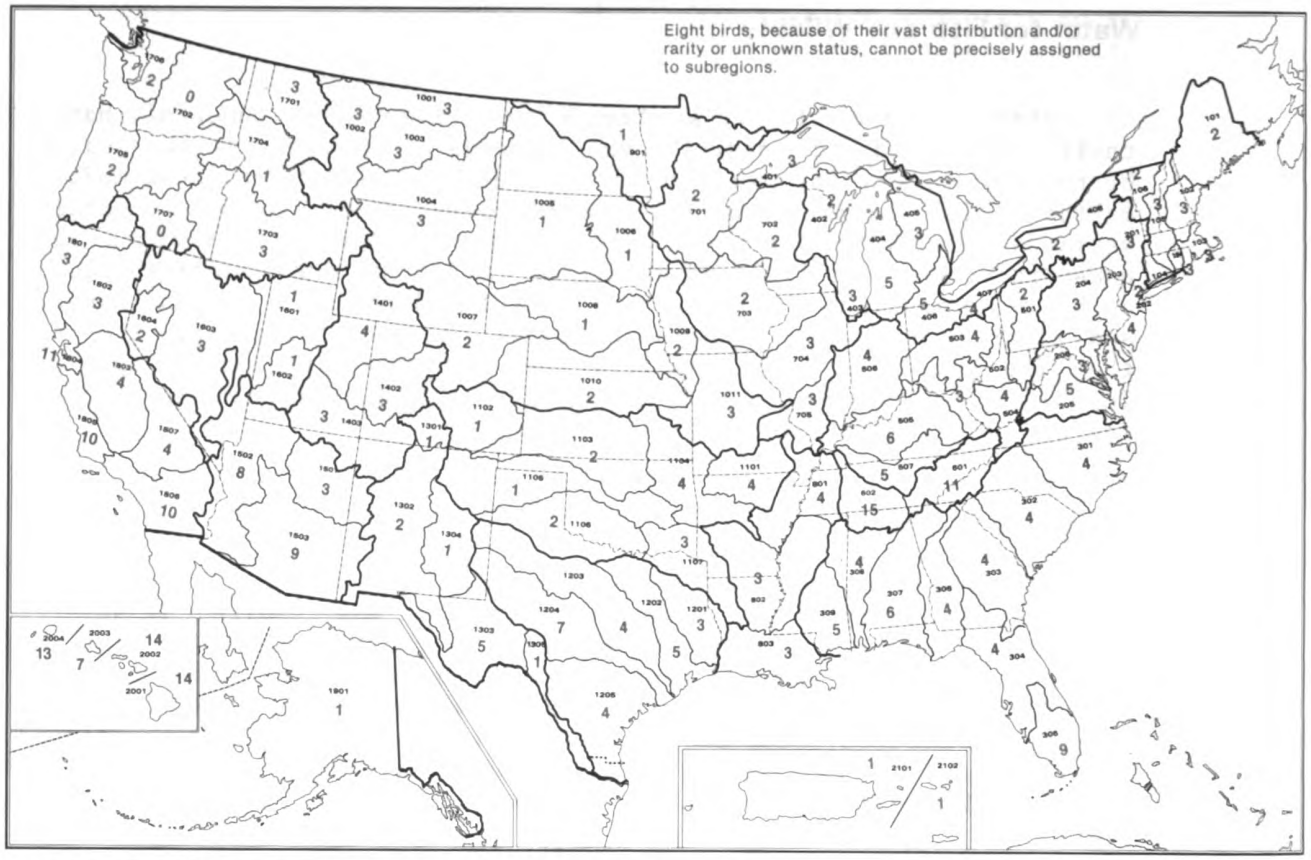

Figure III-15.—Number of endangered species, June 1977

water resource projects and other developmental activities in some areas. However, the costs of such delays and recovery measures serve to indicate the long-range cost of less sensitive development that has endangered or threatened species.

The water requirements for fish and wildlife involve three major ecosystem types: riverine, wetlands and coastal, and upland.

Riverine Ecosystems

A riverine ecosystem is a natural water course containing flowing water at least part of the year and supporting a biotic community of aquatic plants and animals. In addition to the stream channel, the ecosystem usually includes a zone of riparian vegetation dependent upon surface or subsurface flow and a flood plain that is formed by the kinetic energy of the stream during periods of high flow.

The thousands of miles of streams in this Nation are as diverse as its climate and physiography. Although several Federal programs mandated by law call for identification, classification, and preservation of nationally significant streams, there is no one official, nationwide,

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aggregated display or map of such streams. In an initial attempt to classify rivers for the second assessment, a series of maps were compiled from State classification systems and information supplied by the U.S. Fish and Wildlife Service's Ecological Services field personnel. The criteria used included the presence of nationally significant recreation fisheries and reproduction habitat for significant anadromous species. These maps were further refined to include riverine habitat of endangered species, selected National Wildlife Refuges, stream reaches either included in or proposed for the Federal Wild and Scenic Rivers system, and nationally significant inland river commercial fisheries. Results available from the Fish and Wildlife Service's ongoing stream priorities project were also included for nine States. The resultant map, available from the Water Resources Council as a separate product of the assessment, shows the current perception of stream priorities and serves as a starting point for measures to improve the management of the Nation's waters. The first generation map should be given broad review, so that refinements to the map can be made. Then a second generation map can be published to help water resource planners, developers, and managers recognize fish and wildlife values and locations.

Water allocation problems stem from past decisions that placed constraints on future choices. In many areas, limited water resources are in great demand, so that tradeoffs with long-standing vested interests will become necessary. Figure III-16 illustrates the conflict for water supply.

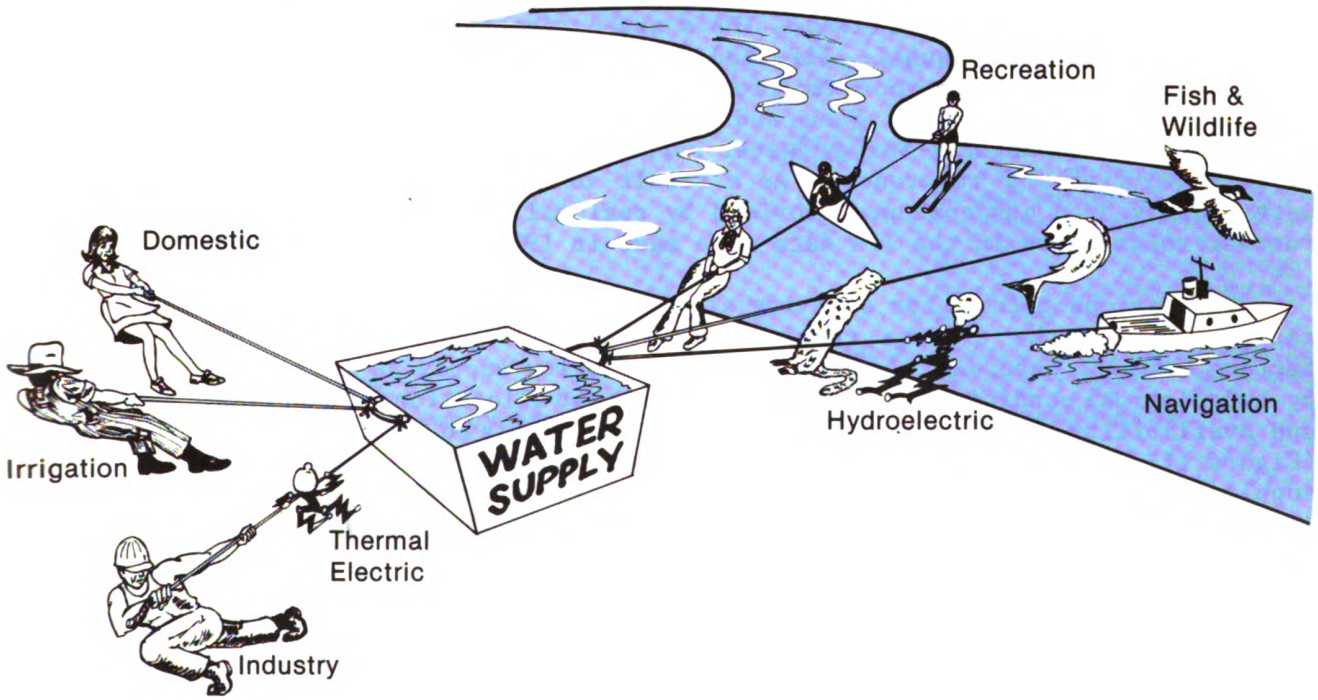

Figure III-16.—Conflicts in instream vs. offstream use

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Instream Flow Approximations

Because data were lacking, the first assessment did not address instream flows, but it did state that in future assessments, a more complete analysis of the flow adequacy for instream uses would be undertaken. In fulfilling that promise, this assessment provides the first nationwide examination of instream flow conditions and the implications of accelerated offstream uses of water. This was accomplished through a water adequacy analysis to determine whether streamflow supplies can meet consumptive and nonconsumptive water requirements for each of 106 subregions. In order to perform the adequacy analysis, a set of numbers was needed to represent the instream flow needs for fish and wildlife.

Any analysis of the collective water requirements of a group of streams comprising a major river basin cannot be made without sacrifice in precision. Furthermore, instream flow needs had to be measured at the outflow point of streams. At best, this measurement truly indicates conditions only in the immediate outflow area. For much of the country, almost no satisfactory biological data are available to correlate hydrologic data. Moreover, an acceptable methodology to evaluate the data was not available when the assessment was begun.

However, to facilitate problem identification--a major objective of the second assessment--approximations of instream flow needs were based on judgment and the best available information. These estimates were called instream flow approximations (IFA). IFA's are estimates of monthly flows sufficient to support aquatic life and outdoor recreation, estimated at the outflow point. These approximations were initially developed in 1974 and 1975 by a team of U.S. Fish and Wildlife Service biologists, who used the U.S. Geological Survey water supply statistics* and a variety of methodologies and references. As a result of further changes in the water supply data and comments provided by regional sponsors and others, further refinements in the IFA data were made in 1977.

The various methods for arriving at the final instream flow approximations reflect the diverse combinations of factors considered. These factors include: nature of the ecosystem; streamflow supply as influenced by hydrological conditions, storage, and man's past allocation of supplies; and availability of previous instream studies applicable to this assessment (Figure III-17). The rationale of factor combinations is discussed in a supplementary report on "Instream Flow for Fish and Wildlife," to be published by the Water Resources Council in late 1979. IFA data consist of annual and monthly figures for each of the 106 subregions. See Volume 3, Table II-3 of Appendix II and Table III-3 of Appendix III.

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*The USGS Water Supply Statistics for the Second National Water Assessment prepared in the fall of 1974 included depletions at near "1975" levels of development and reflect operation of reservoir storage as it would have been detected by USGS discharge recording stations.

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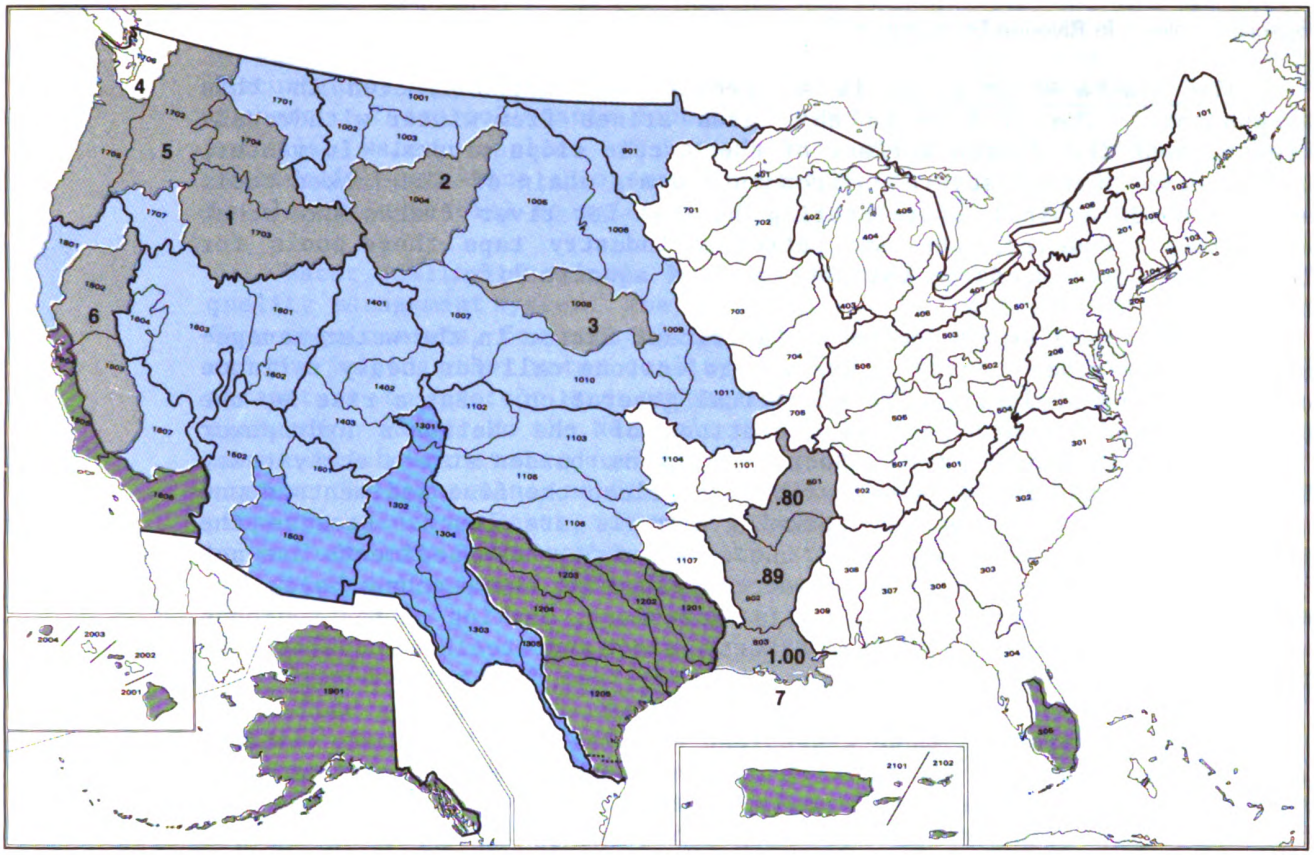

The patterns on the map show where each of the following methods were used to obtain instream flow approximations (IFA). Except for method D below, IFA are based on water flow data prepared for the Second National Water Assessment.

A. Monthly IFA are 50 percent chance monthly streamflows. Annual IFA are averages of monthly IFA.

B. Annual IFA are 50 percent chance annual streamflows. Monthly IFA are computed by multiplying the monthly 50 percent chance streamflows by the factor required to make the average of the monthly IFA equal the annual IFA.

C. Monthly IFA are either 40, 60, or 100 percent of the estimated monthly natural flows depending on seasonal needs. Annual IFA are averages of monthly IFA. The estimated natural flows are obtained for this purpose by adding consumptive uses and exports to present average streamflows and subtracting imports and ground-water overdraft.

D. Method C above was used except that flushing flows (100%) were not included.

E. Methods for these locations are based on more detailed information available from the following references:

1. Bayha, Keith and Charles Koski (Editors), *Anatomy of a River: Report of Hells Canyon Controlled Flow Study Task Force*, Washington. 1974.
2. *Reservation of Water in the Yellowstone River Basin*, Montana Fish and Game Commission. Helena, Montana. 1976.
3. *Platte River Basin, Nebraska Level B Study*, Missouri River Basin Commission. Omaha, Nebraska. 1976.
4. Puget Sound Task Force. *Puget Sound and Adjacent Waters, Comprehensive Water Resource Study*. Pacific Northwest River Basins Commission, Vancouver, Washington. 1970.
5. Columbia Basin Fishery Technical Committee September 1975 letter report to Division Engineer, North Pacific Division, Corps of Engineers from Fred Cleaver, Program Director, National Marine Fisheries Service, Portland, Oregon.
6. Personal communication with U.S. Fish and Wildlife Service Biologists Ed Whitsell, Stockton, California, and Robert Hayden, Sacramento, California. 1977.
7. Interagency Ad Hoc Study Group. *Report on Mississippi River Flow Requirements for Estuarine Use in Coastal Louisiana and the Atchafalaya Basin*. Mississippi River Commission, Vicksburg, Mississippi. 1970. IFA for ASR 801 and 802 are obtained from the IFA for ASR 803 using the ratio of streamflow from ASR 801 and 802 to the streamflow from ASR 803.

Figure III-17.—Methods used in arriving at instream flow approximations (IFA)

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Special Problems in Riverine Ecosystems

The Alaska North Slope is a special case not reflected in this assessment. The problem in this area arises from winter withdrawals from beneath the frozen surface of the Arctic slope rivers. In winter, the streams in this severe environment form a chain of ice-locked pools which provide a vital overwintering habitat for river fishes and other organisms. However, the new petroleum industry taps these pools for industrial water needs to the detriment of aquatic life.

Hydropeaking could become a significant factor in the water management of many river basins. Energy projections call for heavy reliance upon coal- and nuclear-fueled electrical generation. But a rise in the present trend toward peaking operations of the Nation's hydropower facilities is also assumed. Such operations burden stream ecosystems. Violently fluctuating streamflows tend to flush the fine sediments downstream, so that beaches and spawning gravels are lost. Because the upstream bedload is trapped in the reservoir, these sediments are not replaced. As a result, the stream ecosystem in the reaches below the dam is vastly different. In the Pacific Northwest, peaking of the region's substantial hydropower facilities affects salmon and steelhead populations. This problem is now being studied.

Stream alteration is a widespread problem for fish and wildlife populations. Manipulation of rivers and streams through structural developments such as dams, levees, dredging, and channels in the past has been the traditional solution to water management problems in the United States. Stream channelization for flood control and drainage destroys the riparian habitat and disturbs the character of the streambed itself. Studies have shown that channeling destroys the stream ecosystem for a substantial period, in some cases for decades. In recent years, greater public awareness of the consequences of channelization has led to more selective clearing and snagging, as well as special techniques such as excavation from one side only and construction of mitigation features such as deflectors, low water weirs, and vegetative plantings. The shift is toward nonstructural solutions, which will benefit fish and wildlife populations. Many nonstructural programs offer exceptional opportunities for complementary greenway development and recreational uses. Preservation of remaining natural stream systems now gaining momentum is stimulating demand for better inventory data and analytical techniques for assessing values of riverine ecosystems.

Riparian habitats are very susceptible to damage from over-grazing. Removal of the understory in forest cover is of special concern, particularly in the Southwest where this habitat is vital to the native fauna. When riparian lands are grazed, stream channels tend to become wider, shallower, and warmer. These physical changes adversely affect the aquatic organisms. Grazing of adjoining lands and fencing of streams and riparian zones have been useful for reversing this effect.

Water quality is vitally important to fish and wildlife resources. Although the quality of the Nation's streams reportedly is improving,

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nonpoint-source pollution (primarily in the form of contaminants carried by surface runoff from agricultural lands, urban developments, and sites disturbed by logging operations and construction) continues to be a major concern. These pollutants contaminate not only the aquatic environment but also water supplies of downstream communities and industry, and, eventually, estuarine ecosystems. Control of nonpoint-source pollution is clearly essential to maintain fish and wildlife habitat.

Water quality standards are an essential part of any State water quality management system. They provide a basis for establishing instream flow requirements, for controlling the introduction of toxic substances, and for judging other water quality programs. The chemical and biological parameters to protect and propagate fish and wildlife and to support recreation in and on the Nation's waters have been well studied in order to establish State water quality standards. If the Nation's waters are to support the maintenance of fish, wildlife, and recreation, physical stream properties such as depth, velocity, turbidity, and temperatures must also be included in State water quality standards. Water quality problems are discussed in more detail in the section on water quality in Part IV of this volume.

Ground-water and surface-water relations are both insufficiently understood and poorly documented. Failure to manage use of ground-water and surface-water resources as one water supply has led to substantial problems in certain areas (e.g., subsidence in Texas, Louisiana, and Florida; degraded riverine habitat in Nebraska, California, and Arizona). Changes are urgently needed in both the research and data collection programs and in our institutions and laws.

Future options are basically twofold: (1) take limited action and witness the decline of the ecological balance of our riverine ecosystem with consequent economic, esthetic, and social impacts; (2) alter existing trends and mitigate adverse effects on a major scale. While technical expertise can offer new practices, processes, and strategies, ultimately legal and institutional mechanisms that have failed to keep pace with the Nation's growth must be revised.

Wetlands and Coastal Ecosystems

Wetlands are lands where water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in that area, including the terrestrial and aquatic systems.

The Federal Water Pollution and Control Act Amendments of 1972 (Public Law 92-500) defines a coastal ecosystem or estuarine zone as "...an environmental system consisting of an estuary and those transitional areas that are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and inter-tidal areas, bays, harbors, lagoons, inshore waters, and channels; the term 'estuary' means all or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connections with the open sea and within which the sea water is measurably diluted with fresh stream water delivered

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from land drainage." Although there are obviously some overlaps in these definitions, there are also some unique aspects. Wetlands and coastal ecosystems are considered in tandem here primarily because current institutions relate similarly to both.

Wetlands Ecosystems

During the past two centuries, the Nation's heritage of wetlands has decreased from approximately 120 million acres to about 70 million acres. No nationally consistent data describe the location and type of these remaining wetlands; however, the U.S. Fish and Wildlife Service is currently conducting a National Wetlands Inventory. The inventory has been designed to provide a single, hierarchical system of classification and storage of information that will describe all wetlands on an individual and cumulative basis in terms of their ecological and physical characteristics, geographic location, and natural resource values. An information base is being developed in both map and computer file form. This will permit compilation, storage, and retrieval of information after 1979.

Wetlands not only provide habitat for waterfowl and other wildlife, breeding grounds for fish, and recreational opportunities, but they also act as natural filters that absorb pollutants and recycle nutrients and as a buffer for extreme events such as floods and storm tides. They frequently play an important role in recharging aquifers. Wetland ecosystems are more valuable than is generally perceived.

Until the President's Executive Order of May 24, 1977, drainage had been promoted by some Federal programs in direct opposition to other Federal programs aimed at preserving waterfowl habitat. Prairie grasslands and associated wetlands converted to cropland through private action and Federal programs have significantly reduced waterfowl and prairie wildlife habitat. Draining of bottomland hardwood forests to provide additional agricultural production has also adversely affected these natural ecosystems. Furthermore, dredging and filling of coastal wetlands for navigation and real estate development have caused substantial losses to flora and fauna.

Coastal and Estuarine Ecosystems

A wide spectrum of habitats and coastal types are found along the thousands of miles of shoreline in such diverse areas as the ice-stressed systems of Arctic Alaska, the coral reefs and mangrove swamps of the Gulf of Mexico and Hawaii, the rocky shores of New England and the Pacific Coast, and the extensive salt marshes of the Mid- and South-Atlantic and the Gulf Coast.

In recent years, economic returns from nearshore marine and estuarine areas have reached $490 million from commercial fisheries landings (1972); $160 million from sportfishing (1970); $224 million from waterfowl hunting (1970); and $5.7 million in fur harvests (1970). Other uses such as recreational boating, bird watching, and swimming also depend heavily

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on the quality of water and water-related resources. Within these diverse ecological systems, man has become a major force in shaping the systems to his own needs.

Since World War II, alteration of our coastal ecosystems has accelerated through the dredging and filling of estuarine waters to produce high value land for building construction and other works. Already, 75 percent of the Nation's estuaries have been severely degraded by dredging, filling, or pollution. This loss of coastal ecosystem habitat has, in some areas, crippled estuarine and nearshore marine fishery resources through loss of vital nursery areas.

Upstream flow depletions and dredging of navigation waterways in the coastal zone change the flow of fresh water and tidal salt water. This upsets the circulation patterns of the estuarine community. Reduction of fresh-water flows into an estuary can affect the estuary in a number of ways: by increasing salinity, increasing flushing time, changing circulation, and decreasing sedimentation. An estuary has a mix of sea water and fresh water, but the amount of fresh water in proportion to the size of the estuary varies enormously, not only from one estuary to another, but also seasonally within a single estuary. The biota found within an estuary reflects the relative stability or instability of the salinity regime existing there.

Any change in the fresh-water flow will affect the salinity regime and consequently affect the biotic communities. Within the lower reaches of a river or in a bay or sound, salinity is a continuum, with the proportion of salinity increasing nearer the sea. The continuum is dynamic, however, in that it fluctuates in response to tidal influence, weather conditions, and fresh-water discharge. A decrease in fresh-water discharge causes the salinity to move farther upstream. Significantly, the lowest diversity of organisms is found in the transition zone between the salt and fresh water where salinity fluctuates most widely.

The most significant effect of reduced fresh-water flows is the change of salinity and its resulting effect on fish and wildlife habitats. In tidal rivers, such as the Potomac River near Washington, D.C., a reduction of fresh-water flow has the same effect as low-flow conditions in the summer months; it moves the salinty upstream but on a more permanent basis. Fauna requiring a particularly range of salinities reestablish themselves farther upstream. Oyster beds are also subjected to higher salinities, and those in the lower reaches may be subjected to predators and to infectious oyster diseases that are salinity-limited under normal conditions. New oyster rocks and cultch need to be established farther upstream in order to keep the larval oyster set viable. Normal spawning and nursery areas for anadromous fish such as herring and shad might be reduced in size. This could be significant if suitable substrates are not available or if a physical barrier to upstream migration is present. In rivers such as the Potomac, the size and salinity of the receiving body of water (the Chesapeake Bay) determine the extent of the river's salinity change caused by a reduction in fresh-water flow. The Texas-Gulf coast and south coastal California have estuaries deprived of substantial fresh-water inflow. (See discussion below.)

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The damming of rivers and reductions in flow reduce the amount of sediment reaching the estuaries. These sediments are important in controlling the ecosystem, since they are sites for the absorption of nutrients and for microbial activity responsible for the decomposition of organic matter. In some cases this sediment reduction can be an advantage, particularly where navigation channels must be maintained. In other cases where large flows are prevalent, deltas depend upon this continued nourishment by sediments. Without the sediment load and coastwide dispersion, erosion takes place, which leads to loss of beaches and even the deltas themselves. In all cases, the wildlife habitat changes.

The river flows are also important in offsetting pollution in the estuaries and bays. Within each coastal region of the United States, pollution is a major concern. In some areas, such as southwest Florida and California, the major sources of pollution are frequently domestic waste, whereas in other regions, such as New England and the Pacific Northwest, industrial pollution is the major concern. Fresh-water flows help to flush estuaries. Any flow reduction tends to increase the concentration of pollutants within the estuaries. Since the Texas bays have a tidal range of only about 0.5 foot, the flushing characteristics must be considered along with fresh-water input.

The effects of projected water use and supply on estuarine and nearshore marine environments cannot be adequately assessed on a regional basis for 1985 and 2000 because the differing demands on subregions within the same region have a tendency to minimize these effects when the water demands are aggregated. When individual subregions are examined, however, certain regions appear to face significant problems.

Four areas have estuaries that are highly affected by changes, principally increases in water use: the Texas-Gulf and Louisiana-Gulf coasts, southern Florida, and the San Francisco Bay-Sacramento delta.

Texas-Gulf Coast--In this area, if predicted increases in consumptive water use are realized, changes in salinity of estuarine areas could seriously affect nursery areas and fishery habitats. The Laguna Madre and Baffin Bay are examples of shallow estuaries in which evaporation in an arid climate has exceeded fresh-water inflow, resulting in hypersaline conditions. Further east, the Nueces River feeds Corpus Christi Bay, and the Guadalupe and San Antonio Rivers empty into San Antonio Bay. Since connections of these bays with the Gulf of Mexico are quite restricted by the barrier islands, any reduction of flow increases the salinity of the extensive bay system. The Colorado and Brazos Rivers empty directly into the Gulf of Mexico, but the Trinity and San Jacinto Rivers feed the extensive Galveston Bay complex. Again, passes through the barrier islands are limited, so that any reduction of flow will increase the salinity from the present average of about 12 parts per thousand. Even a minor increase could seriously disrupt shrimp and shellfish nursery areas and adversely affect the commercial industry dependent on them.

Louisiana Coast--Leveeing of the Mississippi River has altered the distribution of silt-laden fresh water so that the coastline is subsiding

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rapidly. The land mass of coastal Louisiana is being reduced at a rate of 16 square miles per year. Salt-water intrusion is dramatically altering the fresh-water and brackish marshes.

Southern Florida--Diversion of fresh-water supplies by the cross-Florida navigation system through Lake Okeechobee has reduced the size of the Everglades, damaged the estuarine ecosystem off south Florida, and increased the adverse effects of normal droughts.

San Francisco Bay - Sacramento Delta--Massive diversions of the Sacramento River through the delta to supply water to southern California have transformed San Francisco Bay from an estuarine to a marine environment. This change jeopardizes the substantial anadromous fish and waterfowl resources of central California. Planners in these areas must face major challenges as they seek to reallocate available supplies in order to preserve the productivity of these ecosystems. Detailed, area-related analyses must be made on each estuarine area threatened with water supply modifications before the effects of these changes can be assessed. Although estuarine systems are adapted to widely fluctuating natural flow conditions, any long-term increase or decrease of an area's water supply or any change in the chemical balance will markedly affect the area's resources and the ability of the system to rebound to a healthy condition.

Although not an estuarine or nearshore environment of the coastal United States, the Gulf of California is a region that must anticipate similar problems. Water-use projections for the Lower Colorado Region (subregion 1502) and the Rio Grande Region (subregion 1305), which constitute the major portion of the Gulf of California watershed, are similar to those in some of the Texas-Gulf subregions. United States water demands in these regions may affect the international waters.

Legal and Institutional Ramifications

Management responsibility for estuarine and nearshore marine areas is shared by a multiplicity of Federal, interstate, State, and local agencies. Recent Federal initiatives, particularly the Coastal Zone Management Act of 1972 and the 1972 Federal Water Pollution Control Act Amendments, encourage, and even mandate, coordination of environmental considerations by various agencies at all levels. At the State level, it is not likely that agencies will be created within the States' organizational frameworks to function exclusively as managers of the States' estuarine or nearshore marine areas. However, awareness of the need for closer and more visible coordination among agencies is increasing.

Upland Ecosystems

At higher elevations, areas that adjoin drainage land or lands with standing water have a great diversity of ecosystems that range from prime wildlife habitat to areas almost totally converted to man's intensive uses. Man's ability to alter the face of the earth has developed to the point that change is occurring faster than the biota can adjust to it. The

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degree to which all uses collectively have altered the natural ecotypes has not been displayed. Expansion of agriculture, stripmining, and urban-industrial encroachment are rapidly reducing some ecotypes, such as prairie grasslands and bottomland hardwoods.

The high commercial value of uplands is demonstrated by accelerating land values. The value of the native vegetative communities which support most of our wildlife population is more difficult to quantify. While conversion of native communities to the specialized uses of man is no doubt beneficial to a degree, perpetuating our natural heritage is also desirable. Fish and wildlife populations are at the mercy of change in land use, and there is a point beyond which the gene pools of certain species will be irretrievably lost. While other sections in this volume detail the expected trends in agriculture, mining, and urban activities, the effects of these land-use changes on fish and wildlife populations are not yet adequately understood.

Requirements for Fish Hatcheries

Fish hatcheries, both State and Federal, are important for meeting the Nation's demand for recreation fishing. These stocking programs also supplement commercial fish harvests.

The Pacific Northwest Region accounts for 43 percent of Nation's total diversions for fish hatcheries. In "1975," the ten regions west of the Upper and Lower Mississippi Regions withdrew about 75 percent of the Nation's total water requirements for fish hatcheries. Federal fish hatcheries (an offstream use) withdrew about 627 million gallons of water per day in "1975" (Table III-65). These withdrawals are expected to increase by about 15 percent by 2000. Withdrawals for fish hatcheries constitute only 0.2 percent of total fresh-water withdrawals.

Withdrawals for fish hatcheries should not present a major regional water supply problem between "1975" and 2000, but isolated areas in the West may have periodic supply problems. The larger problem will be to maintain adequate and quality streamflow to use fully the fish stocks produced in the hatcheries.

Comparison of National and State-Regional Futures

Only four regions submitted instream flow data, which for the most part described minimum flows. Some regions did not account for instream flows for fish and wildlife, recreation, etc., because such uses are not recognized as beneficial uses or because determination of instream flow requirements is difficult, as discussed earlier. To assess the National Future, these four regions joined several other regional sponsors in the acceptance of the instream flow approximations for fish and wildlife, as developed by the U.S. Fish and Wildlife Service, for use in this assessment, but not necessarily for valid general application. It is clear that a more widely understood and acceptable standard must be devised and applied.

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Table III-65.—Federal fish hatchery fresh-water withdrawals—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals[a]		
	"1975"	1985	2000
New England (1)	37	55	55
Mid-Atlantic (2)	21	21	21
South Atlantic-Gulf (3)	17	17	17
Great Lakes (4)	22	26	28
Ohio (5)	36	45	46
Tennessee (6)	15	15	15
Upper Mississippi (7)	5	6	6
Lower Mississippi (8)	1	1	1
Souris-Red-Rainy (9)	3	3	3
Missouri (10)	46	48	48
Arkansas-White-Red (11)	43	46	48
Texas-Gulf (12)	17	11	11
Rio Grande (13)	7	9	11
Upper Colorado (14)	20	27	34
Lower Colorado (15)	22	22	23
Great Basin (16)	2	3	3
Pacific Northwest (17)	272	301	314
California (18)	41	41	41
Total, Regions 1-18	627	696	724
Alaska (19)	0	0	0
Hawaii (20)	0	0	0
Caribbean (21)	0	0	0
Total, Regions 1-21	627	696	724

[a] Consumption by hatcheries is negligible.

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Water for Natural Areas, Historic Resources, and Wilderness Areas

Natural areas need surface-water flows, ground-water levels, and a high water quality. Disruptions to any of these natural conditions generally deteriorate natural areas and their related esthetic qualities. This section addresses some conflicts between land and water uses that jeopardize cultural resource preservation. First, the scope of existing natural and historic preservation programs is described and specific conflicts with other water uses are examined. The discussion focuses on how water resource management can balance preservation needs with development projects.

Preservation of the functional and esthetic integrity of some historic resources depends on maintaining water conditions as they appeared during the time of the historic event or period represented. Examples are the Chesapeake and Ohio Canal, the battlefield near the Concord River in Minuteman National Historical Park, Massachusetts, and the Arkansas River adjacent to Bent's Old Fort National Historic Site in Colorado. Water also contributes to the esthetic setting of some historic properties (historic docks, lighthouses, locks, dams, and waterfront districts) and to the operation of others (mills and boatyards). Seldom does the use of water for these purposes conflict with other water uses.

Occasionally water projects aid in historic preservation. For example, a well-planned flood damage reduction program is imperative for protecting historic areas, especially since these are irreplaceable resources. But problems and conflicts can arise when projects for reservoirs, canals and pipelines, stream channelization, agricultural operations, and private land developments are undertaken in areas containing historic resources. Natural areas and historic resources are issues in planning for water resources development because projects may adversely affect biotic communities or conflict with preservation. Consequently, water resource assessment and planning is needed to balance national economic development with historic and cultural values. The direct offstream water requirements for natural areas and historic resources are small but critical for those instream uses that enhance or support the areas and associated ecosystems.

Natural Areas

Water resource development projects frequently degrade conditions for biotic communities that are integral to a natural area. Depending upon the nature of the project, the effects range from near total destruction to only minor damage. Construction of reservoirs submerges geologic features and destroys terrestrial and aquatic ecosystems. Reservoirs constructed upstream from natural areas and used for diversion of water may reduce surface-water flow and downstream ground-water levels with a negative effect on biotic communities. Everglades National Park in Florida is an example of a natural area affected by the construction of canals and levees upstream of the park. These canals and levees have reduced the natural southward flow of fresh water from Lake Okeechobee into the park and have threatened some of the park's unique flora and fauna with extinction.

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Natural areas are particularly sensitive to water development projects that increase agricultural production. Pastures and croplands often are created either by draining wetlands or by introducing irrigation water. In either case, natural ecosystems are destroyed or damaged. Some sources of irrigation water adversely affect an aquatic environment far removed from the irrigation. If ground water is used for irrigation, the resulting lower water tables could seriously affect natural areas and their associated species.

Energy production also conflicts with natural area preservation in many ways. It could involve adverse effects associated with reservoir construction for generation of hydroelectric power; attendant effects from coal-fired powerplants (including discharge of heated water and other pollutants into the water and stack emissions harmful to plants); natural esthetic values interrupted by construction of electric transmission lines; and a multitude of other effects resulting from associated industrial, commercial, and residential growth. Mining for coal and other minerals frequently destroys riparian areas and their ecosystems, and acid drainage from abandoned mines has polluted many rivers and streams.

Even the use of water resources for recreation and for maintaining fish and wildlife populations occasionally conflicts with natural area preservation. Natural shorelines and backup land areas are drastically modified to provide large numbers of people with opportunities for swimming, boating, and other recreation pursuits. Likewise, natural areas may be modified with dikes, fences, irrigation systems, and farming programs to maximize production of wildlife foods or improve habitat for specific species of wildlife.

Efforts to reduce flood damages by constucting impoundments and levees or to increase navigation by dredging and stream channelization often have disastrous effects on biotic communities. On the other hand, nonstructural solutions frequently foster retention of natural conditions and preservation of natural diversity.

Historic Resources

Conflicts between water resource development and historic preservation are aggravated by the fact that prehistoric and historic communities were concentrated along water courses and in proximity to flood plains and other arable lands. As a result, historic resources and needs for present-day water resource development frequently are concentrated in the same places.

Water from reservoirs can inundate historic resources. Visitors collect artifacts and vandalize sites and structures around the reservoir. Archeological and architectural salvage programs mitigate some of these problems, but they can rarely prevent damages that undermine the authenticity of the historic resources.

Agricultural operations have led to the discovery of, but also caused the loss of many historic and prehistoric sites. Water resource develop-

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ment for agriculture can intensify land surface disturbance. Land leveling, subsoiling, and excavation practices are particularly disruptive.

Private and public development of land dependent on the availability of water has complex direct effects on historic resources. Urban renewal can destroy historic buildings and structures; suburban development of open land destroys archeological sites. Construction of sewers, roads, streets, highways, power generation and transmission facilities, and support systems necessary for such growth destroy both prehistoric and historic sites and structures.

Because most major water resource projects either take place on Federal land or involve Federal funding or licensing, the Federal historic preservation laws are applicable to these projects. The U. S. Environmental Protection Agency funds the preservation or salvage of historic properties within the rights-of-way of sewer projects, but it must rely on local jurisdictions to identify and mitigate the secondary effects of such projects (for example, when urban growth and development have adverse effects on historic resources). Often, however, the local jurisdiction has no policy whatever for historic preservation.

The U.S. Army Corps of Engineers tends to require the identification and protection of historic properties by permit applicants only when there is definite information indicating that the applicant's project will threaten such property. But, because many historic properties have not yet been identified, such information is usually not available.

To add further complications, State and local provisions for historic preservation may conflict with or crosscut Federal regulations. Some local jurisdictions, for example, have protective ordinances applying only to prehistoric archeological sites, historic buildings, landmark buildings, historic districts, or Indian burial sites. It is easy for a project planner to confuse compliance with a local ordinance or State law with compliance with Federal law or vice-versa. The comprehensive nature of Federal concern for historic preservation may conflict with more limited preservation interests held by local communities. On the other hand, the specific interests of local communities in preserving their important properties may be poorly identified through the Federal process.

Programs for Natural and Historic Resources Preservation

National programs for the preservation of natural areas have been developing in an uncoordinated and fragmented fashion. In response to increasing concerns for protection of environmental quality, the Federal Government has recently enacted a number of laws dealing with natural area preservation. The Wilderness Act (Public Law 88-577) was passed in 1964; the Wild and Scenic Rivers Act (Public Law 90-542) in 1968; the National Environmental Policy Act (Public Law 91-190) in 1969; the Marine Protection, Research, and Sanctuaries Act (Public Law 92-532) in 1972; the Coastal Zone Management Act (Public Law 92-583) in 1972; amendments to the Federal Water Pollution Control Act (Public Law 92-500) in 1972;

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the Endangered Species Act (Public Law 93-205) in 1973; and amendments to the Land and Water Conservation Fund Act of 1965 (Public Law 94-422) in 1976.

States administer a variety of programs for protection of natural resources on their lands, e.g., State parks, monuments, preserves, wildlife refuges, reservations, forests, estuarine sanctuaries, and designated national wild and scenic rivers. They also have statewide programs such as forest fire protection and they assist local governmental units in natural resource protection, frequently through participation in cooperative programs with the Federal Government. States conduct or participate in river basin studies, prepare State water plans using Title III of the Water Resources Planning Act (Public Law 89-80) and other grant programs, coordinate preparation of coastal zone management programs, and prepare comprehensive State outdoor recreation plans that recognize the need for natural area preservation. A 1972 survey by the U.S. Department of the Interior, Bureau of Outdoor Recreation, indicates that local governments were protecting about 1.7 million acres of wilderness, primitive, and natural areas.

Some of the Nation's choice natural areas are being preserved by industries and privately-financed citizen organizations. The Nature Conservancy is an outstanding example of such an organization. Its goal is to preserve ecological diversity through protection of significant natural lands. It acquires lands both for later transfer to government units and for its own stewardship. It has acquired and transferred to government units and private organizations about 390 natural areas containing 900,000 acres. In 1977, it owned and managed some 660 preserves having 400,000 acres. The National Audubon Society is another leading conservation organization administering natural areas. In 1977, it had 67 wildlife sanctuaries with some 180,000 acres.

A national program to preserve historic (archeological, historic, and architectural) resources was expanded by the National Historic Preservation Act of 1966. The act provided for establishment of the National Register of Historic Places, under the Secretary of the Interior, to foster preservation of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, and culture.

The Federal Government administers programs to preserve historic resources in Federal ownership. At the end of 1976, the national park system included 170 historical areas having about one-half million acres. Historic resources on lands adminstered by the U.S. Bureau of Land Management are protected in designated "Important Cultural Sites" and in the national forest system.

State historic preservation officers conduct comprehensive statewide surveys and develop historic preservation plans under the authority of the National Historic Preservation Act. The States administer a variety of programs to protect historic resources on their lands. They also assist local government units in historic resources protection. The States also administer the historic preservation grants program for eligible projects within their borders.

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Local governments undertake local historic preservation planning and projects. They also regulate activities of the private sector through local preservation and environmental ordinances and regulations. According to the Department of the Interior's 1972 survey, local government units were protecting 22,000 acres containing historic resources.

Privately financed citizen organizations also play a major role in preservation of historic resources throughout the Nation. They are organized at national, State, regional, and local levels to preserve single properties, groups of properties, and historic districts. The National Trust for Historic Preservation and the many State and local historical societies do outstanding work in preserving historic resources. State and local archeological societies work for the identification, study, and protection of historic and prehistoric sites and exercise control over the quality of archeological excavations. Professional organizations such as the Society of Professional Archeologists are active throughout the Nation.

Opportunities for Preservation

As the population of our Nation continues to grow, so will the problem of preserving natural and historic resources. In view of the rapid rate of land development, water resource development, and other factors, the Nation must substantially increase efforts to identify and preserve in perpetuity units of land and water representing a full array of biotic communities, geologic features, and other components of natural heritage. In future studies, there may be opportunities to identify and acquire lands that have been damaged by erosion, stripped by surface-mining, cluttered with abandoned and obsolete industrial and commercial facilities, or otherwise scarred by man, but that may be preserved for natural and historic purposes.

The variety of legislated programs, the lack of coordination, and the broad Federal involvement make it difficult to comprehend both the scope of natural area preservation and its subsequent effects on water resources planning and development. Data are needed to facilitate preservation of the important remaining natural areas and historic resources. Adequate information on the extent and integrity of our remaining biotic diversity in the country, including wetland communities, is urgently needed. Research is also urgently needed on various topics related to natural area establishment and management so that preservation of genetic diversity within a national system may proceed in a more enlightened way. A resources inventory and plans for management, research, and education are needed for each preserved area.

Water Requirements for Public Lands

An important aspect of preserving natural and historic resources and maintaining them for the public benefit is the Nation's public lands. These public lands are largely those managed by the U.S. Bureau of Land Management, the National Forest Service, and the National Park Service. The operation and management of these lands require minimal water withdrawals that are largely consumptive.

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Withdrawals of fresh water for public lands were estimated at 1,239 billion gallons per day in "1975," less than 1 percent of the total for all offstream withdrawals (Table III-66). By 2000, these withdrawals are expected to increase by 40 percent, at which time the proportion of national use for these lands will still be less than 1 percent.

Table III-66.—Public lands withdrawals and consumption—"1975," 1985, 2000
(million gallons per day)

Region	Withdrawals			Consumption		
	"1975"	1985	2000	"1975"	1985	2000
New England (1)	2	2	3	2	2	3
Mid-Atlantic (2)	4	4	7	3	3	6
South Atlantic-Gulf (3)	5	6	10	5	6	10
Great Lakes (4)	6	13	17	6	13	17
Ohio (5)	5	8	12	5	8	12
Tennessee (6)	1	2	3	1	2	3
Upper Mississippi (7)	2	3	4	2	3	4
Lower Mississippi (8)	1	3	4	1	3	4
Souris-Red-Rainy (9)	1	2	2	1	2	2
Missouri (10)	159	198	266	159	198	266
Arkansas-White-Red (11)	26	33	39	26	33	39
Texas-Gulf (12)	<1	2	2	<1	2	2
Rio Grande (13)	22	27	28	22	27	28
Upper Colorado (14)	103	120	127	103	120	127
Lower Colorado (15)	20	49	56	19	47	54
Great Basin (16)	319	351	411	319	351	411
Pcaific Northwest (17)	190	262	332	190	262	332
California (18)	363	371	394	362	369	391
Total, Regions 1-18	1,229	1,456	1,717	1,226	1,451	1,711
Alaska (19)	10	10	20	10	10	20
Hawaii (20)	0	0	0	0	0	0
Caribbean (21)	0	0	0	0	0	0
Total, Regions 1-21	1,239	1,466	1,737	1,236	1,461	1,731

As expected, the largest uses of water on public lands are in the western regions, the Great Basin, Pacific Northwest, and California Regions, which together withdrew and consumed 70 percent of the total for public lands in "1975." Collectively, the regions west of the Mississippi Region withdrew and consumed 98 percent of the total for public lands.

Nearly 100 percent of public lands withdrawals of fresh water are consumptively used. The public lands will consume about 1.2 bgd in "1975" and 1.7 bgd in 2000. Consumptive uses on public lands were about 1.2 percent of the total national consumption for offstream uses in "1975." Significant savings or improved efficiencies in water on these lands are not contemplated.

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Because large holdings in State, local, and private organizations are not recorded, these fresh-water withdrawal estimates for public lands substantially understate the real requirements for natural areas and historic resources. In addition, the instream flows and stocks needed for natural areas are considered only for fish and wildlife purposes. However, these instream flow approximations required for fish and wildlife should be sufficient for maintaining most natural and historic resources.

Wilderness Areas

The Wilderness Act of September 3, 1964, established congressional policy "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness." To this end, the Act required the Secretaries of Agriculture and the Interior to review the suitability of their respective primitive and roadless areas for wilderness inclusion.

The 1964 Act declares that areas classified as "wilderness" will be managed so as to preserve their wilderness character into perpetuity. This should not be construed as a "lock up of resources," but rather as a preservation of those uses that are compatible with wilderness values.

The quality of the surface water is of key importance to the national wilderness system, not only for its recreation and scenic values, but also because of its importance in maintaining the viability of wilderness areas themselves. In some cases, water problems for these areas may be influenced by conditions and activities upstream. An upstream project may interrupt the normal water flow and alter the wilderness character of an area. Strip-mining upstream, for example, could lower water quality in a downstream wilderness area. Thus, preserving wilderness areas may require that special precautions be taken for certain activities in adjacent areas.

Fifty-four of the highest quality areas within the national forests were made wildernesses by 1968, and an additional 181 areas were proposed by the U.S. Fish and Wildlife Service, the National Park Service, and the U.S. Forest Service (Figure III-18). By 1977, a total of 161 areas involving 14.4 million acres had been enacted into the wilderness system, with an additional 70.5 million acres proposed.

(1) National forest roadless and undeveloped areas--Anticipating the requirement for completion of primitive area studies that are specified in the Wilderness Act, the U.S. Forest Service issued a 1967 directive to the regional foresters* to identify all areas that seem to satisfy the criteria meriting recommendation for inclusion in the national wilderness preservation system. Subsequent Congressional action also has directed the identification of other eligible lands.

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*Forest Service Manual 2321.31b, Revised 1969. Appendix 11.

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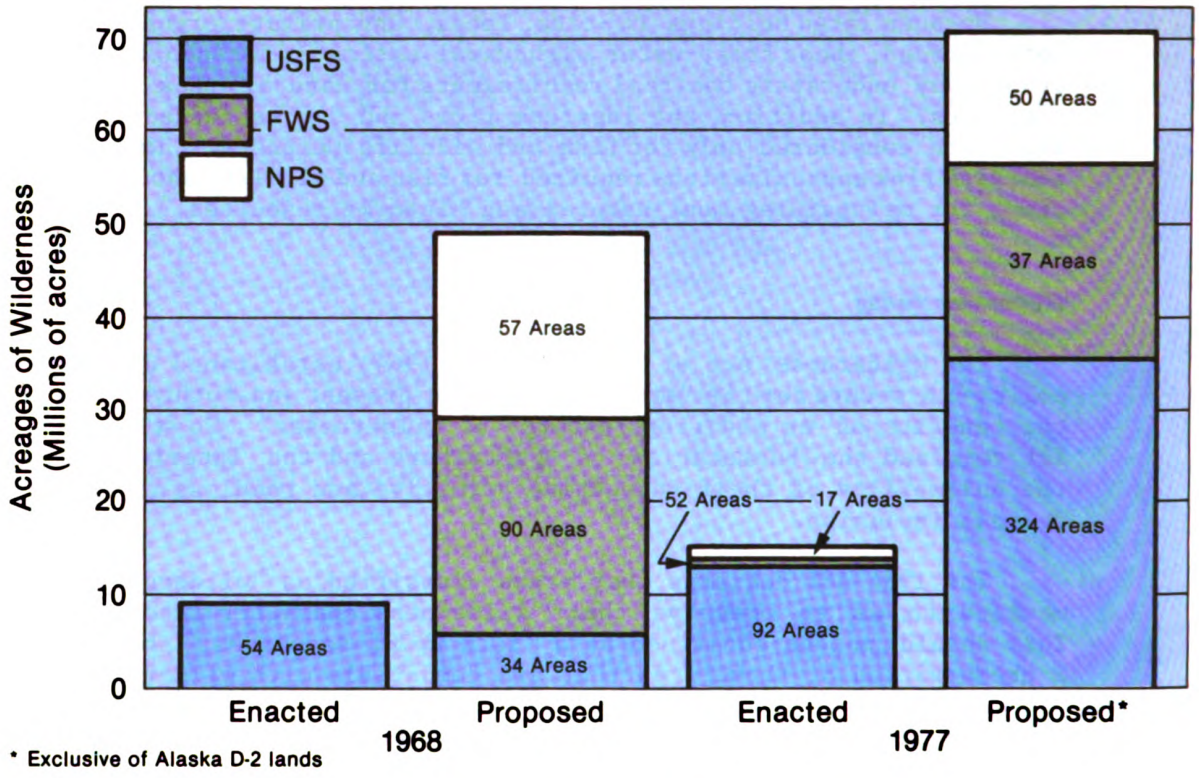

Figure III-18.—Current and proposed increases in wilderness areas from first (1968) to second (1977) assessments

National forests contain many areas of significant size that are roadless and undeveloped and are not specifically mentioned in the 1964 Wilderness Act. These lands represent potential high quality additions to the national wilderness preservation system. It is essential that they be given special consideration in planning, because the irreversible nature of some actions could damage their wilderness character. It is generally accepted that the wilderness characteristics and values that now exist in some roadless areas may be reduced if certain kinds of development are allowed.

Areas on which roads are constructed, timber is harvested, land is cultivated, or permanent structures are built are essentially precluded from wilderness consideration; therefore, the roadless area review was designed to select the remaining areas having highest quality for additional study and to continue to protect their wilderness characteristics until a final determination could be made. A second roadless area review evaluation (RARE II) was initiated during the final days of this assessment. It is possible that additional potential wilderness may be identified.

(2) National parks and monuments and national wildlife refuges--The National Park Service and the Fish and Wildlife Service have examined the lands under their jurisdiction to determine which tracts meet the wilderness

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criteria. These areas were then studied and recommendations sent forward for most of them.

(3) Public domain lands--The Wilderness Act does not specifically mention public domain lands administered by the U.S. Bureau of Land Management. However, passage of the Federal Land Policy and Management Act of 1976 (Public Law 94-579) extends the provisions of the Wilderness Act to public domain lands. The Bureau administers about 450 million acres of Federal land, including 279 million acres in Alaska. About 322 million of the 450 million acres are roadless and undeveloped. The Bureau of Land Management has designated 11 areas as primitive areas (234,013 acres). In addition, 27 other areas (1,486,000 acres) have been identified as being primitive in character as of April 1974. There are also 43 natural areas. Such roadless and undeveloped areas are a potential source of classified wilderness. All of these are subject to a current inventory and should be considered in determining the need for areas to be left in an undeveloped state.

(4) Alaska--The Alaska Native Claims Settlement Act of 1971 (Public Law 92-203) provided for withdrawal of 80 million acres to be studied for possible inclusion in the national parks, wildlife refuge, forest, and wild and scenic rivers systems (often termed D-2 lands). In 1973, the Secretary of the Interior recommended that 83 million acres be added to these systems and that a 3-year study of these areas for suitability as designated wilderness be undertaken. Congress is currently working on H.R. 39 which calls for instant wilderness designation for some areas.

These proposed D-2 lands are included in a map, available from the Water Resources Council as a separate product of this assessment. This map illustrates the spatial relationship between the enacted, proposed, and potential wilderness for the four Federal agencies. It is obvious that the wilderness preservation program cannot attain equal distribution by States or drainage basins.

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Flood-plain Management

Background

In the past, the general response to floods was to increase flood control, that is to use structural means such as levees or walls to keep the water from the people and their property. To some extent this worked. However, this method also cut off the natural "relief valve" and established a false sense of security leading to continued or increased use of the "protected" flood plain. Moreover, as the number of people increased and as property values grew, flood damages soared so that people put more pressure on governments--primarily on the Federal Government, which first took the lead--to build more controls, more structures. Flood control structures often significantly disrupt the natural and beneficial values of the flood plains.

Federal involvement in flood-related programs, however, has increasingly changed direction since the mid-1960's. Federal support is now aimed at breaking the ever-enlarging cycle of flood destruction, reactions to destruction by increased flood control, increased flood-plain occupancy, flood destruction, more controls, etc. Instead of flood control, flood-plain management is emerging as the objective. Sound flood-plain management entails the balancing of sometimes competing concerns. Although flood-damage reduction is important, recreation, agriculture, water supply, navigation, and fish and wildlife management are also important. As a result, attention has shifted from a narrow focus on flood modification through structrual means to the way man occupies the flood plain, how he manages it, and how he adjusts to the dangers of occupancy.

The new approach does not exclude controls or structural measures; instead, it aligns these measures with an increased focus on nonstructural measures. It also increasingly emphasizes the role of State and especially of local governments, where the bulk of flood-related decisions are made.

In this section, the nature and costs of floods and the consequences of flood-plain occupancy are discussed in light of the shift to the flood-plain management policy. Future losses and damages are projected against four scenarios of management decisions on various combinations of measures to deal with flooding and flood-plain occupancy. Since all floods do not occur in plains only, the term flood plain here also includes coastal areas affected by hurricanes, tidal waves, or other elements that cause inundation of the area.

Definition of Terms

In the discussion, the term flood losses refers to loss of life and flood damages refers to dollars lost in property or income, either as direct or indirect result of flooding.

Flood control techniques that physically contain or modify the flooding are called structural measures, e.g., dams, levees, reservoirs.

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Nonstructural measures are all other means to modify either the type and amount of flood-plain occupancy or the behavior of the occupants toward the threat of floods. These measures include altered land uses; regulation of types of flood-plain occupancy; floodproofing; disaster preparedness and response planning; flood forecasting, warning systems, and emergency plans; insurance programs; tax adjustments; and flood recovery assistance.

Flood-plain regulation is the use of legal tools to control use of the flood-plain, e.g., zoning, building codes, land acquisition, tax incentives or subsidies to implement the regulations.

Flood-plain management is the generic term that includes various practical mixes of regulation, structures, education, monetary inducements, Federal support to flood-plain insurance, etc.

Data Parameters

At best, approximations of flood damages are simply that--approximations. Damages may be long- or short-term, realized or potential, direct or indirect, primary or secondary, to person or property, etc. Beyond this complexity, these damages may be expressed as an average of a yearly actual experience or an "average annual" in the sense of a probable value. In this presentation both expressions of estimates are used: (1) historical damages identified by year or years and (2) average annual damages used to express probability for a current or future year. Although both expressions of damages are given in this section, clearly the two cannot be compared.

In the assessment, future flood damage estimates are based on various historical trends and on assumptions about future land use and flood-plain management programs. The national estimates are aggregated from regional projections of probable recurring damages. The regional estimates have been adjusted to reflect certain assumptions about future management and regulation of flood-plain development.

Consequence of Floods

Although there are regional exceptions, there is no widespread evidence that on the national level flooding is increasing in magnitude or frequency. Increasing overall costs may seem to belie this evidence, but the escalating flood damages actually result from two primary causes: continued development on the flood plain and rising costs to make repairs.

Flood damages averaged $104 million in the 15 years from 1926-40, but varied from $2.8 million in 1931 to $440 million in 1937. Flood damage exceeds $50 million in about one out of every two years. Since 1941 the damage has never been less than $50 million in any year. The most frequent yearly damage is in the range of $100 million to $400 million, although damage of about $1 billion has occurred several times since 1951, the first year that flood damage exceeded $1 billion. Flood damage

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reached nearly $4.5 billion in 1972, the highest ever (Table III-67). The 1972 flood damage was unusually high over a wide area not normally damaged by hurricanes and the storms associated with them. From 1925 to 1970, the total loss of human lives from floods was 3,738. The number of flood-related deaths varies widely from one year to another, so no estimates were projected for this assessment. In general, the number of losses has tended to drop over the years.

Table III-67.—Annual losses of life and property from floods in the United States, 1926-1975

Year	Annual loss of property ($1,000)	Annual loss of life	Average loss of property ($1,000)	Average loss of life	Year	Annual loss of property ($1,000)	Annual loss of life	Average loss of property ($1,000)	Average loss life
1926	23,468	16			1951	1,028,741	51		
1927	347,656	423			1952	254,064	54		
1928	44,611	15	99,937	112	1953	122,204	40	501,468	100
1929	68,098	89			1954	106,842	55		
1930	15,850	14			1955	995,491	302		
1931	2,808	0			1956	64,688	42		
1932	10,295	11			1957	360,303	82		
1933	36,679	33	37,454	74	1958	218,255	47	175,495	56
1934	10,362	88			1959	141,255	25		
1935	127,127	236			1960	92,976	32		
1936	282,549	142			1961	154,033	52		
1937	440,738	142			1962	75,237	19		
1938	101,098	180	175,737	121	1963	177,946	39	369,381	66
1939	13,834	83			1964	651,642	100		
1940	40,467	60			1965	788,046	119		
1941	39,524	47			1966	117,004	31		
1942	98,507	68			1967	375,218	34		
1943	199,732	107	120,928	69	1968	339,399	31	391,946	105
1944	101,079	33			1969	902,654	297		
1945	165,798	91			1970	225,453	135		
1946	70,813	28			1971	287,525	74		
1947	272,328	55			1972	4,465,135	554		
1948	229,959	82	168,616	61	1973	1,894,493	148	1,719,325	201
1949	93,931	48			1974	576,203	121		
1950	176,050	93			1975	1,373,269	107		

The following discussion explains the various elements included in the generic term, flood-plain management. Because each flood area has different physical characteristics and varying levels of development, the mix of each and proportion of money and effort devoted to each must be determined by the community occupying the flood-prone area.

Flood-plain Management

Flood-plain management is based on an informed use of the flood plain. Basic to the informed use is an understanding of the flooding itself. The flood's spread or depth, suddenness or predictability, and velocity or disruptive force area are all basic to an understanding of what mix of measures can best offset the effects of the flood. Moreover,

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given this understanding about the nature of the flooding, the community must also consider what future makes sense to them and what role the flood plain will play in that future. Once these are known, the community can select the appropriate land-use development, whether that is one best use or a mixture of open space, recreational, residential, commercial, agricultural, or industrial. It can then accommodate this development to the natural function of the flood plain and thereby reduce damages and costs.

Structural Measures

Whether by channel straightening or deepening or by the timely releasing of impounded water, large flood discharges can often be accommodated with little damage to the flood plain. The first assessment showed that the estimated cumulative damages prevented by structural measures increased from $5.0 billion in 1950 to $14.6 billion in 1966. The $3.4 billion estimated damages in "1975" would have been 40 percent larger if structural devices had not been installed. If the current trend were to continue, structural means alone should reduce the projected 2000 damages by another 10 percent.

The U.S. Corps of Engineers and the U.S. Soil Conservation Service have active flood control, flood prevention, and watershed protection programs. Much of their activity has involved structural measures averaging a cost of over $600 million per year for the last 10 years. Although emphasis is being shifted to nonstructural measures, significant expenditures are likely to continue for structural measures, such as dams, levees, and channels. But all areas cannot be given structural protection, even if warranted, nor are all flood control works certain to prevent catastrophic events. In fact, flood control works often give a false sense of security and invite further invasion of the flood plain.

Flood-plain Regulation

Indiscriminate development and encroachment in flood plains without regard to what, where, and how development takes place have caused pressures to deny all development on flood plains or at least to make a permit difficult to obtain. Whole systems of flood-plain regulations--zoning, building codes, and subdivision regulations--are being enacted locally. Table III-68 shows the growth in use of these regulations.

Flood-plain regulation is the adoption and use of legal tools to control flood-plain uses. For this report, regulation includes zoning, some construction requirements, and, to a limited extent, land acquisition or other equitable arrangements (such as subsidies or tax incentives) to implement the regulation. Enforcement and compliance with regulations are assumed in the projections.

If the current trend to increase regulation continues, damage could be reduced by 14 percent by 2000. The reduction in urban damage could be 23 percent. Agricultural damages, however, are not expected to drop;

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Table III-68.—Uses of flood-plain regulations

Flood-plain regulations	Number of uses thru FY 1974	1975	1976
Adoption of strengthening	1,003	1,289	1,590
Process of adoption	273	285	300
Planning studies underway	838	923	1,096
Interim flood control	1,522	1,978	2,448
Non-Federal flood control work	110	118	138
Non-Federal control studies	362	391	420
Acquisition of flood plains	543	656	734
Comprehensive land-use planning	1,746	2,023	2,315

Note: These actions have been prompted in many cases by interaction of local interests and Corps of Engineers Flood Plain Management Services. Cumulative responses to requests for flood hazard information and assistance numbered 19,000 in FY 1976.

Source: Corps of Engineers, Flood Plain Information Report (FPIR).

in fact, they may even increase if regulations lead to an intensification of flood-plain agriculture. Available data indicate that maximum practical regulation could reduce damage by 21 percent. This estimate approaches the maximum 25 to 35 percent reduction suggested by White and Haas.* They concluded that as much as 25 to 35 percent of mean annual losses could be reduced over a 20-year period by a combination of measures other than construction of protection works.

Complementary Nonstructural Measures

Two specific Congressional acts underpin the shift from structural to nonstructural measures: the National Flood Insurance Act of 1968 (Public Law 90-448), as amended, and the Flood Disaster Protection Act of 1973 (Public Law 93-234), as amended. These complementary acts are aimed at reducing the general taxpayer's burden of flood relief by distributing the financial burden of floods more equitably. To accomplish this, both acts require that nonstructural measures, primarily regulatory, (land use, public facilities, floodproofing, and construction measures), be implemented before flood-plain occupants can receive Federally-backed insurance to recover from floods or financial assistance to construct or improve property in the designated flood-prone areas. Since its inception, about 15,000 communities have participated in the insurance program. Actuarial rates for new construction can accomplish several things: (1) indicate to prospective builders and buyers the extent of the hazard

*White, Gilbert F., and Haas, J. Eugene, Assessment of Research on Natural Hazards, Cambridge, Mass.; The MIT Press, 1977.

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they face, (2) discourage building in hazardous areas or at vulnerable elevations, (3) discourage nonconforming uses of the flood plain by requiring that flood-damaged structures can be rebuilt only if floodproofed and then must be insured at full actuarial rates.

Legislative opinion seems favorably disposed toward increased use of nonstructural measures as is apparent in Section 73(a) of the Water Resources Development Act of 1974 (Public Law 93-251). Section 73(a) states: "In the survey, planning or design by a Federal agency of any project involving flood protection, consideration shall be given to non-structural alternatives to prevent or reduce flood damages including, but not limited to, floodproofing of structures; flood-plain regulation; acquisition of flood-plain lands for recreational, fish and wildlife, and other public purposes; and relocation with a view toward formulating the most economically, socially, and environmentally acceptable means of reducing or preventing flood damages."

In addition to regulatory measures to modify flood-plain occupancy, more effort should be focused on modifying the occupant's perception of and susceptibility to flood losses, damage, and disruption. The individual and the community must take action on flood preparedness, survival, and recovery. Tools include information dissemination and education, arrangements for spreading costs over time, and the reasonable transfer of some individual losses to the community. For each area, the needs and responses are unique, but flood fighting has helped communities to survive floods. Communities must educate citizens on systems and methods best suited to their specific needs. Effective postflood recovery requires planning and coordination to accelerate the process of recovery. Any flood forecast or warning system depends on local cooperation to supply adequate information and then to make use of the forecasts produced from the information. Although these are short-term emergency measures, they indicate that a community is taking every step to alleviate problems that might arise from the floods.

The estimated flood damages for "1975" were based on the current level of flood-plain development with the current level of flood-plain management in effect. The probable damage was estimated at $3.4 billion in 1975 dollars. This "1975" estimate is used to project future damages under four sets of hypothetical mixes of flood-plain regulation and control. These hypothetical mixes or scenarios are:

(1) the "1975" level of flood-plain regulations to remain constant

(2) trend to increase regulation to be continued

(3) maximum regulation to be applied

(4) regulation to be accelerated while structural measures are slowed.

Figure III-19 shows the overall projections based on these four scenarios; Table III-69 gives a further break-down in projected damages.

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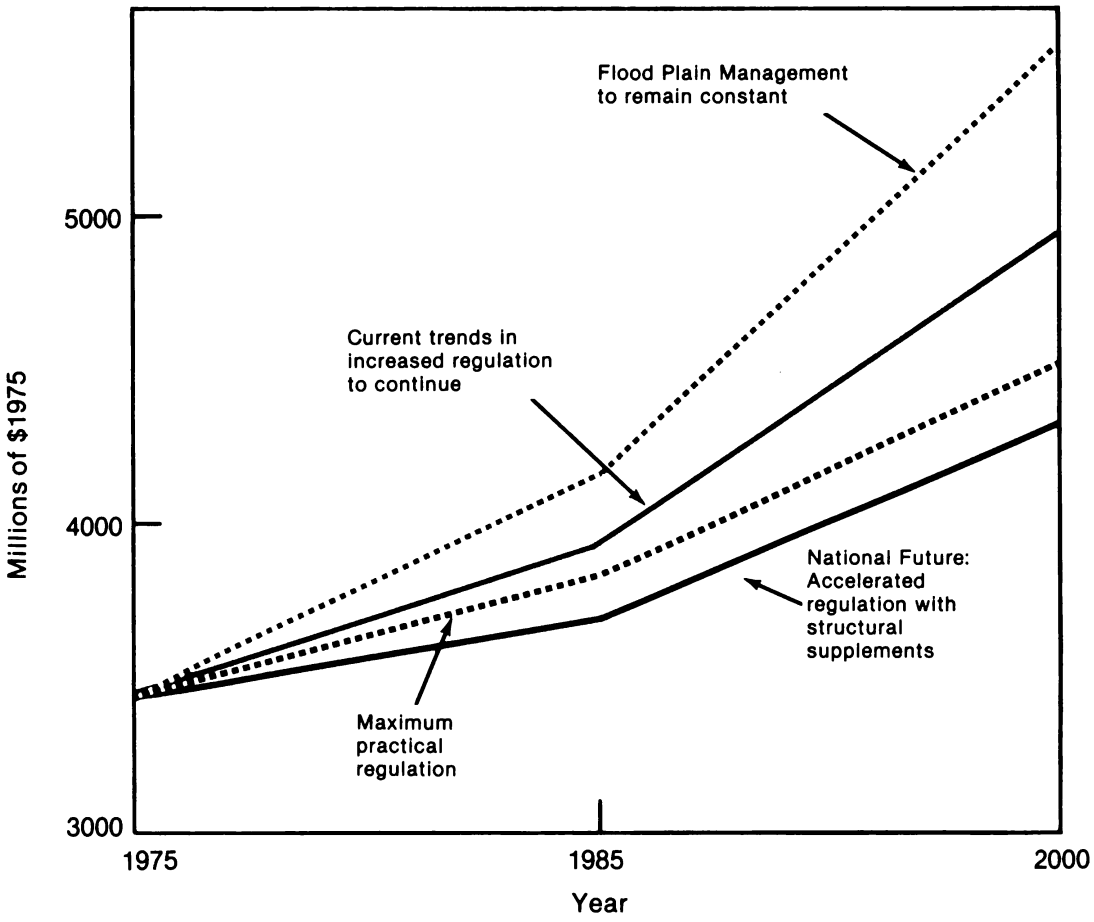

Figure III-19.—Projected average annual flood damages for selected scenarios

The "1975" estimates shown on Table 69 were derived from (1) U.S. Soil Conservation Service inventories for drainage areas less than 400 square miles upstream and (2) the U.S. Army Corps of Engineers inventories for drainage areas generally exceeding 400 square miles downstream.

After data were studied and the likely trends in flood control work were investigated, the fourth scenario was developed. Under this alternative, the damage reduction from structures amounts to 0.4 percent of projected damages remaining, assuming that regulation trends continue to accelerate and structural measures decline. The flood-plain regulations will be implemented faster than at the current rate, but not up to the maximum practical level. This alternative seems to be the one that people will most likely choose. The following projections are based on this flood-plain management scenario.

Estimates of probable flood damage totaled about $3.4 billion for "1975" (Table III-70). This level of probable damage is projected to increase by 26 percent from "1975" to 2000, to about $4.3 billion (1975$). Of the 3.4 billion, agriculture accounted for 48 percent, urban areas

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Table III-69.—Projected national average annual flood damages for selected management scenarios, 1985 and 2000
(million 1975$)

Future alternatives	Urban and built-up areas	Agriculture	Other	Total	Upstream	Downstream
1985						
1. Flood-plain management to remain constant	1,554	1,677	922	4,153	1,889	2,264
2. Increased regulation to be continued	1,424	1,679	803	3,906	1,819	2,087
3. Maximum practical regulation to be applied	1,358	1,677	799	3,834	1,775	2,059
4. Regulation to be accelerated while structural measures are slowed	1,306	1,609	764	3,679	1,713	1,966
2000						
1. Flood-plain management to remain constant	2,240	1,942	1,378	5,560	2,646	2,914
2. Increased regulation to be continued	1,855	1,944	1,130	4,929	2,409	2,520
3. Maximum practical regulation to be applied	1,459	1,944	1,101	4,504	2,088	2,416
4. Regulation to be accelerated while structural measures are slowed	1,575	1,749	1,002	4,326	2,114	2,212

[a]The adopted National Future (NF) alternative.

Table III-70.—Annual total, urban, agricultural, and other flood damages—"1975," 1985, 2000
(million 1975$)

Region	Total			Urban			Agricultural			Other		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
New England (1)	92	121	153	77	103	128	3	3	3	12	15	23
Mid-Atlantic (2)	1,831	213	296	130	158	229	28	26	28	25	28	39
South Atlantic-Gulf (3)	484	528	658	110	133	177	264	254	281	110	140	199
Great Lakes (4)	105	125	146	79	96	111	20	19	24	6	10	10
Ohio (5)	186	201	232	60	69	82	86	88	94	40	44	56
Tennessee (6)	72	76	93	20	23	29	35	32	34	17	21	29
Upper Mississippi (7)	235	258	302	70	77	86	108	114	131	57	67	86
Lower Mississippi (8)	399	420	469	63	73	88	255	256	273	82	91	108
Souris-Red-Rainy (9)	39	41	47	6	6	7	29	30	32	5	6	8
Missouri (10)	350	358	413	52	59	70	223	214	235	76	85	108
Arkansas-White-Red (11)	234	249	303	39	50	65	146	135	144	50	64	93
Texas-Gulf (12)	276	282	302	50	47	50	176	177	188	50	58	64
Rio Grande (13)	67	67	72	12	13	15	44	42	44	11	11	13
Upper Colorado (14)	5	6	8	1	2	2	3	3	4	1	2	2
Lower Colorado (15)	122	137	158	56	65	79	38	39	38	28	34	41
Great Basin (16)	10	11	14	3	4	5	4	4	4	3	3	4
Pacific Northwest (17)	126	134	158	42	49	61	67	64	71	17	21	26
California (18)	417	433	482	259	269	275	101	102	115	56	62	92
Total, Regions 1-18	3,404	3,663	4,306	1,129	1,296	1,562	1,629	1,603	1,743	646	763	1,001
Alaska (19)	13	3	5	13	3	4	<1	<1	<1	<1	<1	<1
Hawaii (20)	10	10	11	5	6	7	4	4	4	<1	<1	<1
Caribbean (21)	3	3	4	1	1	2	1	2	2	1	1	1
Total, Regions 1-21	3,429	3,679	4,326	1,147	1,306	1,575	1,635	1,609	1,749	647	764	1,002

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33 percent, and other areas (public lands and facilities, mining, utilities, rural industries, etc.) 19 percent. Of estimated damage of $4.3 billion for 2000, 40 percent is projected for agriculture, 36 percent for urban areas, and 23 percent for other areas.

During the period "1975" to 2000, agricultural damages were projected to increase from $1.6 billion to $1.7 billion, to account for 40 percent of the total flood damage. This 7 percent increase, however, is still less than that projected for urban and other areas. During this period, urban area flood damage is projected to increase from $1.1 billion to $1.6 billion, which accounts for 36 percent of total damage in the year 2000. This is a 37 percent projected increase. Damages in other areas are projected to increase from $0.7 billion to $1.0 billion. This is 23 percent of the Nation's probable flood damage in 2000 and represents a 55 percent increase.

All of these projected damage increases assume more intensive use of flood plains and a higher value of properties subject to flood damages. Projected flood damage would be $1.2 billion more if the flood-plain management measures assumed in the second assessment projections are not implemented.

The highest total damage should occur in the South Atlantic-Gulf, California, Lower Mississippi, and Missouri Regions. Agricultural damages will be most significant in the South Atlantic-Gulf, Upper and Lower Mississippi, Missouri, Texas-Gulf, Arkansas-White-Red, and the Texas-Gulf Regions. Urban damages are and will be more prominent in California, Mid-Atlantic, South Atlantic-Gulf, Great Lakes, and New England Regions.

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Erosion and Sedimentation

By volume and weight, sediment is the largest pollutant of waters. Sediment, transported and deposited by surface water, damages cropland, pastureland, forestland, urban areas, rivers, lakes, and bays. It can also reduce the capacity of stream channels and cause overwash, swamping, and increased flood damages. It accumulates in reservoirs, reduces the efficiency of hydroelectric power facilities, increases treatment costs of municipal and industrial water supplies, impairs navigation, clogs irrigation systems and drainage ditches, destroys crops, increases maintenance costs of utility and transportation facilities, decreases the recreation value of waters, and adversely affects fishery resources.

However, sediment can also be beneficial. Added to the flood plain, it can provide more land for growing crops and even improve the quality of some croplands. Without sediment transported to the coastal areas, recreation beaches could not be replenished from the eroding effect of waves and littoral currents. Because of their natural energy for transport, streams deprived of sediment from nearby lands will pick up more particles from their banks and beds to compensate for reduced amounts of soil delivered by rainfall runoff. The same phenomenon occurs in rivers where upstream dams and reservoirs cut off sediment supply.

Obviously, erosion is a land management problem directly related to a water quality problem. Although erosion is a natural geologic process, this section deals with manmade alterations to the natural environment that increase the natural process. The focus is on water-induced erosion from agriculture, silviculture, and urbanization and construction, mining, and river and shoreline development activities. Options and costs for controlling erosion and sedimentation are also discussed for each source. A more detailed discussion on the polluting effects of erosion is given in the section on water quality in Part IV of this volume. The effects of erosion on navigation are also given in the earlier section on navigation in this part.

Data Parameters

Although historical erosion information is given for land-use categories such as forestry, ranges, and mining, projected rates for 1985 and 2000 are given only for cropland activity, the heaviest contributor to erosion problems. Streambank and coastal erosion and sedimentation were also not covered in the model. The surge in agriculture exports between 1972 and 1975 was only partially foreseen and included in the National Future. As a result, the erosion problems resulting from the increase in acreage to meet the rising exports may be more serious and expensive to control than the projections for 1985 and 2000 show. Moreover, the current oil shortage and energy crisis will doubtlessly alter the picture of mining-caused erosion as the Nation turns more to other fuels.

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Background

Water interacts with soil in complex ways to produce various types of erosion such as sheet, rill, gully, channel, streambank, and shore erosion. It is estimated that sheet and rill erosion by water accounted for 3 billion tons of soil loss from harvested cropland alone in 1975. Without existing conservation practices, cropland soil losses would be another 1 billion tons annually. Estimates are that the productivity of the soil resource base cannot be maintained if the average soil loss exceeds 1.5 billion tons a year. Much of our cropland is losing topsoil at over twice the rate at which existing levels of soil productivity can be sustained on a permanent basis. The amount of sediment being produced from erosion of urban areas, roadsides, strip mines, and from channel banks and bottoms has not been estimated on a national basis.

Wind erosion may occur wherever a loose, dry, pulverized and unprotected soil is subject to high winds. Generally, it is most serious where precipitation is low and variable, drought is frequent, and temperatures are high. The upper reaches of the Missouri, the Arkansas-White-Red, and the Texas-Gulf Regions are areas subject to high wind erosion.

Gravity generally causes slow movements of soil, but occasionally a movement is sudden in the form of mud flows and landslides. Mass soil movement may constitute the dominant process of erosion in areas with exceptionally steep slopes, high rainfall, or low-strength soil, such as the mountainous areas of Southern California. Because such movement is only locally important, it is not considered further in this assessment.

Water-Induced Erosion and Sediment

The locations of erosion and sources of sediment include cropland, pasture, rangeland, forestland, urban and highway construction areas, surface mines, streams and rivers, and coastal areas (ocean and lake shores). Most of the soil eroded from these lands is deposited close to the site of erosion in land depressions, on channel bottoms or flood plains, and in lakes and reservoirs. Only about one quarter is carried out to the sea. Useful procedures have been developed to estimate soil losses and devise erosion control measures for these areas and conditions.

The most frequently used measure of sheet and rill soil losses is the "Universal Soil Loss Equation," a predictive model based on such factors as rainfall, soil types, slopes, management, and control practices. Mathematical models predict the sediment yield from small acreages and for river basins. It is important to verify these models from known or measured inputs and outputs for each local application. The percentage of sediment delivered from the erosion source to any specified downslope location is affected by such factors as size and texture of erodible material, climate, land use, local environment, and general physiographic position.

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Water-Induced Erosion and Sediment Sources

Until recently, attention has been focused on erosion and sedimentation of cropland where the economic effects of erosion are more apparent. However, other settings for erosion are now being studied more urgently as the pressures of man's activites and expanding population are felt in previously undisturbed areas. The Nation's demand for more energy, for instance, has increased strip-mining in vast areas of the West and parts of the interior and the East. And, as more people have settled in coastal and urban areas and working hours have been reduced, pressures on woodlands and beaches have intensified. Table III-71 shows the Nation's distribution of land uses in "1975." Table III-72 shows how man's activities can accelerate erosion more than 100-fold over the normal geologic rate of erosion.

Cropland

In 1975, just over 50 percent of the 335* million acres of harvested cropland was subject to moderate, severe, or very severe erosion (Table III-73). The 10 regions with high percentages of moderate to very severe erosion hazard are: New England (55.6), Mid-Atlantic (66.1), South Atlantic-Gulf (52.9), Tennessee (71.6), Souris-Red-Rainy (56.1), Arkansas-White-Red (51.9), Texas-Gulf (54.1), Missouri (61.3), Upper Colorado (81.9), and Pacific Northwest (63.1).

The average annual soil loss rate for most soils should not exceed 5 tons per acre for sustained crop production. But in 1975 the average rate was nearly double this amount nationwide at 9 tons per acre with some areas exceeding 25 tons per acre (Figure III-20 and Table III-74). Overall water erosion dislocated 3 billion tons of soil on harvested cropland in 1975. Without existing conservation measures, the loss would have been 4 billion tons.

Estimates of cost burdens for erosion vary widely. One study places the value of soil nutrient losses at $1.2 billion annually.** To date public expenditures on conservation efforts, including erosion control, approximate $15 billion for the last 40 years. The assessment's National Future shows that to reduce cropland erosion from 9 tons per acre annually to only 3 tons per acre by the year 2000, expenditures of about $35 billion would be required.

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*Estimated acres harvested in actual year 1975; this partially reflects the 1972-1975 surge in agricultural exports.

**U.S., Senate, "Conservation of the Land and the Use of Waste Materials for Man's Benefits," prepared for the Committee on Agriculture and Forestry by the Council for Agricultural Science and Technology, GPO, 1975.

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Table III-71.—Surface area and land use, "1975"

	Surface area			Land use					
Regions 1-21	Total	Water[a]	Land	Cropland	Pasture and range	Forest and woodland	Other agri.	Urban	Other
1,000 acres	2,316,966	50,114	2,266,852	422,182	884,932	673,313	38,905	34,896	212,624
Percentage of surface area	100.0	2.2	97.8	18.2	38.2	29.0	1.7	1.5	9.2

[a]Does not include area of Great Lakes or waters classified as "other waters" from U.S. Department of Commerce Area Measurement Reports.

Table III-72.—Selected quantitative effects of man's activities on surface erosion

Initial status of land use	Type of disturbance	Magnitude of specific disturbance[a]	
Forestland	Planting row crops	100 to 1,000	Times
Grassland	Planting row crops	20 to 100	Times
Forestland	Building logging roads	220	Times
Forestland	Woodcutting and skidding	1.6	Times
Forestland	Fire	7 to 1,500	Times
Forestland	Mining	1,000	Times
Row crop	Construction	10	Times
Pastureland	Construction	200	Times
Forestland	Construction	2,000	Times

[a]Relative magnitude of suface erosion from disturbed surface, assuming "1" for the initial status. The first row of the table, for example, indicates that transforming a forestland into row crops may increase surface erosion 100 to 1,000 times.

Source: "Loading Functions for Assessments of Water Pollution from Non-Point Sources," Environmental Protection Technology Series, U.S. Enviornmental Protection Agency, Washington, D.C., May 1976.

The conflicts between increased food production and water quality are covered more fully under the sections on agriculture and water quality in this report. But it is important to note that certain trends in land use and agricultural practices have hastened erosion. The use of machinery that compacts soil and increases runoff, monoculture, use of marginal lands, and irrigation are prevailing cropping practices that generally increase soil erosion and sedimentation.

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Table III-73.—Susceptibility of harvested cropland to erosion, 1975

Region	Susceptibility to erosion (thousand acres) Slight	Moderate	Severe	Very severe	Total cropland harvested[a]
New England (1)	461	529	44	4	1,038
Mid-Atlantic (2)	2,893	4,759	668	226	8,546
South Atlantic-Gulf (3)	9,134	9,402	635	235	19,406
Great Lakes (4)	13,378	7,469	405	125	21,377
Ohio (5)	15,115	9,225	1,202	367	25,909
Tennessee (6)	795	1,628	254	127	2,804
Upper Mississippi (7)	27,108	24,250	1,903	618	53,879
Lower Mississippi (8)	14,016	2,843	219	101	17,179
Souris-Red Rainy (9)	7,600	9,518	237	84	17,439
Missouri (10)	31,118	41,399	6,322	1,528	80,367
Arkansas-White-Red (11)	16,902	14,733	3,059	456	35,150
Texas-Gulf (12)	9,958	10,302	1,208	232	21,700
Rio Grande (13)	1,776	368	38	6	2,188
Upper Colorado (14)	155	464	205	30	854
Lower Colorado (15)	1,197	56	3	4	1,260
Great Basin (16)	924	630	102	9	1,665
Pacific Northwest (17)	5,555	7,778	1,484	230	15,047
California (18)	6,936	1,840	463	109	9,348
Total, Regions 1-18	165,021	147,193	18,451	4,491	335,156

[a]1975 cropland is estimated acres harvested in the actual year 1975. It is distributed to regions on the basis of the 1967 Conservation Needs Inventory.

Source: "Cropland Erosion by Water," U.S. Department of Agriculture.

Pasture, Range, and Forest

Careful management of pastureland minimizes sheet and rill erosion and effectively reduces sediment transport. Native grazing lands or ranges in the Great Plains and western range, generally have lower erosion rates than croplands because rainfall is sparse and vegetative cover exists for the entire year. But range lands are subject to heavy runoff and erosion during sudden thunderstorms. Wind erosion threatens some denuded range lands of the Plains. Erosion on pasturelands and range land is increased by improper management of livestock grazing and periodic cultivation of marginal land. Table III-75 shows the magnitude of the grazing problems.

Well-managed forests provide effective protection against sheet and rill erosion and sediment transport. The dense tree-leaf canopy, understory vegetation, deep root systems, and ground litter prevent rapid runoff of rainfall and major soil movements. The forest's natural protection against erosion is broken when trees are removed too fast, when roads or skid trails are built, and when understory litter is removed or disturbed.

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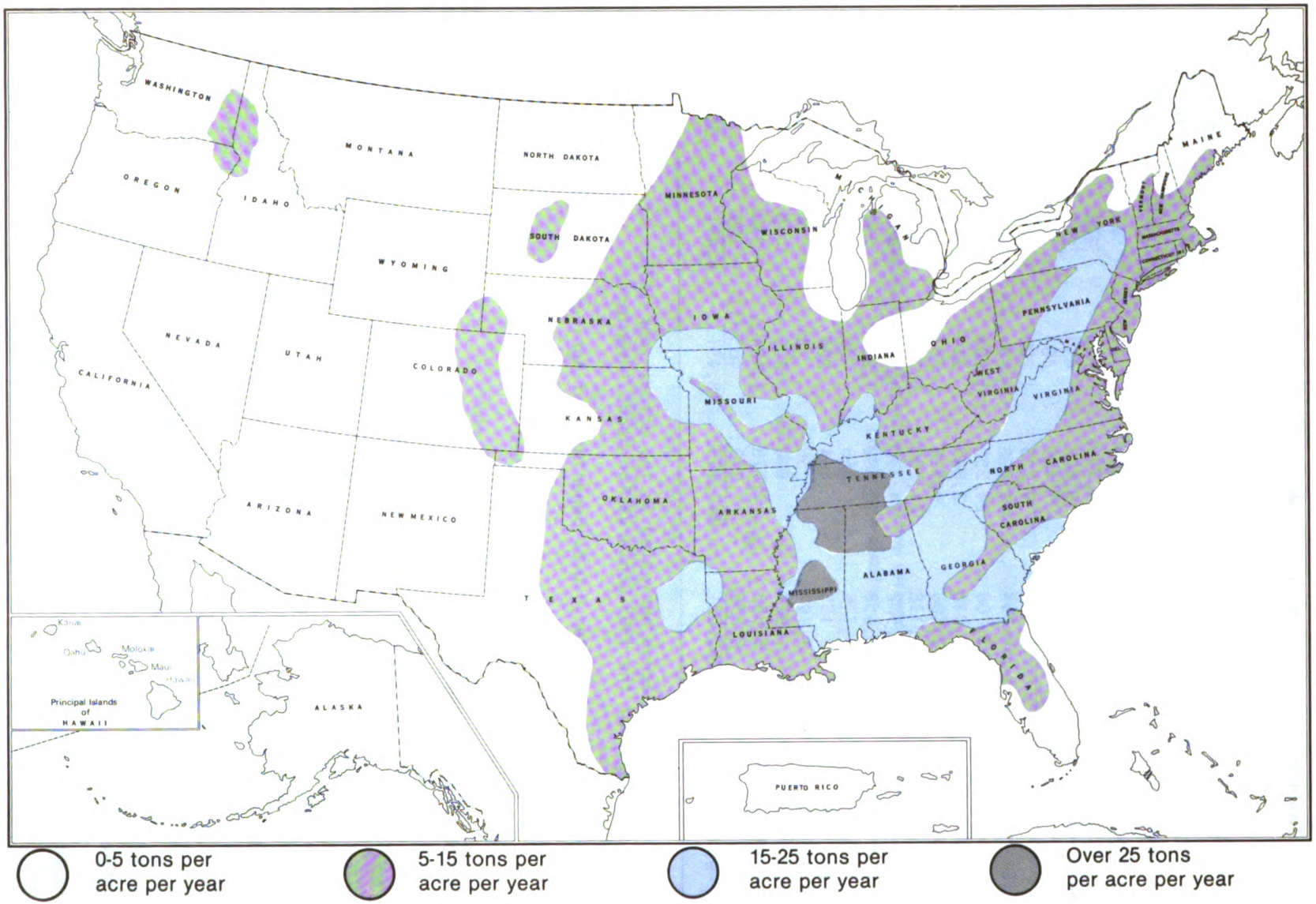

Source: USDA, Soil Conservation Service

Figure III-20. --- Sheet and rill erosion from water, 1975

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Table III-74.—Sheet and rill erosion from harvested cropland, forest, and range lands—"1975," 2000
(tons per acre per year)

Region	Erosion from cropland harvested "1975"	Erosion from cropland harvested 2000[a]	Erosion from forest and range lands "1975"
New England (1)	7	1	0.2
Mid-Atlantic (2)	14	3	0.5
South Atlantic-Gulf (3)	18	6	0.3
Great Lakes (4)	5	2	0.2
Ohio (5)	9	3	0.4
Tennessee (6)	19	4	0.3
Upper Mississippi (7)	10	3	0.6
Lower Mississippi (8)	23	6	0.3
Souris-Red Rainy (9)	2	1	0.6
Missouri (10)	7	3	1.5
Arkansas-White-Red (11)	6	2	1.0
Texas-Gulf (12)	7	3	0.7
Rio Grande (13)	2	3	0.9
Upper Colorado (14)	2	3	2.8
Lower Colorado (15)	2	1	2.0
Great Basin (16)	2	2	4.1
Pacific Northwest (17)	2	4	1.2
California (18)	1	1	2.6
Total, Regions 1-18	9	3	0.9
Alaska (19)	N/A	N/A	N/A
Hawaii (20)	N/A	N/A	N/A
Caribbean (21)	N/A	N/A	N/A
Total, Regions 1-21	N/A	N/A	N/A

N/A - Not available.
[a]Assumes application of sound conservation measures.

Table III-75.—Forests and range lands subject to erosion from grazing and exploitative grazing
(million acres)

Ecogroup	Area	Grazed	Grazed exploitatively
Eastern forests	393.5	159.9	72.4
Western forests	1,606.6	97.2	2.2
Western range	418.6	360.8	0.9
Great plains	228.9	217.1	0.0
Alaska	351.2	19.0	0.0
Hawaii	2.9	1.2	0.0
Total	1,555.7	855.2	85.6

Source: U.S. Forest Service, USDA Forest Resources Report No. 21

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Estimates of erosion rates from forests generally have been on too small a scale to establish general relationships between certain practices, such as between clearcutting and sedimentation, and experimental results have varied greatly. However, estimates made for this assessment indicate that soil losses from forest and range lands average nearly one ton per acre per year with the highest losses in the Great Basin--over 4 tons per acre per year.

Urban Areas and Construction Sites

Urbanization and highway construction generally increase erosion. The natural surface is altered, vegetation is removed, and the soil structure is destabilized by massive earth moving equipment. Gentler slopes may also be replaced by steep ones.

Some studies of small sites in the eastern United States show that urban construction activity may increase soil losses through erosion by as much as 5,000 times. After the construction has been completed, the overall sediment yield from the urban sites tends to drop. Studies made in Maryland and Virginia* indicate that an average of 40 to 50 tons of sediment per acre per year can be expected during urban development when the soil surface is unvegetated and subject to constant reworking. Urban development substantially increases the amount and peak rate of runoff from the affected area. Such peak outflow areas often degrade the adjacent channels so that the resulting bank erosion becomes a source of sediment for many years.

Surface Mines

Surface mines are significant sources of sediment where areas are being cleared, grubbed, and scalped. Roadways, spoil piles, areas of active mining, and areas being reclaimed, also contribute to sedimentation.

Strip-mining of coal is projected to increase substantially in the northern Great Plains and Rocky Mountain areas. This will increase erosion and add to the sediment loads downstream. In 1940 less than 10 percent of United States coal production came from surface-mining. By 1972 strip-mining accounted for 49 percent. For the remainder of the century, over 50 percent of coal production is projected to be surface-mined. The total land area disturbed by surface-mining is estimated at about 4.5 million acres.

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*U.S. Geological Survey, "Sediment Movement in an Area of Suburban Highway Construction, Scott Run Basin, Fairfax County, Virginia, 1961-1964," (Washington, D.C.: 1969). Raymond B., Vice, et al., "Erosion from Suburban Highway Construction," Proceedings, American Society for Civil Engineering, Vol. 94, Jan., 1968. Thomas H. York and William J. Davis, "Effects of Urbanization on Suburban Transport in Bel Creek Basin, Maryland," U.S. Geological Survey paper 750-B, 1971.

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General methods for predicting the erosion rate from surface-mined areas are not available. The influence of strip-mining on the hydrologic environment, including sedimentation, was studied for the Beaver Creek Basin in Kentucky. The study concluded that spoil banks resulting from strip-mining and prospecting are the greatest source of eroded materials. From 1958 to 1966 the average annual soil loss by sheet erosion on the soil banks was about 60 cubic yards per acre. Where the outer slope was rilled and partly terraced, the average annual loss dropped to less than 15 cubic yards per acre. On the other hand, in an area drained by a large gully, the annual rate of erosion was as high as 159 cubic yards per acre. The sediment concentration in the receiving stream increased from 550 to 30,000 parts per million, and the annual sediment yield increased from 25 tons per square mile to 1,900 tons per square mile over the strip-mined area. The average annual sediment yield from the spoil banks was about 27,000 tons per square mile.* Reclamation from surface-mining may cost over $5,000 per acre. Documented costs in Montana were $3,807 per acre (Table III-76). Even at a cost of $5,000, reclamation would add only about 10 cents per ton to the cost of mining coal.**

Channels and Streambanks

In most forest and range country and in areas with less than 20 inches of precipitation annually, channel-type erosion (e.g., gully, streambank) produces the bulk of sedimentation. In primarily agricultural watersheds with more than 20 inches of precipitation, the major source is generally sheet erosion.

Streambank erosion is dominant in semiarid and arid areas and in the mountainous areas of the Pacific Coast. In the north coast watersheds of California and in the Williamette Basin of western Oregon, the sediment contribution from streambank erosion is greater than from all other sources combined.

Of an estimated 3.5 million miles of streams (7 million bank-miles), approximately 8 percent, or 549,000 bank-miles, currently has some degree of erosion. Of this, about 78 percent is west of the main stem of the Mississippi River.

The most visible problem arising from bank erosion is the loss of land at the concave bank or the new channels cut by the stream. The exchange usually results in a net economic loss because the "new" land consists of uncompacted, generally coarse soil and is lower in elevation. Rarely is it

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*U.S., Environmental Protection Agency, Erosion and Sediment Control: Surface Mining in the Eastern U.S.

**Genevieve Atwood, "The Strip-mining of Western Coal," Scientific American, December 1975.

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Table III-76.—Projected costs of reclaiming an acre of land in Montana

Reclamation component	Incremental cost per acre[a]	Percent of total cost
Recontouring	$2,947	77.4
Topsoiling	612	16.1
Revegetation	122	3.2
Management and other	126	3.3
Total	$3,807	100.0

[a]Reclaimed to its past value with a uniform topsoil of 4 inches where spoil slopes are 10-percent grade.

Source: Watts, M.J., Staff Paper 75-24, Department of Economics, Montana State University, cited in Ecology Consultants, Inc.

immediately as valuable or productive as the land that was eroded. In addition, costly resurvey and litigation may be necessary to settle land claim disputes that arise. With few exceptions, eroded banks are unsightly and tend to reduce overall environmental quality. The Corps of Engineers estimates that total damages from streambank erosion range from $120 to 130 million annually. Based on methods currently in use, acceptable streambank erosion control would cost about $420 million annually.

Shorelines

The coastal zone is a uniquely valuable national asset. Nearly half of Nation's population lives within 50 miles of the oceans or Great Lakes. In the past 10 years, 90 percent of the national population growth has occurred in 30 coastal states.

Of the 84,240 thousand miles of shoreline evaluated, about 2,700 miles are suffering from critical rates of erosion (Table III-77). The major coastal areas located in the North Atlantic Region and the South Atlantic-Gulf Region have critical erosion problems directly related to extensive development along the shoreline. Storm wave erosion also threatens the shoreline. Probably the most important effect of shoreline erosion is the threat to recreational beaches. Special erosion problems merit attention, such as the effect of inlets that trap sand in littoral transport and thereby deprive downdrift beaches, especially along the productive barrier beaches.

Nationally, it would cost over 2 billion dollars to halt erosion on the 2,700 miles of shoreline with critical erosion. This includes $1.8 billion in structures and other capital costs, plus about $73 million annually for beach nourishment. More detailed study may be needed to decide where treatment should be the responsibility of potential property owners and/or users of the beaches.

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Options for Controlling Erosion and Sedimentation

The basic techniques and technologies for controlling erosion and sedimentation are simple in concept but complicated to implement. The control techniques fall into three broad categories:

(1) land use management, based on soil resource data and conservation planning, to select for cultivation or other activities the land that is capable of supporting the planned use without excessive erosion

(2) land treatment measures such as minimum tillage and other conservation practices on agricultural land, minimum exposure of soil during urban and highway construction, and planting and preservation of vegetation on streambanks and mining spoil piles

Table III-77.—Severity and extent of shore erosion
(miles)

Region	Total shoreline	Erosion		
		Critical	Noncritical	Noneroding
New England (1) and Mid-Atlantic (2)	8,620	1,090	6,370	1,160
South Atlantic-Gulf (3)	14,620	980	1,840	11,800
Great Lakes (4)	3,680	220	1,040	2,420
Lower Mississippi (8)	1,940	30	1,550	360
Texas-Gulf (12)	2,500	100	260	2,140
Pacific Northwest (17)	2,840	70	190	2,580
California (18)	1,810	80	1,470	260
Alaska (19)	47,300	100	5,000	42,200
Hawaii (20)	930	30	80	820
Total, shoreline evaluated	84,240	2,700	17,800	63,740

Source: U.S. Army Corps of Engineers.

(3) structural measures such as impoundments to control runoff and trap sediment, revetments to protect streambanks, and jetties to help trap sand in littoral currents and thus provide renourishment for eroded beaches.

Controls or treatment must be related to the specific site, including soil type, degree of slope, vegetative cover, climate, etc.

The lack of a coordinated national strategy for conservation reflects, in part, the complexity of the relationship between erosion reduction in a watershed and sediment load in its streams and rivers. It also reflects lack of public consciousness of the magnitude of the problem and the deficiencies of existing institutions to carry out greatly expanded programs. It is difficult to implement comprehensive conservation programs without strong national direction and even stronger local support and understanding of the sources and damages of erosion and sedimentation.

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Nevertheless, there has been progress. Without the soil conservation programs established in the 1930's and implemented on large areas of cropland, soil losses in the United States in 1975 would have been an estimated 1 billion tons greater than they were, or a third more than the estimated 3 billion tons that were lost. The unsightly gullies that commonly laced farmlands 30 years ago are largely stabilized.

Conclusions

The chief factors mitigating against more extensive use and maintenance of erosion and sediment controls are:

(1) lack of incentive to make conservation investments on private land to create public benefits such as cleaner water

(2) incomplete knowledge of the relationship between erosion reduction in a watershed and sediment loads in streams and rivers

(3) lack of institutional mechanisms for resolving conflicts between public interests and private ownership rights as they pertain to erosion and sedimentation

(4) an incomplete evaluation of erosion's effect on the productivity of soil resources

(5) the incomplete coordination of and inconsistencies and gaps between agriculture and environmental policies

(6) lack of specifics in translating national policy for food production, protection of agricultural resource base, and water quality into specific, understandable, and reliable regional, State, county, and river basin erosion and sediment control accomplishments

(7) shortage of technical assistance and site-specific strategies that provide information to the farmer on costs and expected benefits of conservation practices

(8) incompatibility of intensified production systems and monocultures with conservation management systems, and of large machinery with traditional conservation practices.

Except for developing more information, the correction of these deficiencies is not simply a matter of doing more. Attitudes must be changed and conflicts resolved among competing interests for land and water.

The experience gained from the extensive spread of conservation practices on cropland could be used, however, to develop a national strategy. Experience indicates that to be successful a strategy should embrace:

(1) generation of new information (erosion and sediment yield ratios)

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(2) objectives that reflect current goals (relating sediment tolerance levels at different stream locations to particular water uses at those locations)

(3) implementation of erosion and sediment control plans that utilize current technology (action on prioritized problem areas and sources)

a. design of an aggressive system of incentives and disincentives (public sharing of the costs of conservation on private land and withdrawal of public subsidies for failure to implement conservation practices)

b. continued emphasis on technology transfer (technical assistance and demonstration projects)

c. strengthened institutional arrangements (land use regulation that exert pressure on land users who refuse to control land erosion voluntarily or in response to incentives)

(4) monitoring of land erosion rates and sediment delivered to the receiving waters and adjusting action plans (comparison of measured soil losses and sediment loads with objectives).

A comprehensive national strategy must also consider future projections of factors such as food demand, soil losses under different rates of cropland production, and sediment yields. Data must be broken down to the smallest feasible units. Comprehensive projections on gross erosion and sediment yield are not available, but a start has been made for projecting erosion and sediment control needs in the different land and water use classifications.

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PART IV
WATER SUPPLY AND WATER QUALITY CONSIDERATIONS

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CONTENTS

Introduction ---- 1
Hydrologic cycle ---- 1
Nation's water budget ---- 2
Water supply ---- 5
Precipitation ---- 5
Surface-water resources ---- 7
Ground-water resources ---- 16
Water supply conservation and augmentation ---- 21
Water use ---- 29
National ---- 29
Regional ---- 29
Analysis of water supply and use ---- 39
Water adequacy analysis model ---- 39
Effects of offstream use on instream flows ---- 44
Results of the analysis ---- 52
Conclusion ---- 67
Water quality ---- 69
Introduction ---- 69
National patterns of water pollution ---- 70
Conclusions--The diversity of effects ---- 91
Sources of water pollution ---- 93
Control of water pollution ---- 106
Summary ---- 114
Legal and institutional aspects of water management ---- 117
Water laws of the Nation ---- 117
Treaties and compacts ---- 119

TABLES

IV-1. Streamflow frequency -- "1975" ---- 9
IV-2. Variations in monthly regional streamflows ---- 11
IV-3. Summary of manmade reservoirs in the United States, "1975" ---- 12
IV-4. Reservoir storage capacity for the United States, "1975" ---- 13
IV-5. Net evaporation from reservoirs, "1975" ---- 14
IV-6. Withdrawal of saline water and percentage of total withdrawal, "1975" ---- 16
IV-7. Saline- and fresh-water withdrawals from ground and surface sources in the United States since 1900 ---- 19
IV-8. "1975" Fresh-water withdrawals in the United States by source ---- 20
IV-9. Ground-water withdrawals and percentage of overdrafts--"1975" ---- 21
IV-10. Total withdrawals and consumption, by functional use, for the 21 regions--"1975", 1985, 2000 ---- 32
IV-11. Annual water adequacy analysis--base conditions ---- 47
IV-12. Natural water supply analysis ---- 53
IV-13. Summary of fresh-water supply and use--"1975", 1985, 2000 ---- 65
IV-14. Heat generated and discharged to the Nation's fresh and saline surface waters ---- 90
IV-15. Point sources of pollution ---- 95
IV-16. Nonpoint sources of pollution ---- 98
IV-17. New plant and equipment expenditures by U.S. business: total and for pollution abatement ---- 110
IV-18. State cost estimates for industrial pollution control ---- 111
IV-19. Cost estimates for municipal facilities construction ---- 113
IV-20. Total Section 208 grants awarded nationally ---- 113
IV-21. International water treaties of the United States ---- 121
IV-22. Interstate compacts on water resources of the United States ---- 124

ILLUSTRATIONS

IV-1. The hydrologic cycle ---- 2
IV-2. Average daily water budget ---- 3
IV-3. Variations in average precipitation ---- 6
IV-4. Acidity of precipitation ---- 8
IV-5. Average annual runoff ---- 10
IV-6. Water exports and imports by subregion ---- 15
IV-7. Major ground-water aquifers in the Nation ---- 17
IV-8. States with weather modification laws ---- 25
IV-9a. Total fresh-water withdrawals by functional use ---- 30
IV-9b. Total fresh-water consumption by functional use ---- 31
IV-10. Streamflow fluctuations and dominant use ---- 35
IV-11. Instream flow approximations for fish and wildlife, as percentage of total streamflow ---- 36
IV-12. Water supply adequacy analysis model ---- 40
IV-13. Subregional flow patterns ---- 41
IV-14. Natural flow depletion--"1975" ---- 58
IV-15. Current streamflow depletion--"1975" (base conditions) ---- 58
IV-16. Assessed streamflow depletion--"1975" (base conditions) ---- 59
IV-17. Assessed streamflow depletion--2000 (base conditions) ---- 59
IV-18. Assessed streamflow depletion--2000 (dry conditions) ---- 61
IV-19. Comparison of instream flow with current streamflow--"1975" (base conditions) ---- 62

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IV-20. Comparison of instream flow with current streamflow–"1975" (base conditions) — 62
IV-21. Comparison of instream flow with assessed streamflow–2000 (base conditions) — 63
IV-22. Months that assessed streamflow is less than IFA (base conditions) — 63
IV-23. Annual violations of mercury use — 74
IV-24. Trends in mercury – 1967-69 to 1973-75 — 74
IV-25. Annual violations of zinc use — 75
IV-26. Total concentrations of copper — 75
IV-27. Total concentrations of cadmium — 76
IV-28. Total concentrations of lead — 76
IV-29. Violations of criteria for fecal coliform bacteria — 80
IV-30. Fecal coliform bacteria violation rates, 1975 — 82
IV-31. Fecal coliform bacteria violation rates, 1976 — 82
IV-32. Trends in fecal coliform bacteria — 83
IV-33. The natural eutrophication process — 85
IV-34. Mean total phosphorus and nitrogen concentrations vs. land use — 85
IV-35. Geographic distribution of nitrogen concentrations — 86
IV-36. Geographic distribution of phosphorus concentrations — 86
IV-37. Representative inflow of BOD load in a stream — 93
IV-38. Municipal sources of BOD_5 as percentage of total estimated point source discharge — 96
IV-39. Municipal sources of TSS as percentage of total estimated point source discharge — 96
IV-40. Basins affected by pollution from agricultural activities — 98
IV-41. Basins affected by hydrologic modifications — 99
IV-42. Basins affected by pollution from silvicultural activities — 101
IV-43. Basins affected by pollution from mining activities — 101
IV-44. Basins affected by pollution from individual disposal systems — 102
IV-45. Point sources of BOD as percentage of total discharge — 103
IV-46. Point sources of TSS as percentage of total discharge — 103
IV-47. Point sources of BOD_5 as percentage of total estimated discharge = BPT — 104
IV-48. Point sources of BOD as percentage of total estimated discharge = BAT — 105
IV-49. Point sources of TSS as percentage of total estimated discharge = BPT and BAT — 105
IV-50. Enforcement actions brought under Sections 301 and 309 of P.L. 92-500 — 108
IV-51. The Nation's surface water laws — 118
IV-52. The Nation's groundwater laws — 118
IV-53. Treaties and compacts — 120

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Introduction

Part IV of this assessment report analyzes fresh-water supplies (ground and surface). It contains six sections:

1. Introduction -- outlines Part IV, briefly describes the hydrologic cycle, and discusses the water budget of the United States

2. Water Supply -- quantifies surface and ground waters, existing storage capacity, and water transferred between and within regions (water imports and exports)

3. Water Use -- describes present and future national and regional requirements for water by types of use

4. Analyses of Water Supply and Use -- describes the water supply adequacy analysis model and compares water supplies with requirements

5. Water Quality -- describes problems, sources, and controls of pollution problems

6. Legal and Institutional Aspects of Water Management -- discusses the historical development of surface- and ground-water laws and identifies key treaties and compacts.

Basic information includes streamflow quantities and frequencies, storage capacities of large reservoirs, ground-water reserves, water imports and exports (intra- and inter-regional water movements), and saline water use. This information was used to analyze the Nation's water supply and requirements for both instream and offstream uses. Water quality is included in the analyses since quality may limit or restrict water use. Better water use and supply management, including conservation, is also considered.

Hydrologic Cycle

The hydrologic cycle is a complex and continuous process involving the sun, oceans, river systems, ice caps, winds, vegetation, soils, rocks, and man's activities. Figure IV-1 shows how water in the form of vapor continuously moves from the ocean and other water surfaces to the atmosphere; there it condenses and precipitates. Much of this precipitation re-evaporates or transpires and returns to the atmosphere. The remainder runs off to become streamflow or seeps into the earth to become soil moisture and ground water. Plant roots draw upon the soil moisture in plant growth and through transpiration return water vapor to the atmosphere.

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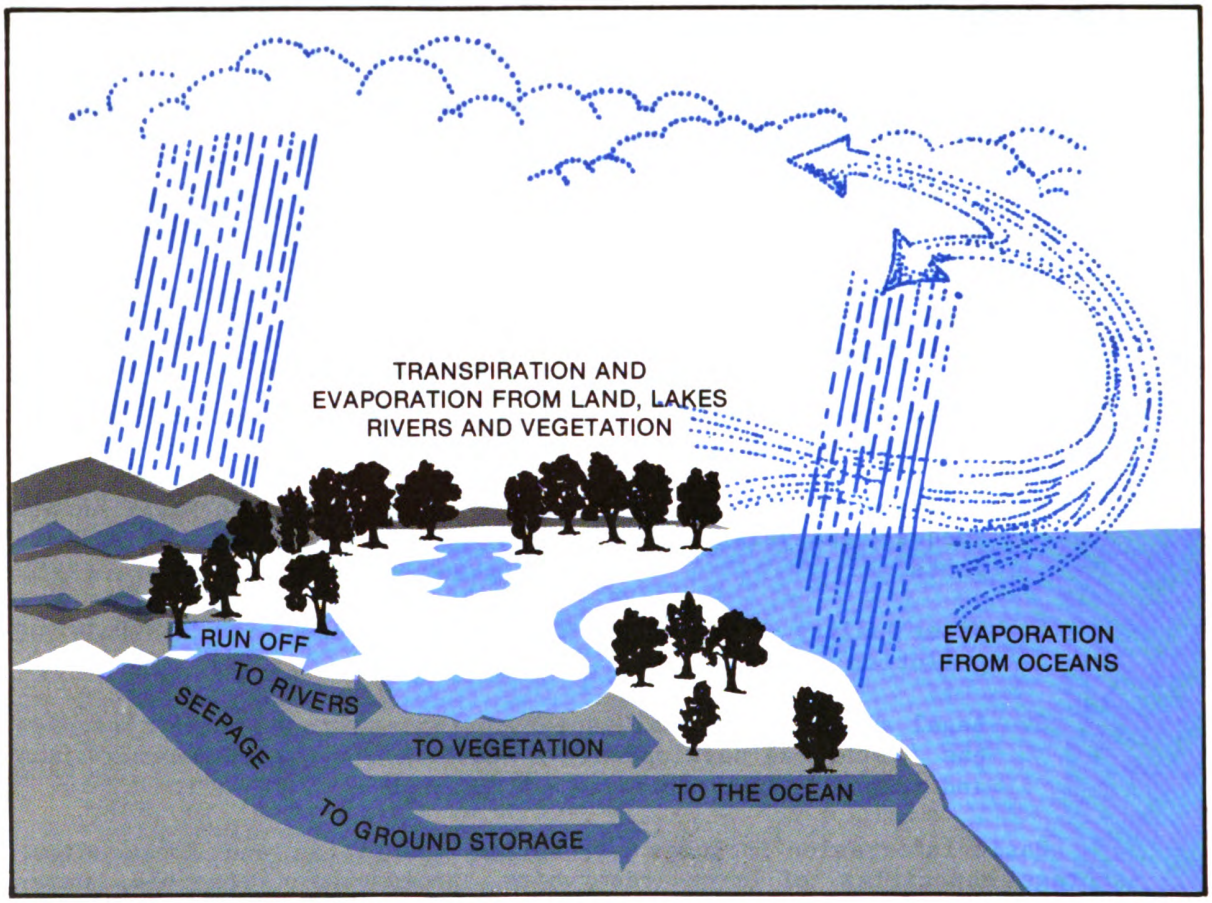

Figure IV-1: The hydrologic cycle

Precipitation may percolate to a ground-water reservoir or aquifer. It may emerge in a spring, seep into a stream channel, be pumped or forced up by nature's geysers, or it may move into tidewater or the ocean. Thus, the hydrologic cycle is a continuous process. The cycle time for water movement varies from a few days to millions of years, depending upon whether the water reaches a river channel, lake, swamp, glacier, polar ice cap, ground water, etc.

Nation's Water Budget

The average daily water budget of the conterminous United States is shown in Figure IV-2. The budget accounts for water in its various phases and locations. On the average, about 40,000 billion gallons per day (bgd) of water pass over the conterminous United States in the form of water vapor. Of this, about 10 percent (4,200 bgd) or the equivalent of an annual 30

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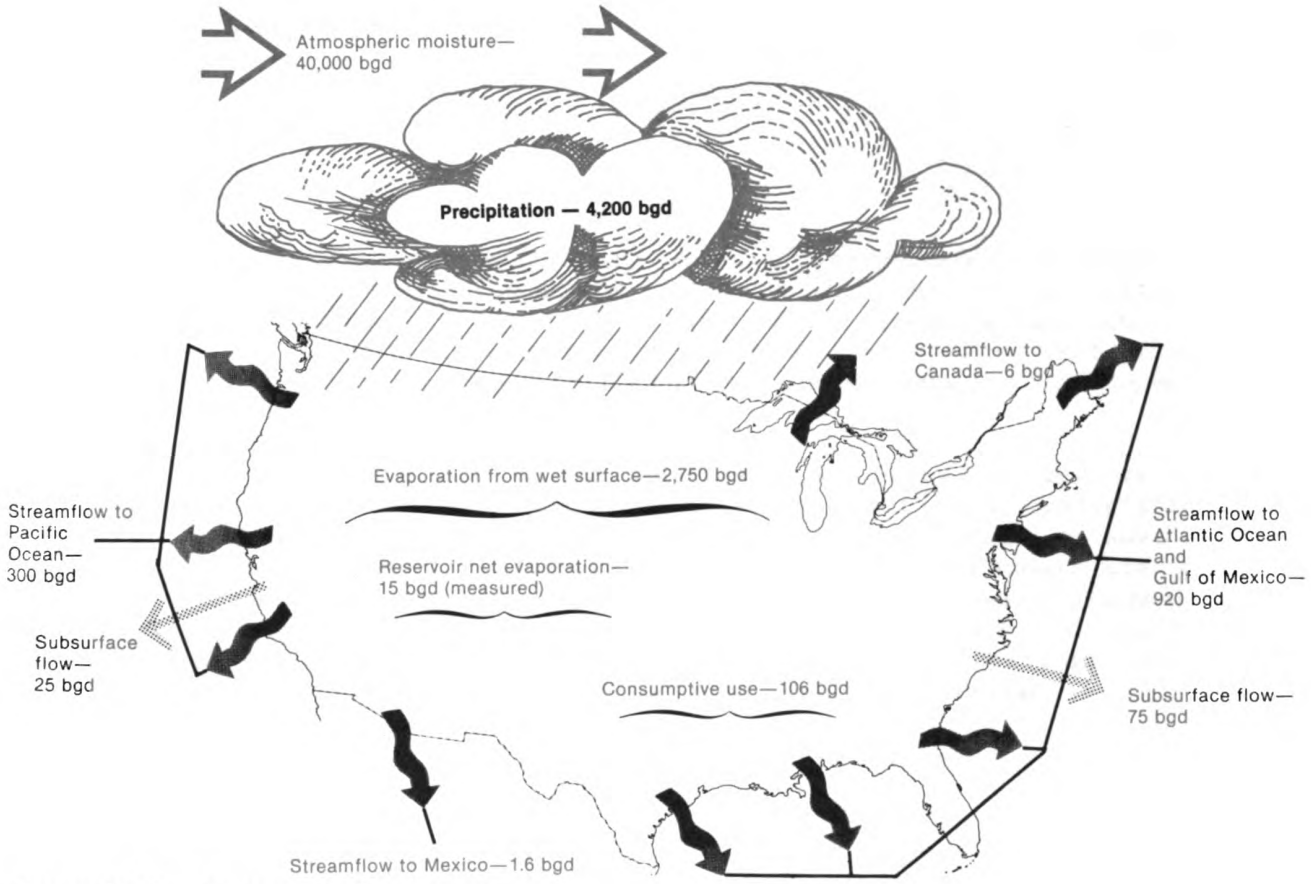

Figure IV-2: Average daily water budget

inches precipitates as rainfall, snow, sleet, or hail. The remainder continues in atmospheric suspension. Of the 4,200 bgd, about two-thirds (2,750 bgd) is re-evaporated from the wet surfaces or transpired by vegetation back to the atmosphere. The remaining 1,450 bgd accumulates in ground or surface storage, flows to the oceans or Gulf of Mexico or across the Nation's boundaries, is consumed, or is evaporated from reservoirs.

Streamflow into the oceans, Gulf of Mexico, Canada, and Mexico amounts to about 1,230 bgd with an additional 100 bgd as subsurface flow to the oceans. Consumptive use is about 106 bgd. Evaporation from major reservoirs and stock ponds accounts for another 15 bgd.

From a national water budget standpoint, the United States seems to have more than sufficient water supplies to meet its needs. However, the water resources vary considerably, from region to region.

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Water Supply

Precipitation

Sources and Quantities

As mentioned earlier, an average of approximately 30 inches of water annually precipitates to the surface of the conterminous United States. About 26 inches of this falls as rain and the remainder as snow, sleet, or hail. Evaporation from the oceans provides over 80 percent of the water vapor for precipitation falling on the conterminous United States. Inland evaporation and transpiration supplies the rest.

Only a portion of the potential 1,450 bgd (4,200 bgd precipitation minus 2,750 bgd evaporation) shown in the water budget analysis in Figure IV-2 is available for intensive beneficial uses. To date, because existing surface storage is inadequate and because extremes of annual precipitation cause floods and droughts, only 675 bgd of the average annual stream flow is considered available in 95 out of 100 years. In the remaining five years, or an average of once every twenty years, an even smaller amount of water can be expected to be available for use.

Geographic Variability

The average annual amount of precipitation ranges from less than 4 inches in parts of the Great Basin and Lower Colorado Regions to more than 200 inches in coastal areas of the Pacific Northwest Region. Figure IV-3 shows the geographic variations in average precipitation for the conterminous United States. The area east of the Mississippi River averages about 44 inches, the area west of the Rocky Mountains about 18 inches, and the intervening area about 28 inches. The average annual precipitation in Alaska ranges from about 5 inches in the extreme north to more than 200 inches at places along the southern panhandle for an overall average of about 20 inches.

In local areas precipitation varies significantly. For example, large amounts of water precipitate on the windward sides of high mountains where water vapor suspended in the atmosphere is cooled as the air passes over the mountainous area, causing it to precipitate. The Olympic Mountain Range in the State of Washington is an example. It receives as much as 200 inches of precipitation a year on the western slope, but as little as 20 inches on the eastern slope. Mt. Waialeale in Hawaii has the world's largest average annual precipitation, 460 inches. However, about 15 miles southwest, on the leeward side of that mountain, the average annual precipitation is less than 30 inches.

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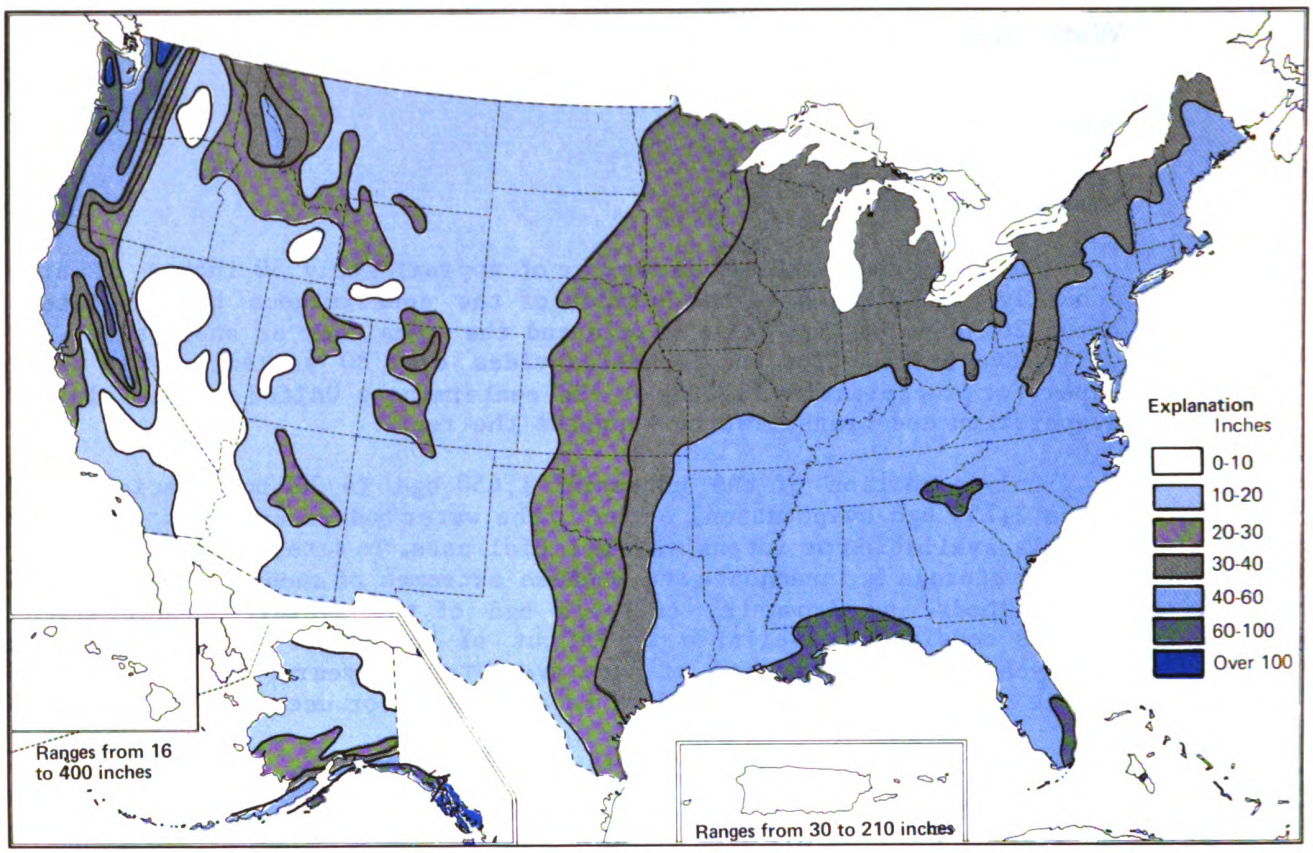

Figure IV-3: Variations in average precipitation

Annual and Seasonal Variability

The extremely varied topographic and climatic conditions of the conterminous United States create continuously varying seasonal and annual precipitation patterns. While normal precipitation is occuring in some areas of the country, subnormal precipitation occurs in others. Locations with low average rainfall generally experience the greatest variations.

In the Northeast there is relatively little seasonal variation in precipitation. On the other hand, summer storms during the May-October period in the midcontinent area typically produce more than twice the precipitation that occurs during the remainder of the year.

In the South the seasonal trend is even more complicated. Thunderstorms provide inland areas with most of the summer precipitation, while hurricane rains provide coastal areas with precipitation in the fall months. Cyclones range far enough south during winter months for some areas to receive most of their precipitation from this source.

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In western mountain areas, winter is the period of greatest precipitation except for low altitudes in southern latitudes where winter precipitation is less than that for the summer. West of the Cascade and Sierra Nevada Mountains, the maximum precipitation occurs during the winter. During the summer months, much of California is virtually without precipitation. In the northern mountain areas, water available for storage during the winter months as snowpack is released to streams as temperatures rise in the spring.

The coastal areas of Alaska receive precipitation primarily in the late fall, while interior areas receive precipitation mostly in summer. In both Hawaii and the Caribbean, fall is the wet season and early spring is dry.

Precipitation Quality

As shown in Figure IV-4, the acidity of precipitation varies substantially nationwide. The pH is lowest, that is, the acidity is highest, in the industrialized Northeast. Concentrations of nitrogen and sulfur compounds in precipitation have increased dramatically during the past 10 years in many large areas of the northeastern part of the United States. For example, concentrations have increased fourfold in New York State. The reason for this is not fully known. Data from the U.S. Environmental Protection Agency show that emissions of both sulfur dioxide and nitrogen oxides increased sharply after 1960. However, the increase in nitrogen oxides doubled that for sulfur dioxide during the 1960-1970 period. The increase in nitrate concentration in precipitation parallels the increase in precipitation acidity. Significantly, the use of nitrogen fertilizers has increased rapidly since about 1950.

Surface-water Resources

Surface water is that which occurs in rivers, streams, lakes, swamps, marshes, and manmade reservoirs. Ground water occurs in the zone of saturation below land surface. For this discussion, surface-water supplies are grouped into two broad categories -- fresh and saline. While saline water ranges from brackish inland water to sea water, for the second assessment, saline water is defined as water that contains more than 1,000 milligrams of dissolved solids per liter of solution, irrespective of the nature of the minerals present.

About two-thirds of the total fresh- and saline-water withdrawals in the conterminous United States comes from fresh-water streamflow and surface storage sources (256 bgd); an additonal 15 percent (61 bgd) comes from groundwater sources that are highly interactive with streamflows. Hence, for this assessment these are considered to be a single source. Therefore, 80 percent of the Nation's water presently being withdrawn comes from those fresh-water sources. An additional 5 percent comes from ground-water overdraft. The remaining 15 percent comes from saline-water withdrawals.

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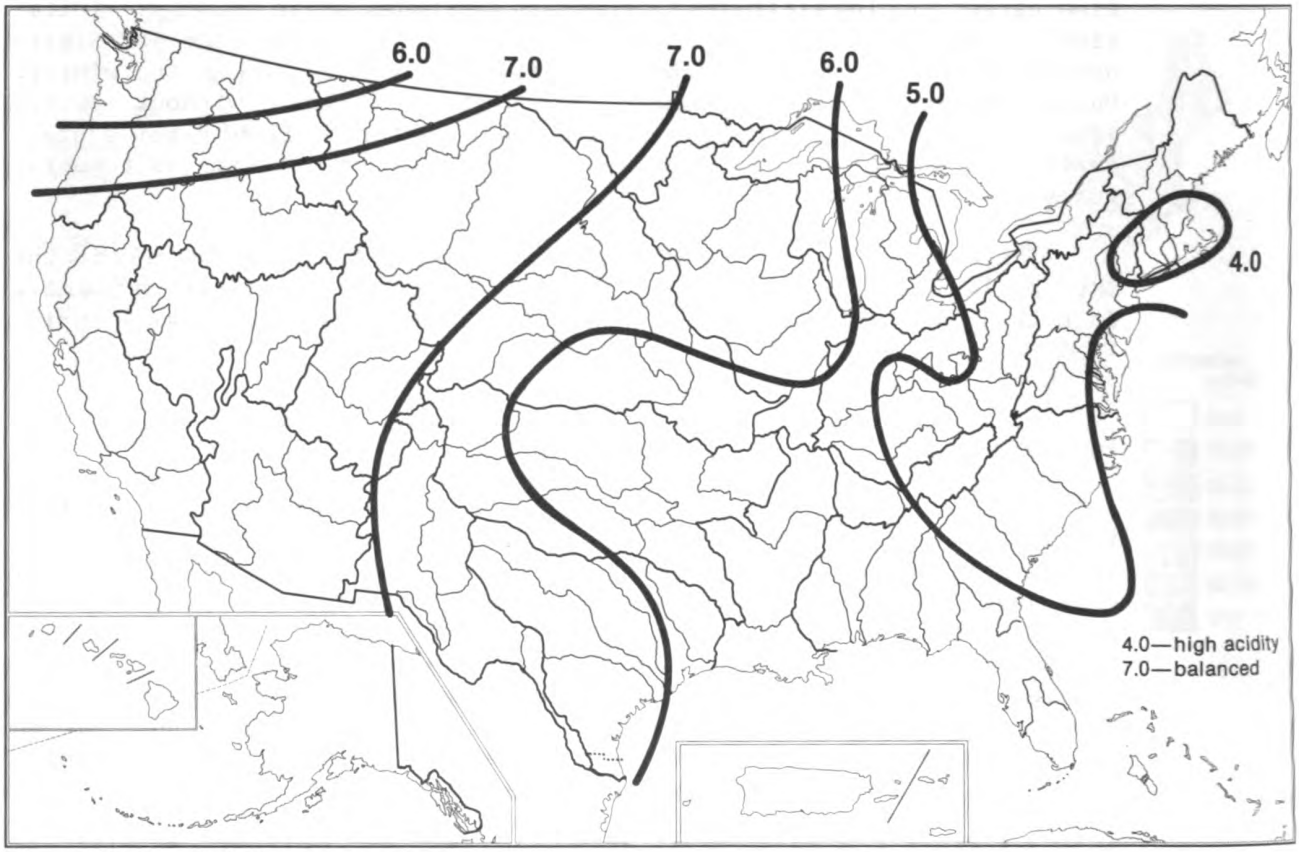

Figure IV-4: Acidity of precipitation

Streamflow and Runoff Variability

The amounts of streamflow from each of the 21 regions are shown in Table IV-1. Variations in annual streamflow are expressed in terms of flow that is expected to be exceeded in a specific percentage of years. For example, a flow of 5-percent exceedance represents an extremely high flow that will be exceeded on the average in only 5 out of 100 years. Many flood plains are inundated when flow in the main stream is at or above this level. The 50 percent exceedance flow is the median flow; streamflow will exceed the median flow half the time. The 80-percent exceedance flow, on the other hand, represents a low flow, one that will be exceeded 80 years out of 100, on the average. During those years when flows are less than the 80-percent exceedance level, water shortages of varying intensity can occur. The 95-percent exceedance flow represents extremely low flows.

Although the average annual runoff is sometimes assumed to be the theoretical upper limit of supply, the storage required to make this amount of water available for use would be so large that much of the water would be lost by evaporation. In general, the percentage of mean

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Table IV-1.—Streamflow frequency—"1975"

[Italic numbers not included in total because these are inflows to another region]

Water resources region and No.	Streamflow, in billion gallons per day				
	Mean	Percent exceedance			
		5	50	80	95
New England (1)	78.2	107.7	77.4	62.7	48.3
Mid-Atlantic (2)	79.2	115.1	77.8	61.2	48.4
South Atlantic-Gulf (3)	228.0	356.6	219.3	164.1	121.8
Great Lakes (4)	72.7	103.9	71.7	57.3	44.9
Ohio (5)	*178.0*	*254.0*	*178.0*	*141.0*	*105.0*
Tennessee (6)	*40.8*	*57.9*	*40.8*	*35.9*	*31.4*
Upper Mississippi (7)	*121.0*	*189.0*	*121.0*	*91.8*	*65.3*
Lower Mississippi (8)	433.0	757.0	433.0	282.0	202.0
Souris-Red-Rainy (9)	6.0	11.4	5.6	3.4	1.8
Missouri (10)	*44.1*	*74.3*	*43.2*	*29.9*	*17.6*
Arkansas-White-Red (11)	*62.6*	*120.7*	*59.1*	*37.4*	*21.6*
Texas-Gulf (12)	28.3	62.4	22.9	12.3	6.3
Rio Grande (13)	1.2	4.4	.6	.3	.2
Upper Colorado (14)	*10.0*	*15.6*	*10.0*	*7.0*	*3.9*
Lower Colorado (15)	1.6	1.7	1.6	1.4	1.2
Great Basin (16)	2.6	4.7	2.4	1.6	1.2
Pacific Northwest (17)	255.3	344.7	254.3	213.3	179.7
California (18)	47.4	87.4	44.3	29.8	19.5
Total, Regions 1-18	1,233.4	1,956.9	1,210.9	889.4	675.3
Alaska (19)	905.0	1,030.0	898.0	795.0	705.0
Hawaii (20)	6.7	10.3	6.3	4.9	3.8
Caribbean (21)	4.9	7.1	4.5	3.3	1.6
Total, Regions 1-21	2,150.0	3,004.3	2,119.7	1,692.6	1,385.7

annual runoff, the ground-water recharge possibilities, the amount of storage and surface area of reservoirs, and the evaporation potential all vary greatly nationwide and all affect water yield. In fact, to make available for withdrawal the amounts shown for 95-percent exceedance values, many regions would need substantial additional storage. Other measures such as water conservation to reduce water use or weather modification to increase precipitation must be considered if increased water requirements are to be satisfied.

The streamflow values estimated by both the regional sponsors and the Water Resources Council are presented for comparison in Volume 3, Appendix V, Streamflow Conditions. The estimates agree closely on the average annual amounts of streamflow being discharged from most of the 106 subregions.

Precipitation varies widely from region to region and within a region, from season to season, and year to year. Similar variations occur in streamflow. For example, within a normal year, the ratio of maximum flows to minimum flows may be greater than 500 to 1. Annual variations in average flows are also substantial. As shown in Figure IV-5, average annual runoff is highest in the Northwest and lowest in the Southwest.

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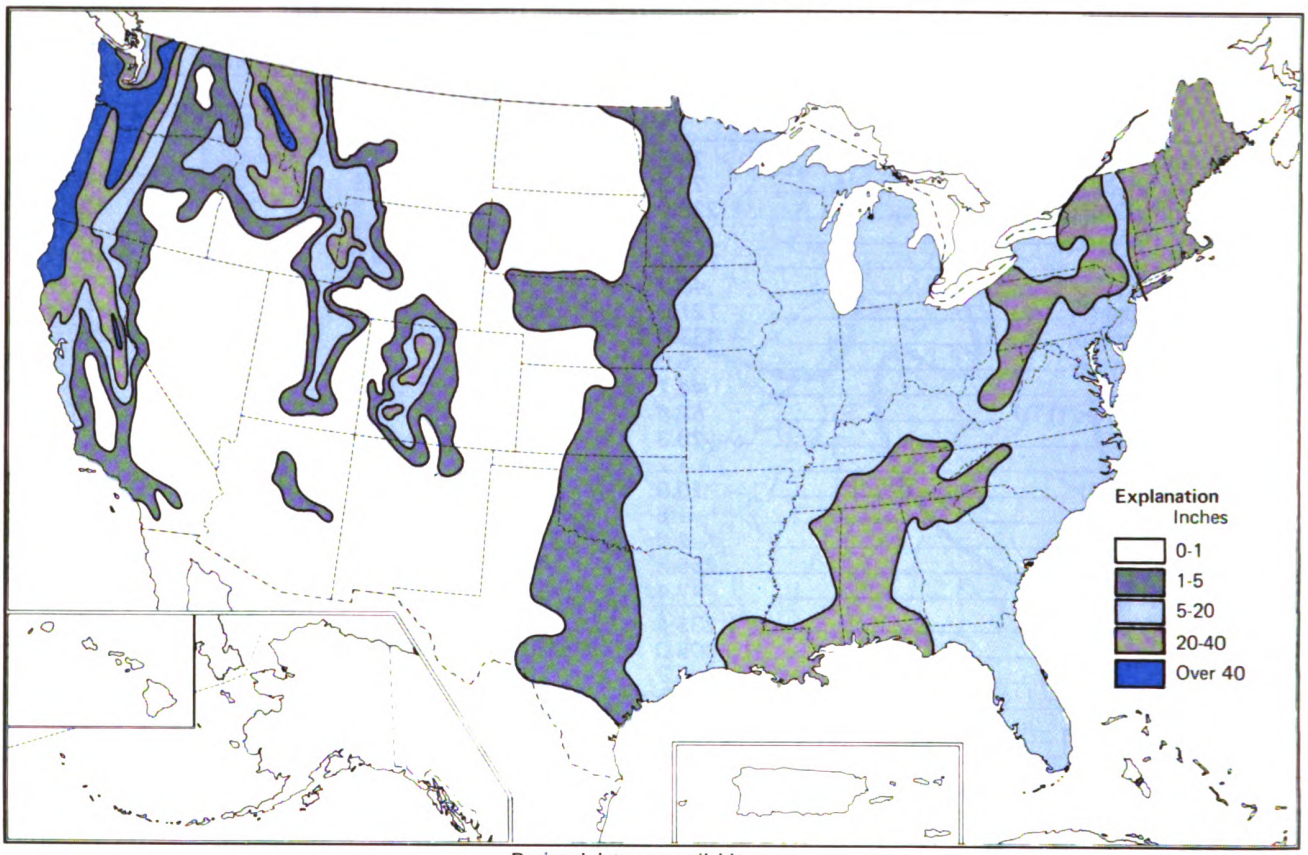

Figure IV-5: Average annual runoff

The adverse effects of droughts are particularly serious in areas that use a high proportion of the available average annual runoff or where storage and distribution facilities are inadequate to provide carryover during periods of low streamflow.

The amount of streamflow in a dry year can be compared to streamflow in an average or median year to show the amount of dependable water supply that a stream can provide. The dry year selected in this comparison is important. One approach is to select a year with a flow that represents the lowest annual, monthly, or daily mean streamflow ever observed (the low flow of record). Another approach, the one used in this assessment, is to select a year from frequency analysis of observed streamflow to determine the flow for various percentages of time; the Council selected the 80-percent streamflow condition to represent the dry year. Table IV-2 shows the variations in the monthly streamflow by comparing the high and low flow values with the average annual values.

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Table IV-2.—Variations in monthly regional streamflows
(billion gallons per day)

Region	Very dry year (95% exceedance)[a]				Very wet year (5% exceedance)[b]			
	Low flow month	Low month regional flow	Ratio to mean annual	Mean annual regional streamflow	Ratio to mean annual	High month regional flow	High flow month	High month to low month ratio
		bgd		bgd		bgd		
New England (1)	SEP	13.0	0.17	78.2	4.06	317.3	APR	26.4
Mid-Atlantic (2)	SEP	10.5	0.13	79.2	3.46	273.7	MAR	26.1
South Atlantic-Gulf (3)	NOV	43.5	0.19	228.0	3.22	734.9	MAR	16.9
Great Lakes (4)	AUG	18.4	0.25	72.7	3.80	276.3	APR	15.0
Ohio (5)	SEP	27.0	0.15	178.0	3.88	691.0	FEB	25.6
Tennessee (6)	SEP	15.3	0.38	40.8	3.46	141.0	JAN	9.2
Upper Mississippi (7)	JAN	28.2	0.23	121.0	3.11	376.0	APR	13.3
Lower Mississippi (8)	OCT	88.9	0.21	433.0	3.97	1720.0	FEB	19.3
Souris-Red-Rainy (9)	FEB	0.3	0.05	6.0	6.41	38.5	MAY	132.3
Missouri (10)	JAN	8.3	0.19	44.1	3.65	161.0	JUN	19.3
Arkansas-White-Red (11)	OCT	5.0	0.08	62.6	4.95	309.9	MAY	61.4
Texas-Gulf (12)	OCT	1.3	0.05	28.3	6.50	183.7	MAY	144.1
Rio Grande (13)	APR	0.02	0.01	1.2	13.50	16.6	OCT	922.2
Upper Colorado (14)	JUL	1.2	0.12	10.0	3.16	31.6	MAY	25.7
Lower Colorado (15)	NOV	0.37	0.24	1.6	1.81	2.8	AUG	7.6
Great Basin (16)	SEP	0.16	0.06	2.6	4.82	12.4	MAY	77.7
Pacific Northwest (17)	SEP	87.9	0.24	255.3	2.16	552.7	JUN	6.3
California (18)	OCT	5.5	0.12	47.4	5.88	278.7	JAN	51.1
Alaska (19)	MAR	91.1	0.10	905.0	2.91	2630.0	JUN	28.9
Hawaii (20)	AUG	0.8	0.12	6.7	4.70	31.7	DEC	39.9
Caribbean (21)	APR	0.6	0.12	4.8	3.79	18.4	OCT	32.0

[a]The annual flow for a "very dry year" will be exceeded in 95 of 100 years (95-percent exceedance).

[b]The annual flow for a "very wet year" will be exceeded in only 5 of 100 years (5-percent exceedance).

Reservoir Storage

Water can be stored naturally in lakes and wetlands or artifically in manmade storage reservoirs. In the second assessment, storage reservoirs were identified and the amount of storage capacity tabulated for the 21 regions and 106 subregions. Large reservoirs include impoundments and diversion works created by barriers and appurtenant works that are 25 feet or more in height and which have a capacity of at least 50 acre-feet (approximately 16.3 million gallons). As shown in Table IV-3, there are about 49,130 large reservoirs (capacity of 50 acre-feet or more) and more than 1,843,000 smaller reservoirs in the United States.

Of the large reservoirs, 1,631 have storage capacity greater than 5,000 acre-feet. As shown in Table IV-3, 31 of these have a combined total of approximately 191 million acre-feet of normal storage that accounts for about 41 percent of the total normal reservoir storage in the United States. In addition to the large reservoirs, more than 1.8 million small reservoirs and an undetermined number of farm ponds have been developed for water supply, fire protection, and recreation. These smaller water bodies have about 10 million acre-feet (3,260 billion gallons) of storage capacity or about 2 percent of the total capacity. Normal operating storage of all reservoirs in the Nation is about 146,800 billion gallons (450 million acre-feet), as shown in Table IV-4.

Table IV-3.—Summary of manmade reservoirs in the United States, "1975"

Reservoir size (thousand acre-feet)	Number of reservoirs	Normal storage capacity (thousand acre-feet)	Percentage of total normal storage capacity
More than 10,000	5	117,000	25
2,000 to 10,000	26	74,000	16
	31	191,000	41
5 to 2,000	1,600[a]	168,000[a]	37[a]
0.05 to 5	47,500[a]	91,000[a]	20[a]
Less than 0.05[b]	1,843,000[a]	10,000[a]	2[a]
Total	1,892,131	460,000	100

[a]Approximate values.
[b]Note that 0.05 thousand acre-feet equals 50 acre-feet.

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Table IV-4.—Reservoir storage capacity for the United States, "1975"

Region	Maximum storage[a] (billion gallons)	Normal storage[b] (billion gallons)	Normal pool surface area (1,000 acres)
New England (1)	6,310	4,722	412
Mid-Atlantic (2)	7,853	6,271	142
South Atlantic-Gulf (3)	19,799	13,382	1,766
Great Lakes (4)	4,199	3,292	182
Ohio (5)	14,098	5,161	681
Tennessee (6)	7,724	3,600	466
Upper Mississippi (7)	7,574	4,231	469
Lower Mississippi (8)	6,398	2,034	542
Souris-Red-Rainy (9)	2,429	1,430	18
Missouri (10)	38,488	27,161	2,087
Arkansas-White-Red (11)	22,761	9,853	1,515
Texas-Gulf (12)	17,912	7,660	930
Rio Grande (13)	4,410	2,534	173
Upper Colorado (14)	3,691	3,329	318
Lower Colorado (15)	23,491	19,962	251
Great Basin (16)	1,368	1,239	130
Pacific Northwest (17)	21,257	17,839	1,280
California (18)	14,416	12,697	413
Total, Regions 1-18	224,179	146,397	11,774
Alaska	283	267	12
Hawaii	17	13	1
Caribbean	132	92	7
Total, Regions 1-21	224,612	146,769	11,793

[a]Maximum storage is flood capacity; over normal storage.

[b]Normal storage is that capacity designated for purposes other than flood control.

Evaporation

The amount of evaporation from reservoir surfaces is significant, particularly in the arid West. The basic factors influencing the rate at which water will evaporate from the surface of an extensive body of water are short-wave and long-wave radiation, humidity, air temperature, wind movement, and temperature of evaporating surfaces. The average rate of gross

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evaporation from reservoirs varies from about 20 inches per year in the Pacific Northwest and New England Regions to more than 80 inches per year in the Rio Grande and Lower Colorado Regions.

Precipitation falling onto reservoir surfaces makes up for, and in some cases exceeds, evaporation. Thus, evaporation is less than precipitation in the humid East. Net evaporation for the East was treated as zero for this assessment. The largest net evaporation occurs in the Southwest. Table IV-5 shows the net evaporation by region for "1975."

Table IV-5.—Net evaporation from reservoirs, "1975"

Region	Estimated net[a] evaporation
	mgd
New England (1)	0
Mid-Atlantic (2)	0
South Atlantic-Gulf (3)	0
Great Lakes (4)	0
Ohio (5)	0
Tennessee (6)	0
Upper Mississippi (7)	43
Lower Mississippi (8)	0
Souris-Red-Rainy (9)	16
Missouri (10)	4,924
Arkansas-White-Red (11)	2,615
Texas-Gulf (12)	1,705
Rio Grande (13)	730
Upper Colorado (14)	711
Lower Colorado (15)	1,202
Great Basin (16)	327
Pacific Northwest (17)	2,014
California (18)	669
Alaska (19)	0
Hawaii (20)	1
Caribbean (21)	0

[a] If precipitation exceeds evaporation, net evaporation is shown as zero (0).

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Water Imports and Exports

There are physical regional and intraregional transfers of water in the United States. Figure IV-6 shows where water imports and exports occurred in "1975" and are projected for 2000. The estimates of future increases or decreases in transfers are based on authorized and/or funded projects only.

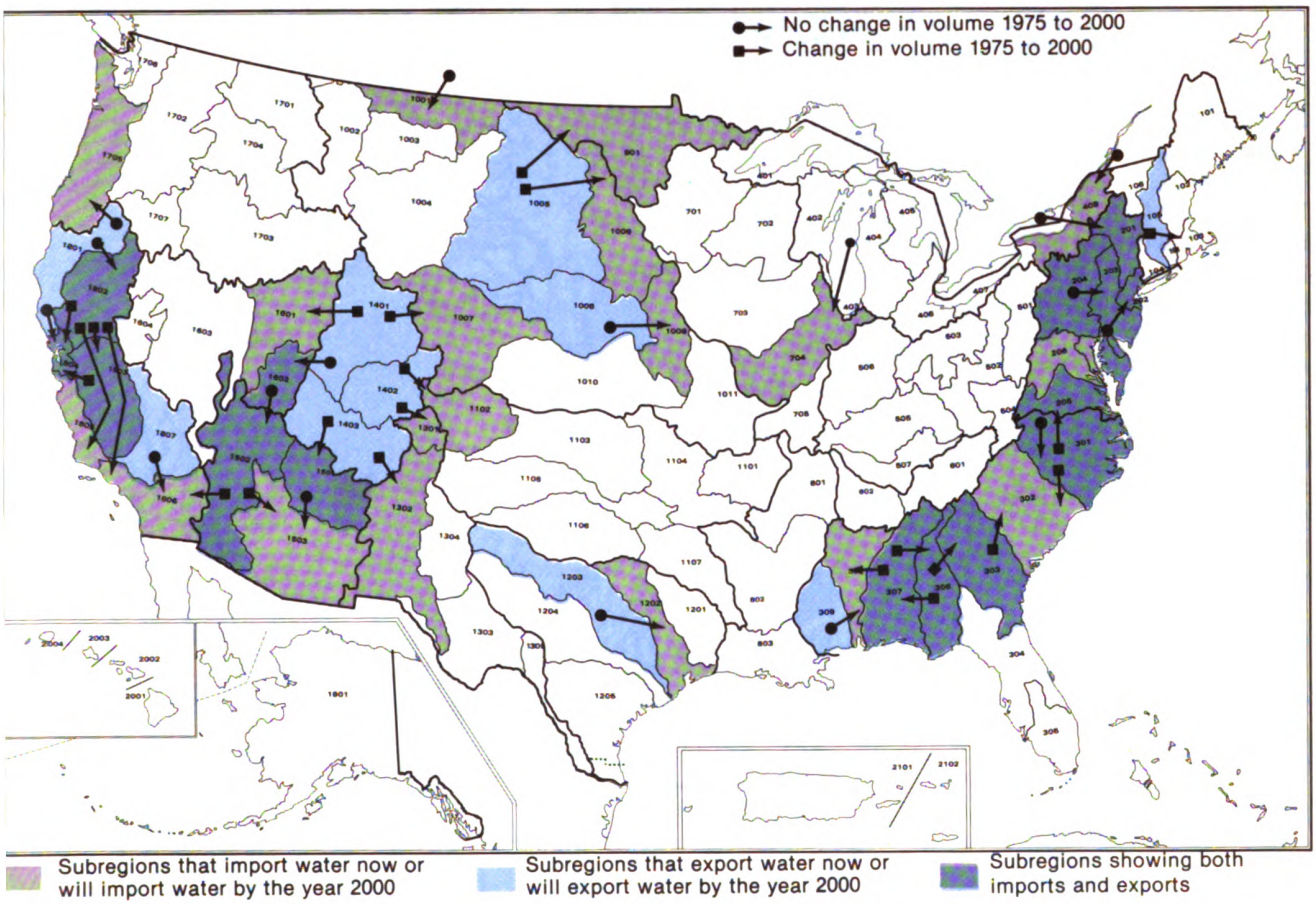

Figure IV-6: Water exports and imports by subregion

Saline-water Supplies

For the second assessment, saline-water supplies are described largely in terms of water uses. The major sources are the limitless supplies of oceans. Of the total fresh and saline withdrawals, 15 percent (59.7 billion gallons per day) is saline water. Manufacturing and steam electric generation are the largest users of saline water. Table IV-6 shows the regions that withdraw saline water and what percent of total water withdrawals this represents.

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Table IV-6.—Withdrawal of saline water and percentage of total (fresh and saline) withdrawal, "1975"

Region	Saline withdrawal	Percent
	mgd	
New England (1)	5,216	51
Mid-Atlantic (2)	19,625	52
South Atlantic-Gulf (3)	7,460	23
Great Lakes (4)	0	0
Ohio (5)	0	0
Tennessee (6)	0	0
Upper Mississippi (7)	0	0
Lower Mississippi (8)	1,253	8
Souris-Red-Rainy (9)	0	0
Missouri (10)	0	0
Arkansas-White-Red (11)	0	0
Texas-Gulf (12)	9,163	35
Rio Grande (13)	0	0
Upper Colorado (14)	0	0
Lower Colorado (15)	0	0
Great Basin (16)	0	0
Pacific Northwest (17)	131	0.3
California (18)	14,569	27
Total, Regions 1-18	57,417	15
Alaska (19)	57	16
Hawaii (20)	1,139	38
Caribbean (21)	1,124	55
Total, Regions 1-21	59,737	15

Ground-water Resources

Distribution and Characteristics

Figure IV-7 shows the physiographic distribution of the Nation's major ground-water aquifers. Aquifers vary widely in their ability to accept replenishment. Some ground-water reservoirs receive ample recharge from

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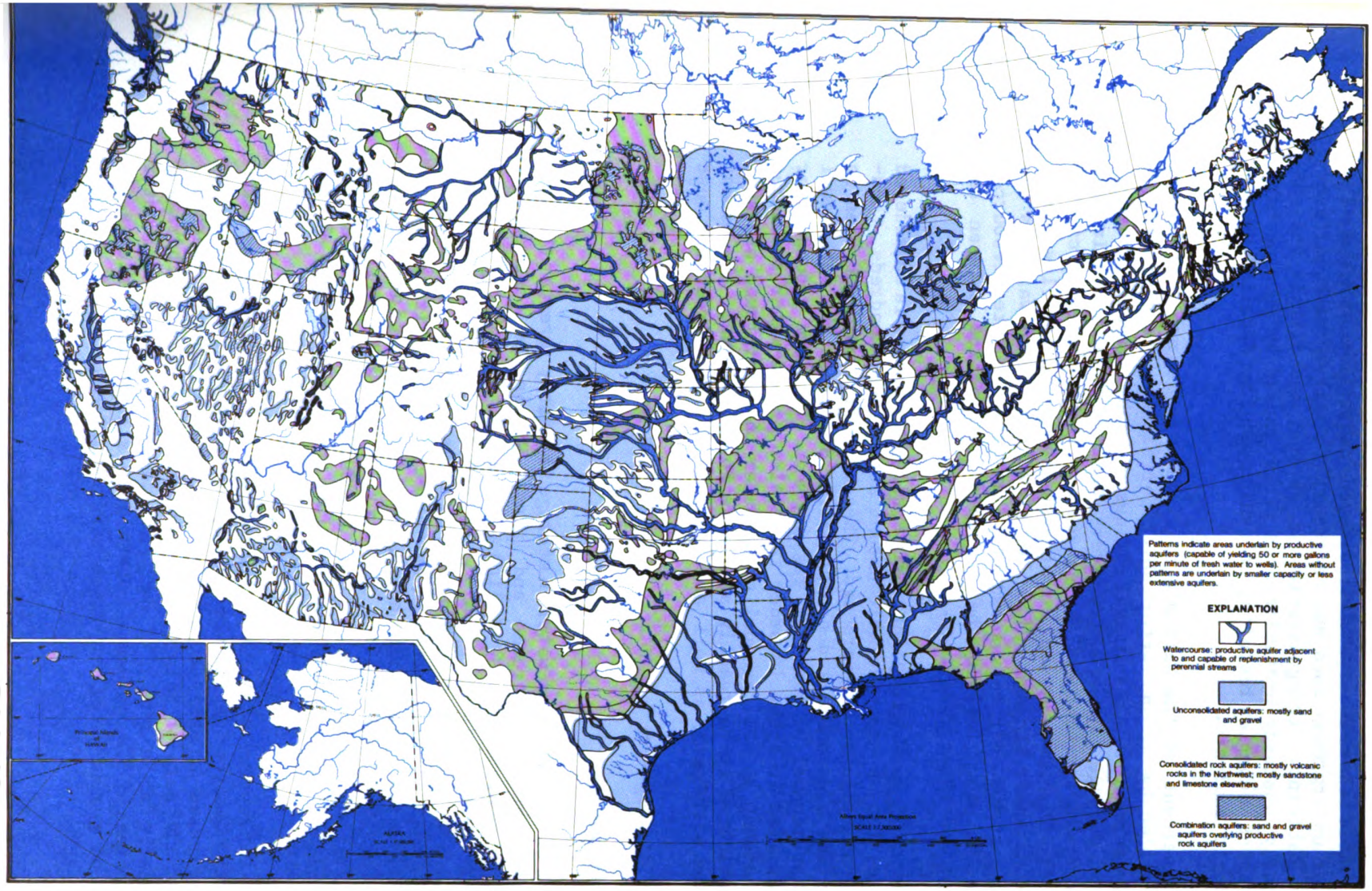

Figure IV-7: Major ground-water aquifers in the nation

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rain and snow, while others receive small or even negligible amounts. The movement of water underground does not necessarily coincide with surface-water drainage patterns. Irregularities in geology and climate and the characteristically unsteady hydraulic conditions caused by pumping make ground-water basins a complex resource, one which requires detailed hydrologic and geologic analysis.

About 30 percent of the Nation's streamflow during a year of normal rainfall is supplied by ground water which percolates into aquifers and then emerges as streamflow from natural springs and other seepage sources. In arid regions, seepage from streams, rivers, and reservoirs is a principal source of ground-water recharge. During years with subnormal precipitation, most of the flow in many smaller streams during the low flow months comes from ground-water storage. This low flow from ground water is the "base flow" of a stream. For an assessment of the Nation's water resources to be accurate, it must include the degree of interaction between the surface- and ground-water resources.

From a historic, geologic point of view, all ground water is considered to be renewable, but a considerable amount accumulated hundreds, thousands, and even millions of years ago. These waters that have been in storage a long time are considered nonrenewable. Sometimes the withdrawal is so great that renewal or recharge takes years. The term ground-water overdraft is applied to both. In order to develop ground-water resources properly, the amount as well as quality of water in underground storage, the amount considered to be readily available for withdrawal, the amount currently being withdrawn, as well as the rate of annual recharge must be known.

Ground-water Quantity and Use

The amount of fresh ground water in storage is vastly greater than the quantity of fresh water in streams and lakes. Within the conterminous United States, there are about 180 billion acre-feet or 59,000,000 billion gallons of ground water within about 2,500 feet of the earth's surface. Of this amount, about half is considered to be extractable if no consideration is given to changes in streamflow, the effect on the environment, and the costs of extraction. To put these huge quantities of water into perspective, compare that 59,000,000 billion gallons to the 1,290,000 billion gallons of water in Lake Michigan or to the 33,000,000 billion gallons of water that the Mississippi River discharged into the Gulf of Mexico during the last 200 years.

Table IV-7 presents historical information on ground-water withdrawals. For the period of 1900 to "1975," withdrawals of saline and fresh water increased annually at an average compound rate of 3 percent. During the last 25 years of this period, fresh surface-water withdrawals increased annually at a rate of 2 percent, whereas fresh ground-water withdrawals increased 3.8 percent. This is a significant increase in the dependency on ground water for fresh-water supplies.

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Table IV-7.—Saline- and fresh-water withdrawals from ground and surface sources in the United States since 1900
(billion gallons per day)

Year	Saline water		Fresh water			Total	Saline and fresh ground water in percent of total
	Ground	Surface	Ground	Surface	Reclaimed		
1900						40	
1910						66	
1920						92	
1930						110	
1940						136	
1950	N/A	10	34	160	N/A	204	17
1955	0.7	18	47	180	0.2	246	19
1960	0.4	31	50	190	0.1	272	19
1965	0.5	43	60	210	0.7	314	19
1970	1.0	53	68	250	0.5	372	19
1975	1.0	69	82	260	0.5	412	20

N/A Not available.
Sources: Years 1900-1940: National Water Commission, Water Policies for the Future, Table 1, p. 7.

Years 1950-1975: USGS, "Estimated Uses of Water in the United States," Geological Survey Circular 765, Table 3, p. 10.

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The principal use of ground water is for irrigated agriculture. Over 80 bgd of ground water was withdrawn in "1975" (Table IV-8). Based on the United States Geological Survey information shown in this table, 69 percent of ground-water withdrawals in "1975" were for irrigation. This accounts for 40 percent of all water used for irrigation.

Table IV-8.—"1975" Fresh-water withdrawals in the United States, by source
(billion gallons per day)

Uses	Withdrawals				
	Ground[a]	Surface[a]	Reclaimed sewage[a]	Total USGS[a]	Total WRC[b]
Irrigation	56.3	83.9	0.4	140.6	158.7
Public supplies	10.7	18.8		29.5	27.9[c]
Self Supplied					
Electric power	1.4	130.0		131.4[d]	88.9[d]
Other industrial	9.6	29.0		38.6	58.3[e]
Rural domestic	2.7	0.1		2.8	2.7[f]
Livestock	1.2	0.9		2.1	1.9
Total - USGS	81.9	262.7	0.4	345.0	338.4
Total - National Assessment[g]	82.3				

[a]U.S. Geological Survey (C.R. Murray & E.B. Reeves), "Estimated Use of Water in the United States in 1975," Circular 765, 1977.

[b]Column provides a rough equivalency between USGS categories for uses and national assessment categories.

[c]Commercial (5.5 bgd), Domestic central (21.2 bgd), Public lands (1.2 bgd).

[d]Difference largely due to definition for once-through cooling.

[e]Manufacturing (51.2 bgd), Minerals (7.1 bgd).

[f]Noncentral (2.1 bgd), Fish hatcheries (0.6 bgd).

[g]Ground-water withdrawals from Volume 3, Appendix II, Table II-1.

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Table IV-9.—Ground-water withdrawals and percentage of overdraft—"1975"

Water resources region and No.	Total withdrawal (mgd)	Overdraft		Subregions		
		Total (mgd)	Percent	Number in region	Number with overdraft	Range in overdraft (percent)
New England (1)	635	0	0	6	0	---
Mid-Atlantic (2)	2,661	32	1.2	6	3	1- 9
South Atlantic-Gulf (3)	5,449	339	6.2	9	8	2-13
Great Lakes (4)	1,215	27	2.2	8	1	30
Ohio (5)	1,843	0	0	7	0	---
Tennessee (6)	271	0	0	2	0	---
Upper Mississippi (7)	2,366	0	0	5	0	---
Lower Mississippi (8)	4,838	412	8.5	3	3	7-13
Souris-Red-Rainy (9)	86	0	0	1	0	---
Missouri (10)	10,407	2,557	24.6	11	10	4-36
Arkansas-White-Red (11)	8,846	5,457	61.7	7	7	2-76
Texas-Gulf (12)	7,222	5,578	77.2	5	5	24-95
Rio Grande (13)	2,335	657	28.1	5	4	22-43
Upper Colorado (14)	126	0	0	3	0	---
Lower Colorado (15)	5,008	2,415	48.2	3	3	7-53
Great Basin (16)	1,424	591	41.5	4	4	7-75
Pacific Northwest (17)	7,348	627	8.5	7	6	4-45
California (18)	19,160	2,197	11.5	7	5	7-31
Regions 1-18	81,240	20,889	25.7	99	59	1-95
Alaska (19)	44	0	0	1	0	---
Hawaii (20)	790	0	0	4	0	---
Caribbean (21)	254	13	5.1	2	1	5
Regions 1-21	82,328	20,902	25.4	106	60	1-95

Table IV-9 presents the ground-water withdrawal and overdraft by region. For example, in "1975" ground water obtained from nonrenewable sources was 77.2 percent in the Texas-Gulf Region, 28.1 percent in the Rio Grande Region, 24.6 percent in the Missouri Region, 11.5 percent in the California Region, and 8.5 percent in the Lower Mississippi Region.

In "1975" ground water provided 40 percent or more of the total fresh water withdrawn in 23 of the 106 subregions. The West, in particular, experienced significant scattered ground-water overdrafts. For example, 48 percent of the total fresh water used in California in "1975" was obtained from wells. This accounted for 23 percent of the total national ground-water withdrawal. California extracted more ground water than all of the eastern regions (1 through 8) combined.

Water Supply Conservation and Augmentation

The importance of water conservation has been demonstrated by the President's frequent messages that conservation is a cornerstone of his overall water policy. Past Federal involvement in water resources management has generally supported an increase in supplies rather than a reduc-

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tion in demands through water conservation. Some State and local governments, however, have already made significant advances in developing innovative water conservation programs. The tools of conservation are the elements of management and technology that can balance water requirements with resource availability.

The construction of dams and reservoirs, management of upstream watersheds, and the transfer of water between regions have been regarded as traditional conservation practices. Conservation in this sense means to save water for later use. These technologies seek to reduce the seasonal variability of water supplies within a particular area either by retaining available runoff and streamflow for dry periods or by moving water from water-rich to water-poor regions. Water storage and transfer will continue to be an integral part of a conservation strategy. However, in recent years, increasing requirements for water within the region of origin often dictate against further transfers to other regions. In some regions, a lack of storage sites coupled with escalating costs for storage and distribution facilities often suggest other approaches.

An alternative to supply augmentation is the improvement in use of existing supplies. Modifications in reservoir operation to meet the changing priorities for water use may partially offset the need for new supplies. Water reclamation and reuse is another opportunity to improve use of existing supplies. As of 1975, reuse of water in irrigated agriculture and manufacturing has increased considerably, but the increase could be greater if acceptable practices were developed to use treated water from waste treatment plants for irrigated agriculture.

Perhaps the greatest management possibility lies in enhanced ground-water use. If used properly and if developed and managed in conjunction with surface-water use, ground water is a much greater potential natural resource.

Past patterns of economic growth and associated ground-water development have taxed the natural distribution of ground water. This frequently creates an imbalance within and between hydrologic basins. Ground-water overdraft has led to falling ground-water levels, increased pumpage and treatment costs, land subsidence, surface fissures, and salt-water intrusion into fresh-water aquifers. Wise use of the renewable ground-water resource can enhance the potential supply of existing water.

Technological Means

Desalination

Water requirement projections for the second assessment are similar in magnitude to those for the first assessment. However, projections for withdrawals to meet requirements have been greatly reduced because more intensive water management practices are expected, including desalination or desalting of water that would otherwise be of unacceptable quality.

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From 1955 to 1975 the number of desalination plants in the United States increased from 12 producing a total of less than 2 mgd, to 336 plants producing about 100 mgd. While this is only about one-tenth of 1 percent of the total withdrawals of fresh water for urban and industrial use, it indicates that desalination is increasing. Most of these desalting plants provide water for industrial purposes; however, about 33 percent provide municipal supplies. As of 1975, the largest number of desalination plants were located in California, Texas, and Florida. Some plants are also located in the industrialized Northeast and arid Southwest. About 61 percent of the installed capacity is east of the Mississippi River.

Location of future plants will depend upon specific local requirements and the availability and quality of supplies (including brackish and saline waters) and the comparative costs of desalination versus alternative solutions. The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) also have influenced the need for treatment of water, including desalination, in order to eliminate discharge of pollutants.

Since many major cities are located in the coastal zone areas, water from the Atlantic and Pacific Oceans and the Gulf of Mexico could supply many of the Nation's cities or industries if technology can make desalination less expensive and more energy efficient. The availability of brackish surface waters in many coastal areas and in much of the interior where new supplies are needed provides another possibility for reclaimed water.

In many parts of the Nation, available ground water with concentrations of dissolved minerals exceeds the limit of 500 parts per million (ppm) for total dissolved solids that was established for drinking water by the U.S. Public Health Service Standards of 1962. On December 24, 1975, the initial Interim Primary Drinking Water Regulations of the U.S. Environmental Protection Agency superseded the above standard. Although it is not an enforceable requirement, the 1975 regulations, which set a 250 ppm limit, is a desirable goal.

The April 1975 Westwide Study Report of the Deparment of Interior identifies the increasing salinity of the major western river systems as a serious problem. This salinity is reducing the amount of water of acceptable quality for use by small western communities. The report states that at least one-fourth of the 6,500 nonmetropolitan communities in the 11 western States have water in short supply, of poor quality, or both. It further states that 340,000 people in this area are supplied water containing dissolved solids in excess of 1,000 ppm.

A 1973 study by the Engineering Environment Station of the University of North Dakota found that 43 North Dakota communities with a population of 500 or more had supplies containing total dissolved solids greater than 1,000 ppm and/or hardness, chloride, sulfate, or sodium greater than 400 ppm. A similar study by the South Dakota Department of Health revealed that 150 communities in that State have water supplies containing more than 1,000 ppm of total dissolved solids. During 1971 to 1974, similar reports were prepared by the U.S. Office of Saline Water for Arizona, California, Colorado, Kansas, Nevada, and Illinois.

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Major efforts to desalt brackish water include the recently completed Water Factory 21 of the California Orange County Water Agency and the proposed Yuma Plant of the U.S. Bureau of Reclamation. Water Factory 21 consists of a 5 mgd reverse osmosis plant operated in conjunction with an advanced treatment plant to provide 15 mgd of water for ground-water recharge to prevent sea-water intrusion. It is the largest desalination plant in the United States. The Yuma Plant is planned to desalt annually about 100,000 acre-feet of drainage water from about 3,200 ppm down to about 250 ppm by use of the reverse osmosis process. This is enough water to irrigate over 30,000 acres of row cropland or to provide domestic water to over 100,000 homes.

The reclaimed water will be mixed with Colorado River water to provide 1.5 million acre-feet of water annually to Mexico under provisions of Minute 242 of the International Boundary and Water Commission. Water must be delivered to Mexico at Morales Dam with a dissolved solids concentration that does not vary more than 115 ppm, $\pm$30 ppm, from that available to the United States at Imperial Dam. The Yuma plant will be by far the largest desalination plant in the United States. It will compare in size with several Saudia Arabia plants that utilize the electrodialysis process.

Because desalination operations are still expensive, users install these operations only if less costly sources of water are not available. The need for water of improved quality has stimulated intensive research to improve techniques for desalting brackish and saline water. Five desalting processes currently show the most promise. They are reverse osmosis, electrodialysis, ion exchange, distillation, and freezing. All of these are energy intensive, so a significant breakthrough in reducing the cost of energy, for example from efficient solar installations, would have an extremely favorable effect on the desalination processes.

Weather Modification

Efforts to induce or modify precipitation by seeding clouds with silver iodide, frozen carbon dioxide, and other nuclei have been the subject of considerable applied research and development activities over the past three decades. Considerable progress has been made in understanding how precipitation forms and the relative effectiveness of the various seeding nuclei and application techniques. As a result, many of the arid States have developed legislation in anticipation of increased weather modification activity. Figure IV-8 shows States with weather modification legislation.

In general, seeding of winter storms in the western United States over the past 25 years has increased total precipitation from 5 to 25 percent. Cloud seeding is considered to be effective in increasing snowpack on the western slopes of the western mountain ranges, thereby adding to the amount of streamflow and snowmelt water in downstream storage reservoirs.

The seeding of summer cumulus clouds to produce additional rainfall is considerably more complex. Many experiments have been made on single cumulus clouds; some showed great promise while others did not. The reason

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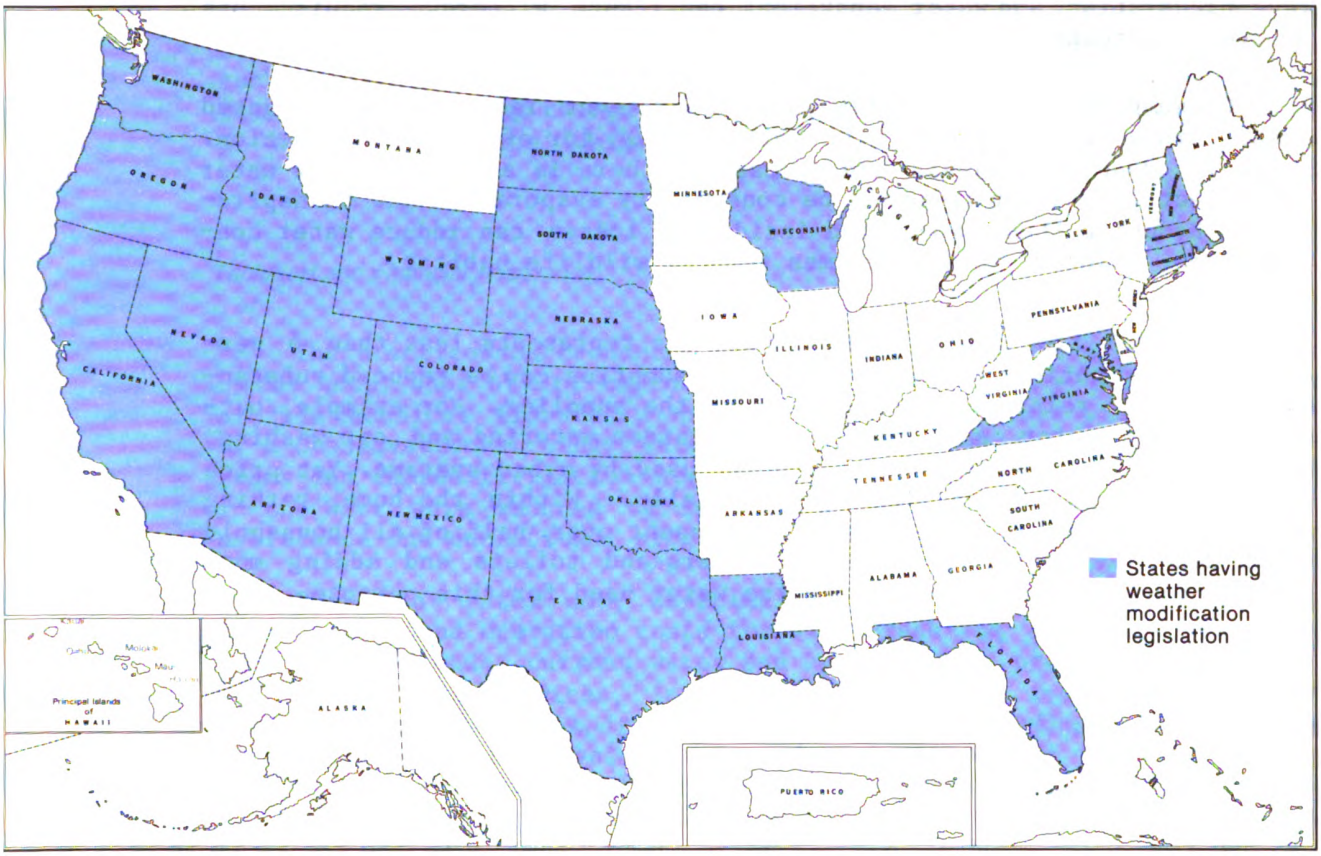

Figure IV-8: States with weather modification laws

why some seedings actually decrease expected rainfall by 100 percent is not understood. However, some recent seedings of multicloud formations have yielded positive results. For example, projects in the Dakotas have increased the total seasonal rainfall by about 10 to 20 percent. For Florida the best rough estimate of the magnitude of the mean seeding effect is from a plus 18 percent to a minus 6 percent. Whether results obtained from these areas can be transferred to other parts of the country is not known.

End-use Technology

Irrigation is the prime candidate for water-saving techniques because it uses large quantities of water and is concentrated in relatively water-short western states. Irrigation accounts for 46 percent of total national withdrawals and 83 percent of consumption of fresh water. Several reports have indicated that the potential reduction in withdrawals for irrigation is around 20 to 30 percent.

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Improved delivery systems are the principal means available for reducing irrigation withdrawals. Lining or converting ditches to pipelines, automated weirs and gates, and computerized scheduling of deliveries are examples. Improved onfarm systems (e.g., trickle, drip, or sprinkle), land preparation, and water management can reduce withdrawal requirements by over 10 percent.

Consumption is not readily decreased without reducing the irrigated area. Crops need a nearly full water supply for efficient production. However, when withdrawals are excessive, there is a tendency for water to collect in noncrop areas and be consumed by evaporation and transpiration. Reducing these so-called incidental losses can reduce water consumption. However, this sometimes reduces wildlife habitat.

Water use from central domestic systems represents less than 6 percent of total national water use. Yet consumption can be reduced substantially and at relatively little cost to the supplier. For example, outside uses of water, such as lawn and garden watering and car washing, account for over one-third of all water used by urban systems. Yet price sanctions do not reduce these substantially. Within the home, bathing and toilet flushing, for instance, represent over half of all household water use. Retrofitting existing showers and toilets and adding more efficient new fixtures can reduce the water used for this purpose.

Institutional Means

Pricing and Charges

When water is delivered by a public authority, charges can sometimes deter the inefficient use of water. Numerous studies demonstrate that price can influence levels of use. Although agricultural water users are generally sensitive to water price, this will vary, at least in part, according to the selling price of the crop.

The following are criteria for promoting efficient water use:

1. The price of the water should be paid by the user as a direct cost

2. The price for water from existing facilities should produce, as a minimum, enough revenue to cover operation and maintenance costs of the service

3. The price for water made available by expansion of existing facilities should provide enough revenue to cover costs of the expanded service

4. The price should reflect the value in alternative uses prevented by the user's consumption.

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Water Transfers

Because some water is self-supplied, charges cannot be universally applied as a mechanism to encourage efficient use. One mechanism to encourage water use efficiency is the sale of excess water where State water laws do not preclude such sales. Uncertainty about water rights makes such transactions difficult. The States in some water-short areas of the West are considering changes in law to promote water transfers through a "water market" or a "water bank."

Technical and Financial Assistance

The practices and technologies to reduce water use often are not known by the water user or are expensive to implement. It may be necessary to provide technical, financial, and educational assistance programs as part of a conservation strategy. Recent efforts in the West show that such programs can reduce irrigation water use. During the 1977 drought, urban uses in the West were reduced by as much as 40 percent through technical assistance and educational programs, and rationing in some cases.

The major water use, especially in dry areas, is for irrigation. Installation and operation costs for water-reducing equipment are often not justified under current water and agricultural price relationships. With rising water prices, improved management may reduce agricultural water use. Unfortunately, in many instances further savings can only come either by reducing the level of irrigated agriculture or by using technology that is not cost-justified for the individual farmer. Financial assistance for these technologies can, of course, help to justify their adoption.

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Water Use

National

In "1975," total ground and surface fresh-water withdrawals for the Nation were approximately 338 billion gallons per day (bgd). Of this amount, 107 bgd were consumed through evapotranspiration or were incorporated into products. The remainder was returned to surface water for possible reuse downstream. By 2000 total fresh-water withdrawals are projected to be about 306 bgd, with about 135 bgd consumed. This is a 9 percent reduction in withdrawals but a 26 percent increase in consumption. Increased emphasis in reuse is the principal reason for the expected decline in water withdrawals by 2000.

The most significant contribution to this reduction in offstream use will be made in the manufacturing sector where fresh-water withdrawals are projected to decline from 51.2 bgd to 19.7 bgd, or 62 percent. Although the quantity of withdrawals for irrigation and steam electric generation will decrease slightly between "1975" and 2000, the percentage of total withdrawals for these two uses will remain essentially unchanged, at about one-half for irrigation and one-fourth for steam electric generation. All other offstream uses will increase both in amount and percentage in their share of the Nation's total withdrawals.

Consumption of water in some respects is more critical than the total quantity withdrawn because consumed water is not available for downstream uses or for ground-water recharge. Consumption is not proportionate to withdrawals among the functional use categories. Offstream consumption was 107 bgd in "1975" and is projected to increase by 26 percent to 135 bgd by the year 2000. Agriculture (irrigation and livestock watering) has the highest consumptive use of water. Agriculture was responsible for 83 percent of the total water consumed in "1975"; this percentage will decrease to about 70 percent in 2000 because of higher consumption expected in steam electric generation and manufacturing. Table IV-10 and Figure IV-9a and b show the withdrawals and consumption by functional use for the 21 water resources regions for "1975," 1985, and 2000.

Regional

During the "1975" to 2000 period, most of the conterminous United States is projected to decrease total water withdrawals, with the greatest decreases projected for the Ohio and Great Lakes Regions. These regions have high concentrations of manufacturing and electric power generation plants. Both fresh-water withdrawal and fresh-water consumption should taper off and possibly decrease in much of the Southwest due to declining ground-water and surface-water supplies. However, the Texas-Gulf Region is expected to increase saline-water withdrawals significantly.

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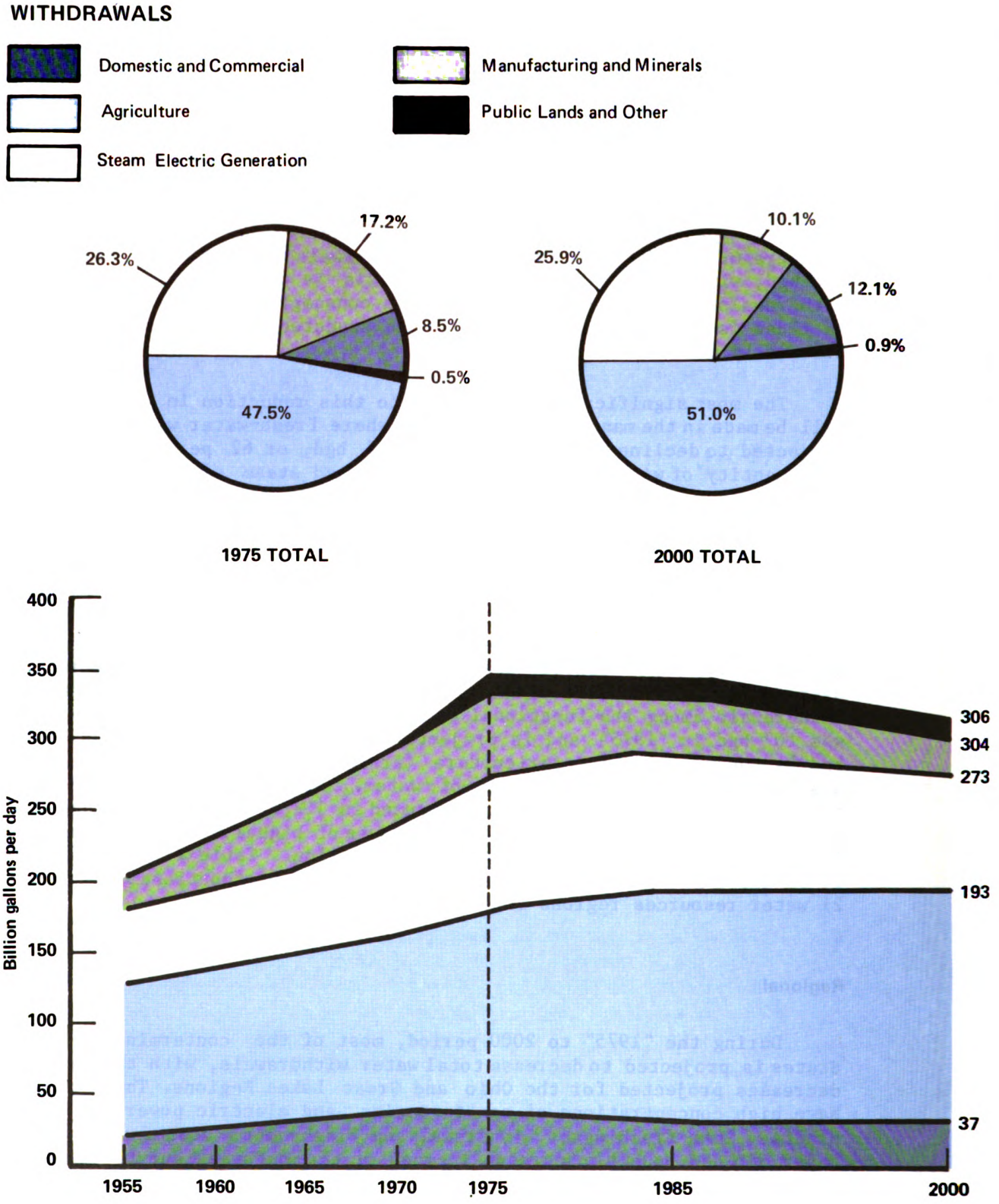

Figure IV-9a: Total fresh-water withdrawals by functional use

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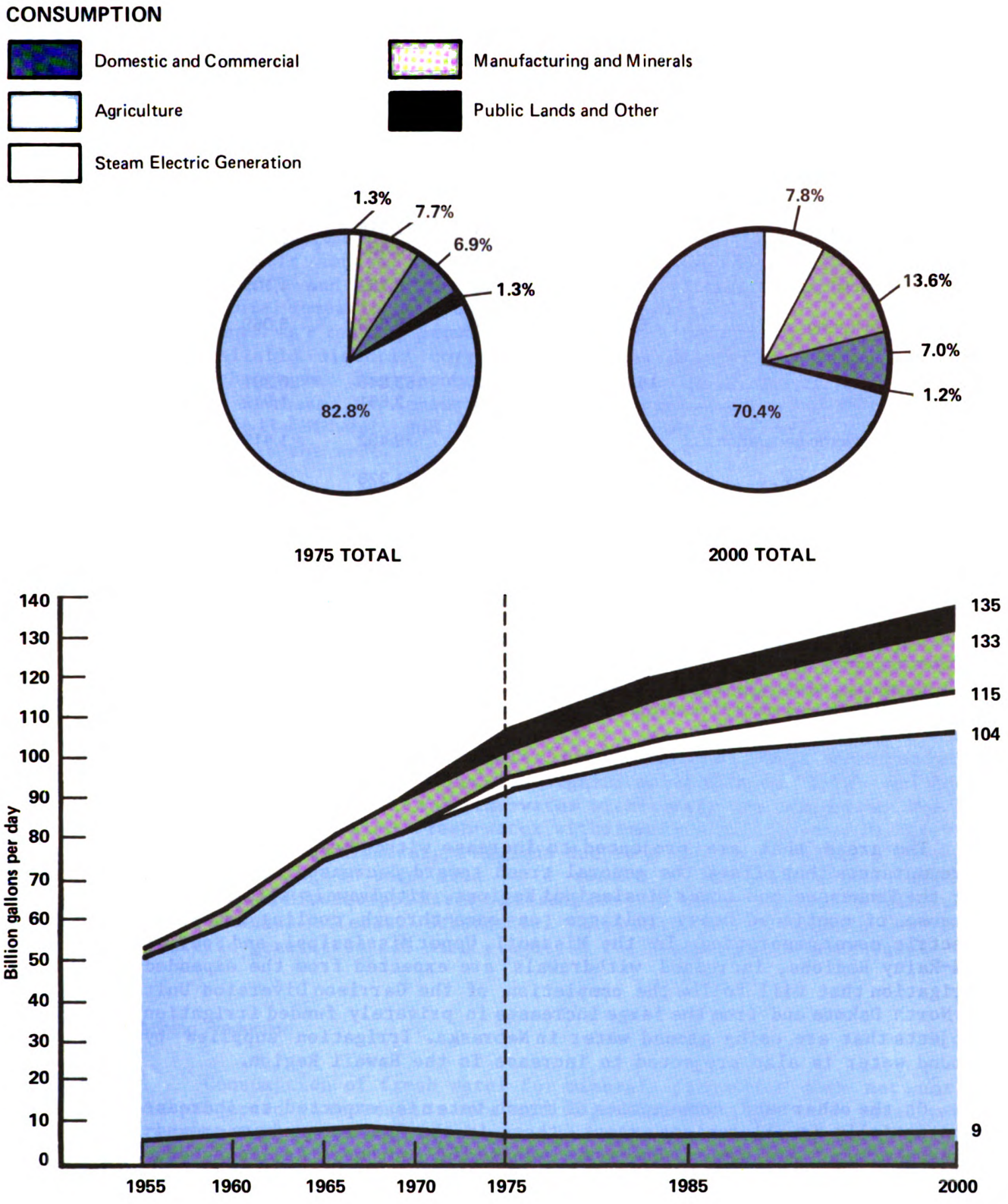

Figure IV-9b: Total fresh-water consumption by functional use

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Table IV-10.—Total withdrawals and consumption, by functional use, for the 21 regions—"1975," 1985, 2000
(million gallons per day)

Functional use	Total withdrawals			Total consumption		
	"1975"	1985	2000	"1975"	1985	2000
Fresh water:						
Domestic:						
Central (municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Noncentral (rural)	2,092	2,320	2,400	1,292	1,408	1,436
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,222	23,687	19,669	6,059	8,903	14,699
Agriculture:						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam electric generation	88,916	94,858	79,492	1,419	4,062	10,541
Minerals industry	7,055	8,832	11,328	2,196	2,777	3,609
Public lands and others[1]	1,866	2,162	2,461	1,236	1,461	1,731
Total fresh water	338,500	330,375	306,397	106,590	120,545	135,080
Saline water,[2] total	59,737	91,236	118,815			
Total withdrawals	398,237	421,611	425,212			

[1] Includes water for fish hatcheries and miscellaneous uses.
[2] Saline water is used mainly in manufacturing and steam electric generation.

The areas that are projected to increase withdrawals have special circumstances that offset the general trend toward decreased withdrawals. For the Tennessee and Lower Mississippi Regions, withdrawals will increase because of continued heavy reliance on once-through cooling for steam electric power generation. In the Missouri, Upper Mississippi, and Souris-Red-Rainy Regions, increased withdrawals are expected from the expanded irrigation that will follow the completion of the Garrison Diversion Unit in North Dakota and from the large increases in privately funded irrigation projects that are using ground water in Nebraska. Irrigation supplied by ground water is also projected to increase in the Hawaii Region.

On the other hand, consumption of fresh water is expected to increase substantially in all regions except those in the Southwest where ground-water shortages are severe. However, even in the Southwest declining consumption by irrigated agriculture will be partially offset by increases in nonagricultural consumption. Total consumption is projected to increase in the Ohio, Tennessee, Upper Mississippi, and Souris-Red-Rainy Regions.

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Although these regions should not have the greatest absolute growth in population and economic activity, their economic activity is projected to have the highest percentage increases.

Domestic

In projecting fresh-water use, it was assumed that the per capita use from domestic central water systems would remain virtually unchanged through 2000 and that there would be only a modest increase in the per capita rural domestic water use. Regional analysis confirmed this assumption for demand. As a result, growth in water use in areas where central systems are available directly corresponds to the population increase and the rural changeover from noncentral to central water supply systems. The largest increases in domestic water use are expected along the Atlantic Coast, in the Midwest, and in the Southwest where population is projected to increase the most.

Manufacturing and Steam Electric Power Generation

Fresh-water withdrawals for manufacturing and steam electric power generation are expected to decline 33 percent by 2000. However, the extent of the decline varies from region to region depending upon the amount of total saline water now being used, plus the types of industries located in each region, their assumed growth rates, and their projected increases in recycling.

Although national fresh-water withdrawals for steam electric power generation are expected to decline significantly between "1975" and 2000, substantial increases in saline-water withdrawals are projected for the coastal regions. Also, fresh-water withdrawals will increase in the Tennessee and Lower Mississippi Regions due to a continued reliance on once-through cooling in this area as a result of the exceptional ability of the Lower Mississippi River to dissipate heat waste without significant environmental effects. Substantial increases in withdrawals for steam electric generation are also projected for Texas and the Southwest.

Mining Production

Consumption of fresh water for minerals production does not nor is it projected to represent a substantial portion of any region's total water consumption, even though consumption is expected to increase about 64 percent. Consumption increases in mining should come primarily from projected increases in coal production and oil shale conversion. Increases in water consumption in areas where mining is unrelated to fuels production can be attributed to increased industrial demand for nonmetallic minerals.

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Irrigation

By 2000, fresh-water withdrawals for irrigation will decrease in areas where water shortages now exist. For example, in the High Plains areas of Texas, Oklahoma, and New Mexico, irrigation is projected to decline because of depleted ground-water supplies and competition from other water-using sectors. Use of irrigation water, however, will increase significantly in the central United States and in the Pacific Northwest where water is available to support additional irrigated acreages. In addition, the South Atlantic-Gulf Region has had a substantial growth in irrigation water development and use.

Instream Flow Use

Instream flow uses, often referred to as instream flow need, is that amount of water flowing through a natural stream channel needed to sustain the instream values at an acceptable level. Values of instream flows relate to uses made of water in the stream channel. These uses include fish and wildlife population maintenance, outdoor recreation activities, navigation, hydroelectric generation, waste assimilation (sometimes termed water quality), conveyance to downstream points of diversion, and ecosystem maintenance, which includes fresh-water recruitment to estuaries, riparian vegetation, and flood-plain wetlands. Streamflow sufficient to maintain all these uses establishes the acceptable level for the instream flow uses. Understandably, at a given location in a given stream system, only certain uses may be applicable. The actual instream flow needs are based on the dominant instream flow uses, or alternatively, on the resulting best mix after tradeoffs with the instream users have been made.

The second assessment has quantified minimum streamflow levels for fish and wildlife population maintenance and for navigation. In all subregions, the fish and wildlife use is the dominant instream flow use. Figure IV-10 illustrates how the flow requirement for each use fluctuates seasonally but that one use dominates at any given time. Many instream values are supported by the instream flow requirement. It is also possible that conflicts between instream uses may necessitate tradeoffs in arriving at the needed instream flow regimen.

Fish, Wildlife, and Ecosystem Maintenance

The U.S. Fish and Wildlife Service was assigned to develop a set of values that represents current and projected instream flow needs. Developing such values proved to be very difficult for the following reasons:

(1) A widely accepted methodology for quantifying instream flow requirements was not available at the time the assessment was initiated.

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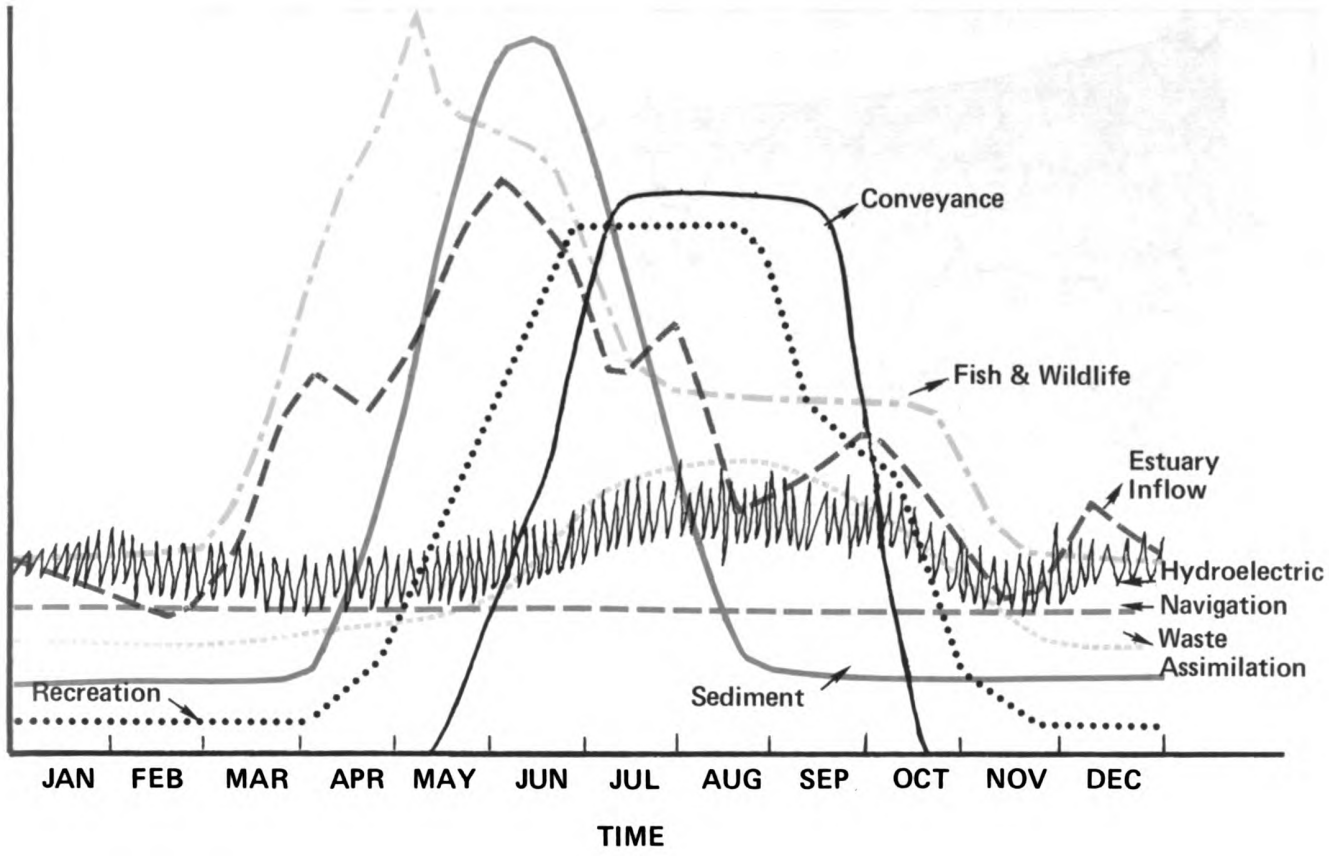

Figure IV-10: Streamflow fluctuations and dominant uses

(2) Most biological background studies are insufficiently detailed on the instream flow requirements of various species of fish. For much of the Nation there are almost no satisfactory biological data with which to correlate hydrologic data.

(3) Use of the outflow point(s) to measure instream flow requirements for an entire river basin can at best only show conditions in the stream reach near the outflow point. Such analysis does not necessarily indicate reliably the situation at other points within the subregions.

Because of this difficulty in quantifying instream flow needs, the values developed can only be considered approximations.

Instream flow approximations (IFA) are defined as estimated flows at the outflow point(s) that are sufficient to support the habitat of aquatic life and outdoor recreation. The IFA values consist of an annual and twelve monthly estimates for the outflows of each of the 106 subregions. See Figure IV-11.

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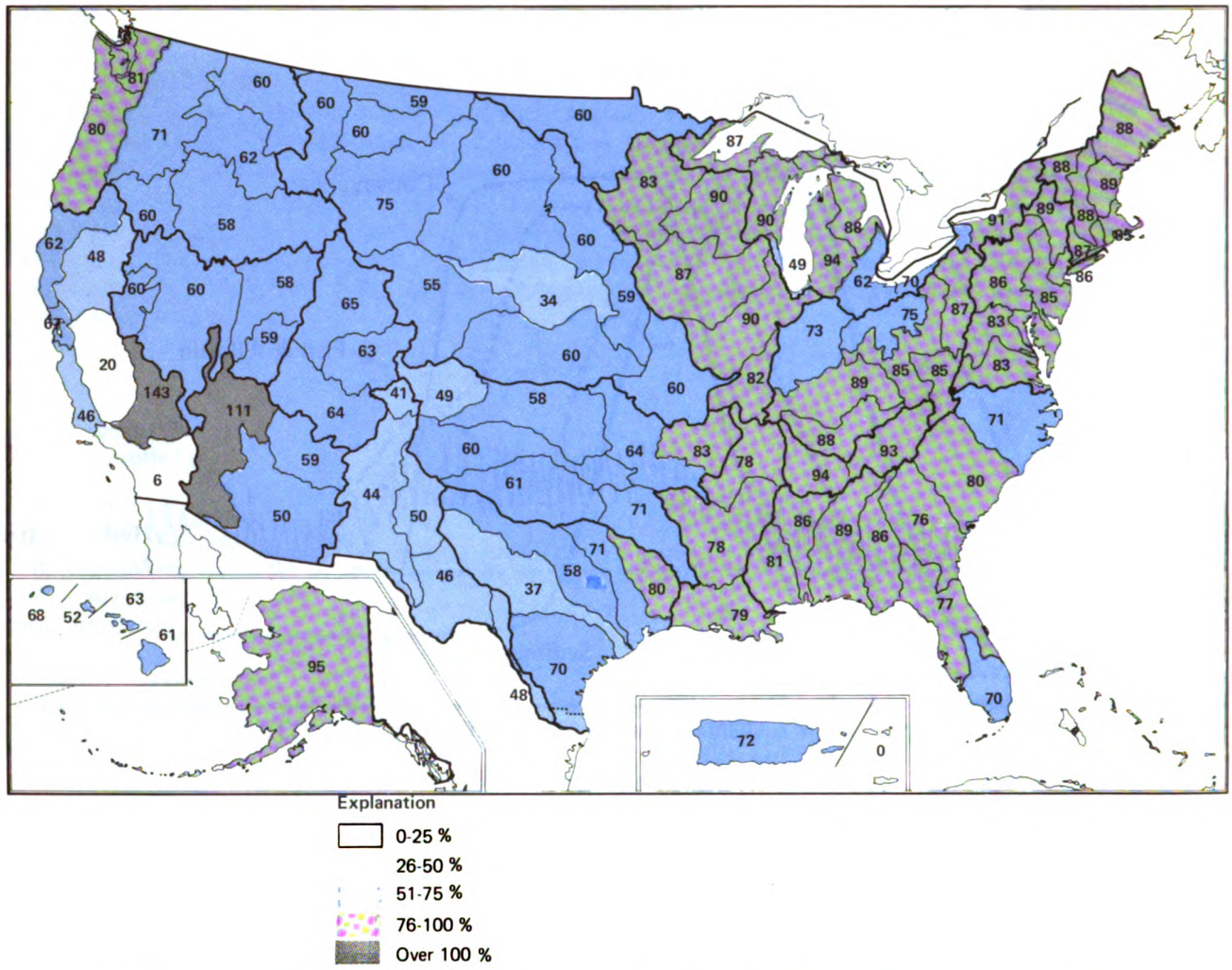

Figure IV-11: Instream flow approximations for fish and wildlife, as percentage of total streamflow

Navigation

Since the flows required for navigation are less than the flows needed to maintain water quality and to support other purposes, the streamflow requirements to support navigation were provided for only selected sub-regions. Among other factors, the instream flow required for navigation

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depends on the degree of channelization, the depth maintained, the number of locks, and how much lockage water is pumped back to upper pools. Because increasingly large flows will be required to maintain suitable water quality and to supply industrial needs in most regions, use of water for navigation should not generally compete seriously with other uses.

Compacts and Treaties

Required streamflows were estimated for those subregions where a compact or treaty affects the flows discharged from the subregions. These flows are included in Volume 3, Table II-3. Except for the Lower Colorado Region, streamflow quantity to meet the terms of the treaties and compacts does not appear to be a problem.

Congress has approved 42 interstate compacts and international treaties; others are still in negotiation. A principal purpose of most of these is to allocate water among political subdivisions for existing or potential uses downstream. The last section of this volume discusses treaties and compacts in more detail.

Hydroelectric Power Generation

Conventional hydroelectric powerplants can produce power without consuming fuel and without polluting water or air. These plants have lower maintenance and operating costs and low outage rates compared to steam electric generating plants. Hydroelectric powerplants are often used only to meet the peak of daily load curve; in the Northwest they are a major contributor of baseload power.

The lack of economical and environmentally compatible impoundment sites has limited the potential for increases in conventional hydropower development. Only four regions are projected to significantly increase the present turbine flows by 2000: the Ohio, Upper Colorado, Pacific Northwest, and Alaska Regions. Studies are now underway to measure the potential for low-head hydroelectric sources and retrofitting of existing dams which, even prior to the recent dramatic increased costs of alternative energy, were economically impractical. Hydropower operations can be compatible with other instream flow needs. However, sudden releases of water during peakload generation can be damaging to other instream uses.

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Analysis of Water Supply and Use

The availability of water for current and future demands was the primary interest of the second assessment. Of particular concern was the identification of areas with water deficiencies. This section describes the water resources analysis model that is the basis for quantifying existing and future ground- and surface-water depletion conditions for both offstream and instream use. The section also provides graphic and tabular examples of water requirements and supply comparisons and discusses some of the Nation's current and emerging water supply problems and related conflicts.

Water Adequacy Analysis Model

Description of the Model

The analysis of the water data in the second assessment includes current information for "1975" and projected estimates for 1985 and 2000. The model, depicted in Figure IV-12, is based on a concept of balance between requirements and availability of water, including the availability of ground water. To compare all related parameters in the model, each subregion is analyzed as if all consumption, evaporation, and water transfers occur at the outflow point (or points) of the subregion. This simplifying assumption implies that streamflow at the outflow point can be made available to the entire subregion, usually by use of the water from the stream network before it actually reaches the outflow point.

The adequacy analysis is based on the streamflows as calculated at the outflow point in each of the 106 subregions. A subregion may have one or more outflow points where water supply data are determined. Linked subregions will have inflow from upstream subregions and possibly imports. Exports, consumption, and evaporation may reduce instream flow. When these reductions are subtracted from the potential supply, the remaining flow equals the outflow. Ground-water movements beneath the gage recording the outflow may cause another loss. The ground-water recharge accounted for in the model is not considered a loss.

For the period of analysis, "1975" to 2000, precipitation contributing to streamflow supplies (runoff) is assumed constant, whereas actual runoff varies somewhat due to changing land use patterns and increased urbanization. Water imports and exports and reservoirs evaporation are held fixed at "1975" quantities except for changes expected from currently authorized and funded projects.

Most ground-water withdrawals are replenished in a short time by precipitation or runoff recharging the underground aquifers. Under this ordinary use, the ground-water aquifer is like a reservoir that fluctuates with time but is considered a stable source of water.

Ground-water overdraft, the long-term withdrawal of ground water faster than it can be replenished, cannot be handled so easily. With groundwater overdraft, the supply is like an initially full large reservoir that is slowly and continuously drawn down faster than it is replenished.

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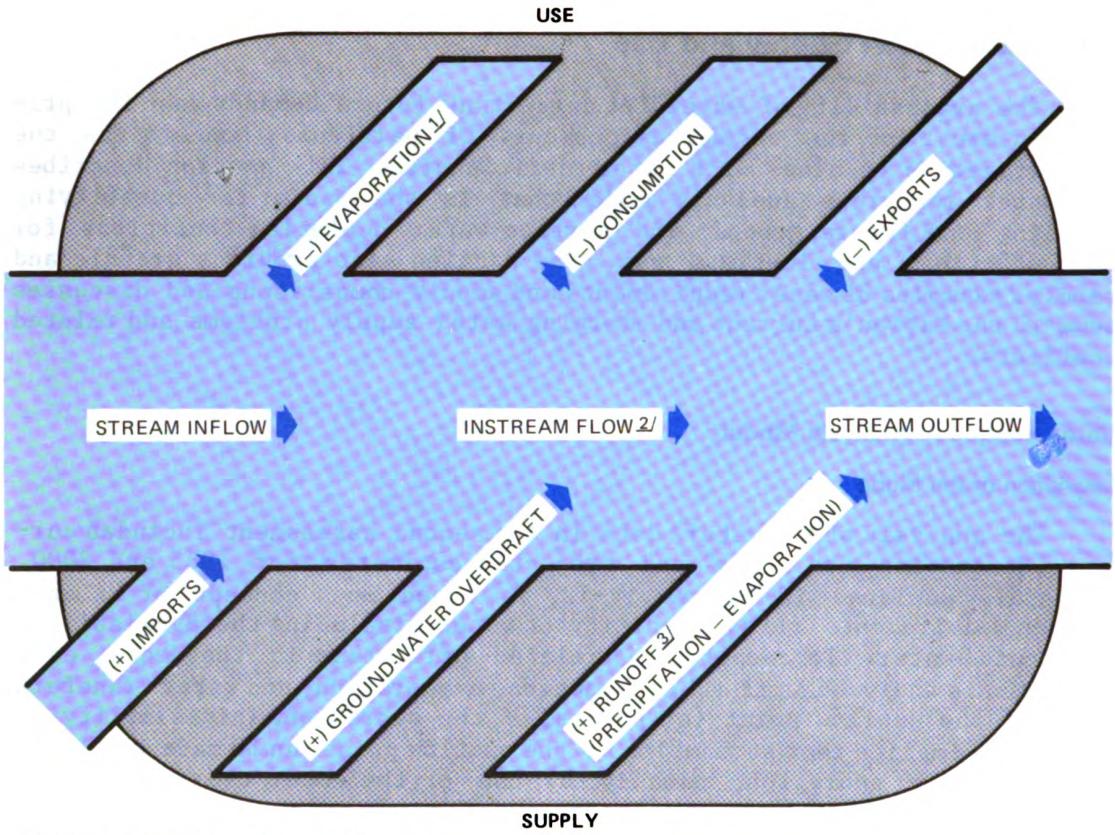

1/ Includes only evaporation from manmade reservoirs.

2/ Includes flow requirements for navigation, hydroelectric, conveyance to meet downstream treaty and compact commitments, fish and wildlife habitat maintenance, waste assimilation, recreation, sediment transport and fresh-water inflow to estuaries.

3/ Includes precipitation minus natural evaporation from the land surfaces and plant transpiration, and drainage to ground water.

Figure IV-12: Water-supply adequacy analysis model

Eventually the reservoir will run dry. For the second assessment, the use of streamflow as a measure of long-term fresh-water supply requires that the contributions to the water balance from ground-water overdraft be eliminated when discussing long-term supply. Therefore, the streamflows in the model (except for current streamflow) deduct the ground-water overdraft from available streamflow supplies. The implicit assumption is that uses currently supplied by ground-water overdraft will instead be supplied directly from streamflow supplies. This may exaggerate problems in certain areas where decreasing ground-water overdraft is expected to reduce both withdrawals and consumption. Consistent data, however, were not available to reflect these reductions.

The water adequacy analysis is used to determine whether river systems can meet current and future requirements of both offstream and instream uses without recourse to ground-water overdraft. The analysis brings into perspective the conflicting requirements of offstream and instream uses. For example, the ratio of total use to total streamflow delineates the intensity of conflict between instream and offstream needs. The assessed streamflow depletion ratios show how the intensity of offstream consumption, if continued, will affect the future supply. The depletion of natural outflow shows how man has already affected the stream network.

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As presented earlier, offstream water requirements (withdrawals and consumption) were developed by Federal agencies for each subregion for the years "1975," 1985, and 2000. Consumptive requirements for these functional uses and the instream flow approximations represent a total use that can be compared directly to the total available streamflow. The comparison shows either an available surplus or a conflict between offstream requirements and instream flows. These instream flow comparisons indicate the pervasiveness of current and future supply conflicts between instream and offstream uses.

Since the comparisons are made at the outflow points of the subregions, the instream flow comparisons discussed here do not necessarily represent the specific conditions within the subregions. Instead, the comparisons indicate what the streamflow conditions would be at the outflow point, given the collective changes in consumptive use and export/import conditions in all upstream subregions. Figure IV-13 shows the downstream routing of outflows for the Nation.

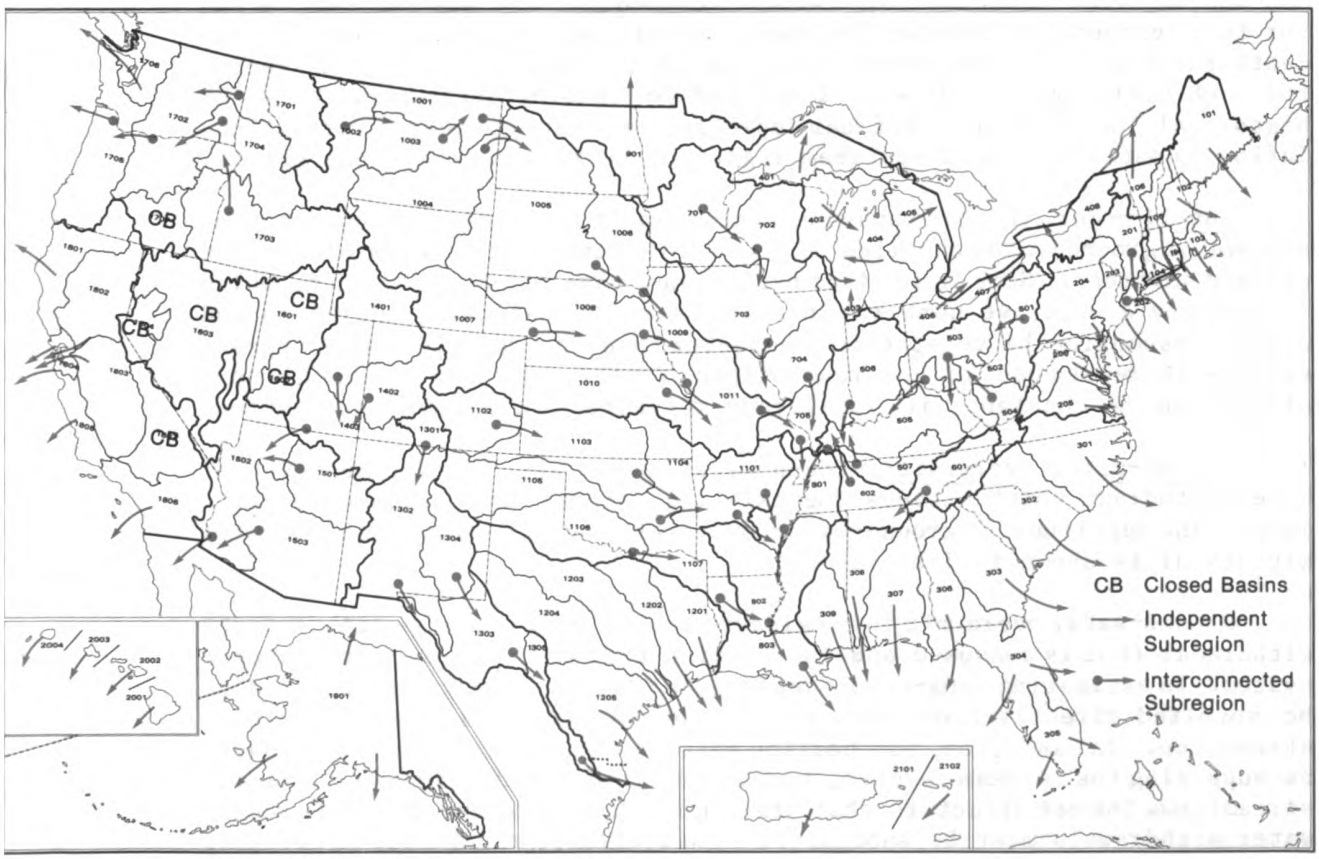

Figure IV-13: Subregional flow patterns

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Streamflow conditions at the outflow point of single-river subregions such as 802 (Lower Mississippi River) represent the effects of the collective changes upstream, i.e., in the Arkansas-White-Red, Missouri, Upper Mississippi, Ohio, Tennessee, and Lower Mississippi Regions. In the coastal areas, several rivers discharge from a subregion into the ocean. In these cases, the comparisons are not for a discrete outflow point; rather, they represent an estimate of the overall effect of collective changes for a group of rivers independently entering the ocean. In the closed basins of Nevada, Utah, Oregon, and California, the comparisons represent what is collectively happening within the one or more watersheds comprising that subregion upstream from the terminal lakes. The Great Lakes are treated as if they were an ocean with only the United States portion of their watershed included. In the lower Rio Grande and Souris-Red-Rainy Rivers, only the United States portion of the watershed is included. However, in the Columbia River system, the Canadian contribution is reflected in the surface-water supply data.

Components of the Model

Stream Inflow and Outflow--Over 300 streamflow gaging stations were analyzed to estimate annual and monthly amounts of streamflow. The annual and monthly streamflow estimates were developed for the mean streamflow and for four exceedance levels--5 percent, 50 percent, 80 percent, and 95 percent. Further, a linear trend analysis of the entire period of record for each hydrologic unit was developed to examine the extent to which historical increases in offstream depletions may have decreased streamflow. Inflow is outflow from an upstream region or subregion, where one exists.

Runoff--For the second assessment, runoff is precipitation reaching streams or ground-water supplies minus natural evaporation from plants and wetland surfaces. Some arid river basins may have a deficit runoff, which is shown by a negative number. In that case the natural evaporation and water consumption by vegetation is greater than the rainfall, which necessitates increased use of upstream-origin runoff. Because runoff is considered to be constant, it is already reflected in current streamflow.

Ground-water Overdraft--Ground-water overdraft is that quantity of water withdrawn which exceeds the existing natural and manmade recharge rates. The magnitude of ground-water overdraft and its comparison to total withdrawal is shown in Table IV-9.

Ground-water overdraft is considered in two parts--the portion of the withdrawal that is consumed and the portion that is returned to the stream system. In estimating long-term supply, the portion consumed is assumed to be supplied directly from streamflow, thereby decreasing the resultant streamflow. In addition, the portion that is not consumed will no longer be supplying the stream system, causing a further reduction in available streamflow. The net effect is that the entire amount of overdrafted ground-water withdrawals must be subtracted from available streamflow to properly estimate long-term supply.

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Imports and Exports--Estimates of average annual and monthly net water exports equal gross exports minus gross imports. These exports and imports directly affect available streamflow. For computing depletions, however, when the difference is negative, a value of zero is assumed to avoid negative total depletions. The locations of exports and imports are shown in Figure IV-6.

Evaporation--The measurement of net evaporation losses from manmade reservoirs is limited to those with a capacity greater than 5,000 acre-feet (as of 1966) and to farm stock ponds averaging about one acre in size. In the East where net evaporation losses were negative, that is, precipitation is greater than gross evaporation, the values were set to zero. Intermediate-size reservoirs were not included because information was lacking.

Consumption--Amounts of water consumption were developed for nine functional use categories on an annual and monthly basis for both average and dry year (80 percent exceedance) rainfall conditions. The categories are:

1. Agriculture
2. Steam electric power generation
3. Manufacturing
4. Domestic
5. Commercial
6. Minerals
7. Public lands
8. Federal fish hatcheries
9. Miscellaneous

Instream Flow Requirements--Instream flow uses are those uses that do not withdraw water from the stream, but rather depend on either an adequate amount of streamflow or depth of water passing through a river reach. Estimates of flow requirements for only three instream uses were developed for this assessment. These are fish and wildlife, navigation, and downstream conveyance requirements for treaties and compacts. Instream requirements are not additive. Flows for one instream use can simultaneously support other instream uses. Thus, the largest instream flow requirement is the dominant or controlling need. In all subregions, fish and wildlife habitat maintenance is the controlling need.

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The water adequacy analysis gives the assessed outflow under existing and projected conditions of consumption. The resultant outflows are compared with the instream flow needs to determine if sufficient flow is available to meet fish and wildlife needs.

Effects of Offstream Use on Instream Flows

The streamflow depletion analysis provides comparative information from which an assessment of instream flow conditions can be made. Results of this analysis indicate the degree to which streams are currently depleted and how much further they will be depleted. The analysis includes how the current and future levels of consumption and import/export conditions affect the instream flow conditions.

To evaluate how changes to instream flow conditions (as indicated by offstream depletion ratios) change the fluvial ecosystems, some criteria for describing the severity of impact are needed.

Tennant has described the instream flow condition at 60, 30, and 10 percent of mean annual flows: (Tennant, Donald L.: Instream Flow Needs, Volume II, American Fisheries Society, Bethesda, Maryland, 1976, pp. 367-369; underscore added for emphasis).

> "Sixty percent (60%) of the average flow [40 percent depletion]...: This is a base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. Channel widths, depths, and velocities will provide excellent aquatic habitat... Most of the normal channel substrate will be covered with water, including many shallow riffle and shoal areas. Side channels that normally carry water will have aquatic flows. Few gravel bars will be exposed, and the majority of islands will serve as wildlife nesting, denning, nursery, and refuge habitat. The majority of streambanks will provide cover for fish and safe denning areas for wildlife. Most pools, runs, and riffles will be adequately covered with water and provide excellent feeding and nursery habitat for fishes. Riparian vegetation will have plenty of water. Fish migration is no problem in any riffle areas. Water temperatures are not expected to become limiting in any reach of the stream. Invertebrate life forms should be varied and abundant. Water quality and quantity should be excellent for fishing and floating canoes, rafts, and larger boats, and general recreation. Stream esthetics and natural beauty will be excellent to outstanding."

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"Thirty percent (30%) of the average flow [70 percent depletion]...: This is a base flow recommended to sustain good survival habitat for most aquatic life forms. Widths, depths, and velocities will generally be satisfactory... The majority of the substrate will be covered with water, except for very wide, shallow riffle or shoal areas. Most side channels will carry some water. Gravel bars will be partially covered with water and many islands will provide wildlife nesting, denning, nursery, and refuge habitat. Streambanks will provide cover for fish and wildlife denning habitat in many reaches. Many runs and most pools will be deep enough to serve as cover for fishes. Riparian vegetation will not suffer from lack of water. Large fish can move over riffle areas. Water temperatures are not expected to become limiting in most stream segments. Invertebrate life is reduced but not expected to become a limiting factor in fish production. Water quality and quantity should be good for fishing, floating, and general recreation, especially with canoes, rubber rafts, and smaller shallow draft boats. Stream esthetics and natural beauty will generally be satisfactory."

"Ten percent (10%) of the average flow [90 percent depletion]...: This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Channel widths, depths, and velocities will all be significantly reduced and the aquatic habitat degraded... The stream substrate or wetted perimeter may be about half exposed, except in wide, shallow riffle or shoal areas where exposure could be higher. Side channels will be severely or totally dewatered. Gravel bars will be substantially dewatered, and islands will usually no longer function as wildlife nesting, denning, nursery, and refuge habitat. Streambank cover for fish and fur animal denning habitat will be severely diminished. Many wetted areas will be so shallow they no longer will serve as cover, and fish will generally be crowded into the deepest pools. Riparian vegetation may suffer from lack of water. Large fish will have difficulty migrating upstream over riffle areas. Water temperature often becomes a limiting factor, especially in the lower reaches of streams in July and August. Invertebrate life will be severely reduced. Fishing will often be very good in the deeper pools and runs since fish will be concentrated. Many fishermen prefer this level of flow! However, fish may be vulnerable to overharvest. Floating is difficult even in a canoe or rubber raft. Natural beauty and stream esthetics are badly degraded. Most streams carry less than 10% of the average flow at times, so even this low level of flow will occasionally provide some enhancement over a natural flow regimen."

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Tennant's benchmark percentages have been used in the assessment as criteria for interpreting how past, present, and future depletions affect instream conditions. For the instream flow discussion, the following terms will be used to relate to Tennant's criteria.

Severe - depletion equal to or greater than 90 percent (10% depletion = 10% mean annual flow)

Stressed - depletion between 70 percent and 89 percent (70% depletion = 30% mean annual flow)

Potential conflict - depletion between 40 percent and 69 percent (40% depletion = 60% mean annual flow)

Acceptable - depletion less than 40 percent

Tennant's criteria are based on "mean annual flows." The significant development of storage transbasin diversion and the use of ground-water overdraft in many subregions requires a surrogate be used for the mean annual flows. Actually, three alternate surrogates are used in the assessment: (1) natural outflow; (2) current streamflow supply; and (3) assessed total streamflow. The primary water adequacy analysis emphasizes the assessed total streamflow as the measure of mean annual flow, but the first two are computed so that all subregions can be fairly compared despite their varied histories of depletions, transbasin diversions, and ground-water overdraft.

The water adequacy analysis (Table IV-11) shows results of both the current and assessed streamflow analysis. Current Streamflow Supply (column 15) restores current "1975" consumption (column 14) to the stream as a surrogate for mean annual streamflow. Assessed Total Streamflow (column 17) also restores "1975" consumption, but subtracts ground-water overdraft (column 16), since it is not considered to be a long-term supply.

For water adequacy analysis, both interbasin transfers and reservoir evaporation are maintained at "1975" levels. Only future changes in these parameters are used to determine the total offstream use (column 12) for computing the depletion ratios. Thus,

$$\text{current streamflow depletion (21)} = \frac{\text{offstream use (12)}}{\text{current streamflow supply (15)}}$$

and

$$\text{assessed streamflow depletion*(22)} = \frac{\text{offstream use (12)}}{\text{assessed total streamflow (17)}}$$

*Also called offstream use to total streamflow ratio.

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Table IV-11.—Annual water adequacy analysis
Base Conditions

REGION		INSTREAM (01)* INSTREAM USE: FISH + WILDLIFE (MGD)	INSTREAM (02) INSTREAM USE: NAVIGATION (MGD)	OFFSTREAM (03) CONSUMPTION: ABOVE INFLOW POINTS	OFFSTREAM (04) CONSUMPTION: WITHIN HYDRO UNIT	OFFSTREAM (05) NET EXPORTS (EXPORTS − IMPORTS): ABOVE INFLOW POINTS	OFFSTREAM (06) NET EXPORTS (EXPORTS − IMPORTS): WITHIN HYDRO UNIT	OFFSTREAM (07)* NET EXPORTS (EXPORTS − IMPORTS): CHANGE OF (05+06) FROM 1975	OFFSTREAM (08)* NET EXPORTS (EXPORTS − IMPORTS): INCREASE OF (05+06) FROM 1975	OFFSTREAM (09) NET EVAPORATION: ABOVE INFLOW POINTS	OFFSTREAM (10) NET EVAPORATION: WITHIN HYDRO UNIT	OFFSTREAM (11) NET EVAPORATION: CHANGE OF (09+10) FROM 1975	OFFSTREAM (12) OFFSTREAM USE (03+04 +08+11)
1	"1975"	69001	N/A	0	481	0	0	0	0	0	0	0	481
	1985	69001	N/A	0	647	0	0	0	0	0	0	0	647
	2000	69001	N/A	0	1063	0	0	0	0	0	0	0	1063
2	"1975"	68840	N/A	0	1843	0	−479	0	0	0	0	0	1843
	1985	68840	N/A	0	2472	0	−479	0	0	0	0	0	2472
	2000	68840	N/A	0	3548	0	−479	0	0	0	0	0	3548
3	"1975"	188655	N/A	0	4867	0	6	0	0	0	0	0	4867
	1985	188655	N/A	0	6772	0	6	0	0	0	0	0	6772
	2000	188655	N/A	0	10053	0	6	0	0	0	0	0	10053
4	"1975"	63951	N/A	0	2598	0	−19	0	0	0	0	0	2598
	1985	63951	N/A	0	3300	0	−19	0	0	0	0	0	3300
	2000	63951	N/A	0	4693	0	−19	0	0	0	0	0	4693
5	"1975"	160520	410	313	1798	0	0	0	0	0	0	0	2111
	1985	160520	530	647	2527	0	0	0	0	0	0	0	3174
	2000	160520	645	1105	4332	0	0	0	0	0	0	0	5437
6	"1975"	38480	16100	0	313	0	0	0	0	0	0	0	313
	1985	38480	16100	0	647	0	0	0	0	0	0	0	647
	2000	38480	16100	0	1105	0	0	0	0	0	0	0	1105
7	"1975"	110750	34880	15469	1145	−411	−2064	0	0	4924	43	0	16614
	1985	110750	34880	19206	1604	−433	−2064	−22	0	5324	45	402	21212
	2000	110750	34880	19913	2688	137	−2064	548	548	5595	46	674	23823
8	"1975"	359033	119500	26789	4027	−2603	0	0	0	7582	0	0	30816
	1985	359033	119500	32753	4554	−2674	0	−71	0	8279	0	697	38004
	2000	359033	119500	36925	5511	−2127	0	476	476	8752	0	1170	44082
9	"1975"	3673	0	0	112	0	0	0	0	0	16	0	112
	1985	3673	0	0	204	0	−58	−58	0	0	18	2	206
	2000	3673	0	0	446	0	−641	−641	0	0	19	3	449
10	"1975"	33958	25840	0	15469	0	−411	0	0	0	4924	0	15469
	1985	33958	25840	0	19206	0	−433	−22	0	0	5324	400	19606
	2000	33958	25840	0	19913	0	137	548	548	0	5595	671	21132
11	"1975"	46169	N/A	0	8064	0	−128	0	0	0	2615	0	8064
	1985	46169	N/A	0	8769	0	−177	−49	0	0	2910	295	9064
	2000	46169	N/A	0	8887	0	−200	−72	0	0	3111	496	9383
12	"1975"	22917	N/A	0	11259	0	−30	0	0	0	1705	0	11259
	1985	22917	N/A	0	10227	0	−30	0	0	0	1875	170	10397
	2000	22917	N/A	0	10529	0	−30	0	0	0	1992	287	10816
13	"1975"	2287	N/A	0	4240	0	−234	0	0	0	730	0	4240
	1985	2287	N/A	0	4320	0	−199	35	35	0	764	34	4389
	2000	2287	N/A	0	4016	0	−199	35	35	0	785	55	4106
14	"1975"	7947	0	0	2440	0	805	0	0	0	711	0	2440
	1985	7947	0	0	3018	0	985	180	180	0	721	10	3208
	2000	7947	0	0	3232	0	1095	290	290	0	728	17	3539
15	"1975"	6864	0	2440	4595	805	4463	0	0	711	1202	0	7035
	1985	6864	0	3018	4754	985	4084	−199	0	721	1222	30	7802
	2000	6864	0	3232	4708	1095	3896	−277	0	728	1236	51	7991
16	"1975"	3389	0	0	3779	0	−101	0	0	0	327	0	3779
	1985	3389	0	0	3765	0	−177	−76	0	0	331	4	3769
	2000	3389	0	0	4036	0	−251	−150	0	0	333	6	4042
17	"1975"	214004	N/A	0	11913	0	−47	0	0	0	2014	0	11913
	1985	214004	N/A	0	14610	0	−47	0	0	0	2055	41	14651
	2000	214004	N/A	0	15196	0	−47	0	0	0	2083	69	15265
18	"1975"	32607	N/A	0	26641	0	−4438	0	0	0	669	0	26641
	1985	32607	N/A	0	27932	0	−4069	369	369	0	679	10	28311
	2000	32607	N/A	0	29699	0	−3881	557	557	0	686	17	30273
19	"1975"	859000	N/A	0	58	0	0	0	0	0	0	0	58
	1985	859000	N/A	0	207	0	0	0	0	0	0	0	207
	2000	859000	N/A	0	459	0	0	0	0	0	0	0	459
20	"1975"	4590	0	0	605	0	0	0	0	0	1	0	605
	1985	4590	0	0	636	0	0	0	0	0	1	0	636
	2000	4590	0	0	666	0	0	0	0	0	1	0	666
21	"1975"	3706	0	0	343	0	0	0	0	0	0	0	343
	1985	3706	0	0	374	0	0	0	0	0	0	0	374
	2000	3706	0	0	300	0	0	0	0	0	0	0	300
NATION (1–18)	"1975"	1035221	N/A	0	105584	0	−2677	0	0	0	14956	0	105584
	1985	1035221	N/A	0	119328	0	−2677	0	0	0	15944	988	120316
	2000	1035221	N/A	0	133655	0	−2677	0	0	0	16614	1658	135313

* (01) INSTREAM FLOW APPROXIMATIONS AS DEFINED IN EXPLANATORY NOTES: FOR USE ONLY IN SECOND NATIONAL WATER ASSESSMENT
* (07) CHANGES IN NET EXPORTS ARE NEGATIVE WHEN THERE IS AN INCREASE IN IMPORTS OR A DECREASE IN EXPORTS
* (08) ONLY POSITIVE VALUES OF (07) ARE CONSIDERED OFFSTREAM USES. NEGATIVE VALUES OF (07) ARE TREATED AS ZERO

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Table IV-11.—Annual water adequacy analysis (continued)
Base Conditions

REGION		STREAMFLOW AS SUPPLY (13) CURRENT STRMFLW AT OUTFLW PT (MGD)	(14)* "1975" CONSUMP-TION (03+04) (MGD)	(15) CURRENT STRMFLW SUPPLY (13+14) (MGD)	(16) GRND WTR OVERDRAFT ABOVE OUTFLW PT (MGD)	(17)* ASSESSED TOTAL STRMFLW (15-16) (MGD)	INSTREAM FLOW (18) MAXIMUM INSTREAM USE (01 OR 02) (MGD)	(19)* ASSESSED STRMFLW AT OUTFLW PT (MGD)	(20) ASSESSED SURPLUS STRMFLW (19-18) (MGD)	WATER ADEQUACY INDICATORS (21) CURRENT STRMFLW DEPLETION (12)/(15)	(22)* OFFSTREAM USE TO TOTAL STRMFLW (12)/(17)	(23) INSTREAM USE TO TOTAL STRMFLW (18)/(17)	(24) TOTAL USE TO TOTAL STRMFLW (22+23)
1	"1975"	78180	481	78661	0	78661	69001	78180	9179	1%	1%	88%	89%
	1985	–	–	–	0		69001	78014	9013	–	1%	88%	89%
	2000	–	–	–	0		69001	77598	8597	–	1%	88%	89%
2	"1975"	79190	1843	81033	32	81001	68840	79158	10318	2%	2%	85%	87%
	1985	–	–	–	0		68840	78529	9689	–	3%	85%	88%
	2000	–	–	–	0		68840	77453	8613	–	4%	85%	89%
3	"1975"	228010	4867	232877	339	232538	188655	227671	39016	2%	2%	81%	83%
	1985	–	–	–	0		188655	225766	37111	–	3%	81%	84%
	2000	–	–	–	0		188655	222485	33830	–	4%	81%	85%
4	"1975"	72710	2598	75308	27	75281	63951	72683	8732	3%	3%	85%	88%
	1985	–	–	–	0		63951	71981	8030	–	4%	85%	89%
	2000	–	–	–	0		63951	70588	6637	–	6%	85%	91%
5	"1975"	178000	2111	180111	0	180111	160520	178000	17480	1%	1%	89%	90%
	1985	–	–	–	0		160520	176937	16417	–	2%	89%	91%
	2000	–	–	–	0		160520	174674	14154	–	3%	89%	92%
6	"1975"	40800	313	41113	0	41113	38480	40800	2320	1%	1%	94%	95%
	1985	–	–	–	0		38480	40466	1986	–	2%	94%	96%
	2000	–	–	–	0		38480	40008	1528	–	3%	94%	97%
7	"1975"	121000	16614	137614	2557	135057	110750	118443	7693	12%	12%	82%	94%
	1985	–	–	–	0		110750	113867	3117	–	16%	82%	98%
	2000	–	–	–	0		110750	111234	484	–	18%	82%	100%
8	"1975"	433000	30816	463816	8426	455390	359033	424574	65541	7%	7%	79%	86%
	1985	–	–	–	0		359033	417457	58424	–	8%	79%	87%
	2000	–	–	–	0		359033	411308	52275	–	10%	79%	89%
9	"1975"	6010	112	6122	0	6122	3673	6010	2337	2%	2%	60%	62%
	1985	–	–	–	0		3673	5974	2301	–	3%	60%	63%
	2000	–	–	–	0		3673	6314	2641	–	7%	60%	67%
10	"1975"	44100	15469	59569	2557	57012	33958	41543	7585	26%	27%	60%	87%
	1985	–	–	–	0		33958	37428	3470	–	34%	60%	94%
	2000	–	–	–	0		33958	35880	1922	–	37%	60%	97%
11	"1975"	62600	8064	70664	5457	65207	46169	57143	10974	11%	12%	71%	83%
	1985	–	–	–	0		46169	56192	10023	–	14%	71%	85%
	2000	–	–	–	0		46169	55896	9727	–	14%	71%	85%
12	"1975"	28270	11259	39529	5578	33951	22917	22692	−225	28%	33%	68%	101%
	1985	–	–	–	0		22917	23554	637	–	31%	68%	99%
	2000	–	–	–	0		22917	23135	218	–	32%	68%	100%
13	"1975"	1230	4240	5470	657	4813	2287	573	−1714	78%	88%	48%	136%
	1985	–	–	–	0		2287	424	−1863	–	91%	48%	139%
	2000	–	–	–	0		2287	707	−1580	–	85%	48%	133%
14	"1975"	10000	2440	12440	0	12440	7947	10000	2053	20%	20%	64%	84%
	1985	–	–	–	0		7947	9232	1285	–	26%	64%	90%
	2000	–	–	–	0		7947	8901	954	–	28%	64%	92%
15	"1975"	1550	7035	8585	2415	6170	6864	−865	−7729	82%	114%	111%	225%
	1985	–	–	–	0		6864	−1433	−8297	–	126%	111%	237%
	2000	–	–	–	0		6864	−1544	−8408	–	130%	111%	241%
16	"1975"	2562	3779	6341	591	5750	3389	1971	−1418	60%	66%	59%	125%
	1985	–	–	–	0		3389	2057	−1332	–	66%	59%	125%
	2000	–	–	–	0		3389	1858	−1531	–	70%	59%	129%
17	"1975"	255270	11913	267183	627	266556	214004	254643	40639	4%	4%	80%	84%
	1985	–	–	–	0		214004	251905	37901	–	5%	80%	85%
	2000	–	–	–	0		214004	251291	37287	–	6%	80%	86%
18	"1975"	47375	26641	74016	2197	71819	32607	45178	12571	36%	37%	45%	82%
	1985	–	–	–	0		32607	43508	10901	–	39%	45%	84%
	2000	–	–	–	0		32607	41546	8939	–	42%	45%	87%
19	"1975"	905000	58	905058	0	905058	859000	905000	46000	<1%	<1%	95%	95%
	1985	–	–	–	0		859000	904851	45851	–	<1%	95%	95%
	2000	–	–	–	0		859000	904599	45599	–	<1%	95%	95%
20	"1975"	6747	605	7352	0	7352	4590	6747	2157	8%	8%	62%	70%
	1985	–	–	–	0		4590	6716	2126	–	9%	62%	71%
	2000	–	–	–	0		4590	6686	2096	–	9%	62%	71%
21	"1975"	4851	343	5194	13	5181	3706	4838	1132	7%	7%	72%	79%
	1985	–	–	–	0		3706	4807	1101	–	7%	72%	79%
	2000	–	–	–	0		3706	4881	1175	–	6%	72%	78%
NATION (1-18)	"1975"	1233357	105584	1338941	20889	1318052	1035221	1212468	177247	8%	8%	79%	87%
	1985	–	–	–	0		1035221	1197736	162515	–	9%	79%	88%
	2000	–	–	–	0		1035221	1182739	147518	–	10%	79%	89%

* (14) "1975" BASE-CONDITIONS CONSUMPTION IS ADDED TO STREAMFLOW TO DETERMINE AVAILABLE FRESHWATER SUPPLY
* (17).(19) TOTAL STREAMFLOW AND ASSESSED STREAMFLOW EXCLUDE CONTRIBUTIONS FROM GROUND-WATER OVERDRAFT
* (19) = (17) − (03) − (04) − (07) − (11)
* (22) ALSO CALLED ASSESSED STREAMFLOW DEPLETION

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Table IV-11.—Annual water adequacy analysis (continued)
Base Conditions

Water adequacy — For purposes of the second assessment, water adequacy is the capability of the river system to meet the requirements of both offstream and instream uses with no overdraft of ground-water sources.

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Above inflow points — Term equivalent to "above outflow point" except it excludes the information for the given region or subregion.

above inflow points = above outflow point — within hydro. unit

Above outflow point — Describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion (within the hydro. unit), plus the sum of values for all upstream regions or subregions. This information represents the total load on the upstream river network.

At outflow point — Describes streamflow information. All streamflow is measured at the downstream edge of the subregions and regions. In many cases, this is the downstream portion of the major river draining the area, but for other (particularly coastal) subregions, the "outflow point" is truly the sum of outflows from all of the major rivers and streams draining the area.

Downstream subregion — The next subregion downstream from a given subregion. If no downstream subregion exists, a notation is included to indicate what is downstream, e.g., Pacific Ocean, Atlantic Ocean, Gulf of Mexico, Canada, Mexico, or terminal lakes (closed basin).

Within hydro. unit — Refers to values within the appropriate hydrologic unit (region or subregion).

Note: numbers in parentheses refer to Table column headers.

(01) *Fish and wildlife instream use* /1/ — Instream flow approximations for habitat maintenance from Volume 3, Table II-1.

(02) *Navigation instream use* /1/ — Instream flow requirements for navigation from Volume 3, Table II-1.

(03) *Consumption above the inflow points* /1/ — Base conditions consumption for all upstream regions or subregions. This represents the consumptive load on the inflows entering the region or subregion. A value of zero indicates there are no upstream regions or subregions.

(04) *Consumption within the hydrologic unit* — Base conditions consumption for the region or subregion from Volume 3, Table II-4.

(05) *Net exports above the inflow points* /1/ — Net exports for all upstream regions or subregions.

(06) *Net exports within the hydrologic unit* — Net exports for the region or subregion. Negative values for net exports represent net imports. Basic export and import information is in Volume 3, Table II-2.

(07) *Change in net exports above the outflow point* /1/ — Represents a change in net exports from "1975". A positive value represents an increase in exports (or a decrease in imports) which decreases assessed streamflow (19); an increase in net exports is treated as an additional depletion for com-

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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Table IV-11.—Annual water adequacy analysis (continued)
Base Conditions

puting assessed streamflow depletion (22). A negative value represents an increase in imports (or a decrease in exports), which increases assessed streamflow; a decrease in net exports is not treated as a decrease in depletion for computing assessed streamflow depletion.

(08) *Increase in net exports above the outflow point* /1/ — Represents that portion of the change in net exports (07) treated as an additional depletion.

(09) *Net evaporation above the inflow points* /1/ — Net evaporation for all upstream regions or subregions.

(10) *Net evaporation within the hydrologic unit* — Net evaporation for the region or subregion from Volume 3, Table II-2.

(11) *Change in net evaporation above the outflow point* /1/ — Represents an increase in net evaporation from "1975" due to construction of reservoirs and farm or stock ponds. This increase represents an additional depletion for computing assessed streamflow depletion (22) and causes a decrease in assessed streamflow (19).

(12) *Offstream use* — Total assessed depletions; sum of consumption [(03) + (04)] plus increases in net exports (08) plus changes in net evaporation (11).

(13) *Current streamflow* /1/ — Mean flow for "1975" from Volume 3, Table II-1, derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

(14) *"1975" consumption above the outflow point* /1/ — Sum of (03) plus (04).

(15) *Current streamflow supply* /1/ — Theoretical streamflow that would currently be available at the outflow point of a region or subregion if current consumption were eliminated. Current streamflow supply is a measure of currently utilized fresh-water supply but does not necessarily represent long-term supply.

current streamflow supply = current streamflow (13)
+ "1975" consumption (14)

(16) *Ground-water overdraft above outflow point* /1/ — Ground-water overdraft for this region or subregion plus overdraft for all upstream regions or subregions. This represents the total upstream overdraft that eventually may be exhausted and no longer available as supply. Basic overdraft information is in Volume 3, Table II-1.

(17) *Assessed total streamflow* /1/ — Long-range streamflow that would be available at the outflow point of a region or subregion if consumption were eliminated, if ground-water overdrafting were discontinued, and if "1975" water transfer and reservoir practices would continue. Total streamflow is the measure for supply utilized in the second assessment. Ground-water overdraft is subtracted as it is not considered to be a long-term supply.

assessed total streamflow = "1975" current streamflow (13)
+ "1975" consumption (14)
− "1975" ground-water overdraft (16)

(18) *Maximum instream use* /1/ — The second assessment has attempted to bring to the attention of water resources planners and policy makers the importance of instream uses. The key instream uses

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/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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Table IV-11.—Annual water adequacy analysis (continued)
Base Conditions

included in the analysis are (01) fish and wildlife habitat maintenance (instream flow approximations), and (02) navigation. The most demanding of these (18) is used in further analysis (20),(23),(24). Details on these uses are in the explanatory notes for Volume 3, Table II-3.

(19) *Assessed streamflow* /1/ — Computed flow that includes effects of consumption, water transfers, and evaporation from manmade reservoirs, but ignores contributions from ground-water overdraft.

assessed streamflow = assessed total streamflow (17)
− offstream use (12)

"1975" assessed streamflow = "1975" current streamflow (13)
−."1975" ground-water overdraft (16)

(20) *Assessed surplus streamflow* /1/ — A measure of available supply for conflict-free development of offstream uses. A negative figure indicates a conflict between offstream uses and the estimated instream flow needs. See also (23),(24).

surplus streamflow = assessed streamflow (19)
− maximum instream use (18)

(21) *Current streamflow depletion* — Depletion rate under current ("1975") conditions of consumption, water transfer, evaporation, and ground-water overdraft. This figure best represents actual current depletion under base or average conditions.

$$\text{current streamflow depletion} = \frac{\text{consumption [(03) + (04)]}}{\text{current streamflow supply (15)}}$$

(22) *Offstream use to total streamflow (assessed streamflow depletion)* — Depletion rate if contributions from ground-water overdraft are ignored. This figure represents the long-range depletion under base or average conditions.

$$\text{assessed streamflow depletion} = \frac{\text{offstream use (12)}}{\text{assessed total streamflow (17)}}$$

(23) *Instream use to total streamflow* — A measure of instream use demands (18) upon assessed total streamflow. Note that a "1975" figure in excess of 100 percent indicates that exports from a region or subregion are already adversely affecting the instream environment. See also (20),(24).

$$\text{ratio} = \frac{\text{maximum instream use (18)}}{\text{assessed total streamflow (17)}}$$

(24) *Total use to total streamflow* — A measure of available supply for conflict-free development of offstream uses. A figure greater than 100 percent indicates a conflict between offstream uses and the estimated instream flow needs. See also (20),(23).

$$\text{ratio} = \frac{\text{total use}}{\text{assessed total streamflow (17)}} \quad \text{where:}$$

total use = maximum instream use (18)
+ offstream use (12)

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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The natural water supply analysis (Table IV-12) estimates conditions in the so-called natural state, i.e., before human influence. However, it is not truly natural in that vegetation and runoff patterns have been altered by humans. "Natural Outflow" (column 17) not only restores current "1975" consumption to the stream, but also eliminates interbasin transfers and reservoir evaporation to obtain a prehuman surrogate for mean annual streamflow. The natural flow depletion then treats actual exports and evaporation as depletions, in addition to consumption.

Thus,

$$\text{natural flow depletion (19)} = \frac{\text{total depletions [(15) + (16)]}}{\text{natural outflow (17)}}$$

Comparison of this ratio with the current and assessed streamflow ratios shows significant differences, especially in subregions with large interbasin transfers or excessive evaporation.

Results of the Analysis

Figure IV-14, Natural "1975" Depletion, shows the depletion of the estimated "natural outflow" of the subregions. These depletion ratios illustrate how offstream use affects historical, "prehuman" streamflows. As can be seen in southern California (1141-percent depletion of naturally available supplies), development has already significantly changed the nature of things. The second assessment did not, however, attempt to take man back to prehistory. Rather, the selected base conditions for the water adequacy analysis assumed "1975" levels of water management and interregional water transfers.

Figures IV-15, IV-16, and IV-17 show streamflow depletion under different assumptions for "1975" and 2000. Complete details, including 1985, can be found in Volume 3, Analytical Data. Regional results are also in Tables IV-11 and IV-12. The parameters that vary among the figures are the contributions from ground-water overdraft, the amount of precipitation, and the volume of requirements or demands. Evaluation of the annual depletion levels at the subregion outflow point(s) for the mean water conditions illustrates the geographic distribution of the gross water adequacy situation. The current situation is already severe in southern California and southern Arizona, and under stress in the headwaters of the Platte and Arkansas Rivers, the San Joaquin Valley, the Rio Grande Region, and in three closed basins in Nevada, Utah, and California.

Ground-water overdraft has been the basis for much agricultural development in the Midwest and Southwest. Because of declining water tables and a corresponding increase in pumping costs, it is assumed that ground-water overdraft will be reduced in the future. For the long-range water supply analysis, contributions from ground-water overdraft have been eliminated from all results except current streamflow and current streamflow depletions. This immediately exaggerates the water problems in some regions, as can be seen by comparing Figure IV-15, Current Streamflow

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Table IV-12.—Natural water supply analysis

REGION		(01) CONSUMPTION ABOVE INFLOW POINTS (MGD)	(02) CONSUMPTION WITHIN HYDRO UNIT (MGD)	(03) NET EVAPORATION ABOVE INFLOW POINTS (MGD)	(04) NET EVAPORATION WITHIN HYDRO UNIT (MGD)	(05) NET EXPORTS ABOVE INFLOW POINTS (MGD)	(06) NET EXPORTS WITHIN HYDRO UNIT (MGD)	(07) NET IMPORTS ABOVE INFLOW POINTS (MGD)	(08) NET IMPORTS WITHIN HYDRO UNIT (MGD)	(09) G W OVERDRAFT ABOVE INFLOW POINTS (MGD)	(10) G W OVERDRAFT WITHIN HYDRO UNIT (MGD)	(11)* TOTAL DEPLETIONS ABOVE INFLOW POINTS (MGD)	(12)* TOTAL DEPLETIONS WITHIN HYDRO UNIT (MGD)
1	"1975"	0	481	0	0	0	0	0	0	0	0	0	481
	1985	0	647	0	0	0	0	0	0	0	0	0	647
	2000	0	1063	0	0	0	0	0	0	0	0	0	1063
2	"1975"	0	1843	0	0	0	0	0	479	0	32	0	1843
	1985	0	2472	0	0	0	0	0	479	0	0	0	2472
	2000	0	3548	0	0	0	0	0	479	0	0	0	3548
3	"1975"	0	4867	0	0	0	6	0	0	0	339	0	4873
	1985	0	6772	0	0	0	6	0	0	0	0	0	6778
	2000	0	10053	0	0	0	6	0	0	0	0	0	10059
4	"1975"	0	2598	0	0	0	0	0	19	0	27	0	2598
	1985	0	3300	0	0	0	0	0	19	0	0	0	3300
	2000	0	4693	0	0	0	0	0	19	0	0	0	4693
5	"1975"	313	1798	0	0	0	0	0	0	0	0	313	1798
	1985	647	2527	0	0	0	0	0	0	0	0	647	2527
	2000	1105	4332	0	0	0	0	0	0	0	0	1105	4332
6	"1975"	0	313	0	0	0	0	0	0	0	0	0	313
	1985	0	647	0	0	0	0	0	0	0	0	0	647
	2000	0	1105	0	0	0	0	0	0	0	0	0	1105
7	"1975"	15469	1145	4924	43	0	0	411	2064	2557	0	20393	1188
	1985	19206	1604	5324	45	0	0	433	2064	0	0	24530	1649
	2000	19913	2688	5595	46	137	0	0	2064	0	0	25645	2734
8	"1975"	26789	4027	7582	0	0	0	2603	0	8014	412	34371	4027
	1985	32753	4554	8279	0	0	0	2674	0	0	0	41032	4554
	2000	36925	5511	8752	0	0	0	2127	0	0	0	45677	5511
9	"1975"	0	112	0	16	0	0	0	0	0	0	0	128
	1985	0	204	0	18	0	0	0	58	0	0	0	222
	2000	0	446	0	19	0	0	0	641	0	0	0	465
10	"1975"	0	15469	0	4924	0	0	0	411	0	2557	0	20393
	1985	0	19206	0	5324	0	0	0	433	0	0	0	24530
	2000	0	19913	0	5595	0	137	0	0	0	0	0	25645
11	"1975"	0	8064	0	2615	0	0	0	128	0	5457	0	10679
	1985	0	8769	0	2910	0	0	0	177	0	0	0	11679
	2000	0	8887	0	3111	0	0	0	200	0	0	0	11998
12	"1975"	0	11259	0	1705	0	0	0	30	0	5578	0	12964
	1985	0	10227	0	1875	0	0	0	30	0	0	0	12102
	2000	0	10529	0	1992	0	0	0	30	0	0	0	12521
13	"1975"	0	4240	0	730	0	0	0	234	0	657	0	4970
	1985	0	4320	0	764	0	0	0	199	0	0	0	5084
	2000	0	4016	0	785	0	0	0	199	0	0	0	4801
14	"1975"	0	2440	0	711	0	805	0	0	0	0	0	3956
	1985	0	3018	0	721	0	985	0	0	0	0	0	4724
	2000	0	3232	0	728	0	1095	0	0	0	0	0	5055
15	"1975"	2440	4595	711	1202	805	4463	0	0	0	2415	3956	10260
	1985	3018	4754	721	1222	985	4084	0	0	0	0	4724	10060
	2000	3232	4708	728	1236	1095	3896	0	0	0	0	5055	9840
16	"1975"	0	3779	0	327	0	0	0	101	0	591	0	4106
	1985	0	3765	0	331	0	0	0	177	0	0	0	4096
	2000	0	4036	0	333	0	0	0	251	0	0	0	4369
17	"1975"	0	11913	0	2014	0	0	0	47	0	627	0	13927
	1985	0	14610	0	2055	0	0	0	47	0	0	0	16665
	2000	0	15196	0	2083	0	0	0	47	0	0	0	17279
18	"1975"	0	26641	0	669	0	0	0	4438	0	2197	0	27310
	1985	0	27932	0	679	0	0	0	4069	0	0	0	28611
	2000	0	29699	0	686	0	0	0	3881	0	0	0	30385
19	"1975"	0	58	0	0	0	0	0	0	0	0	0	58
	1985	0	207	0	0	0	0	0	0	0	0	0	207
	2000	0	459	0	0	0	0	0	0	0	0	0	459
20	"1975"	0	605	0	1	0	0	0	0	0	0	0	606
	1985	0	636	0	1	0	0	0	0	0	0	0	637
	2000	0	666	0	1	0	0	0	0	0	0	0	667
21	"1975"	0	343	0	0	0	0	0	0	0	13	0	343
	1985	0	374	0	0	0	0	0	0	0	0	0	374
	2000	0	300	0	0	0	0	0	0	0	0	0	300
NATION (1–18)	"1975"	0	105584	0	14956	0	0	0	2677	0	20889	0	120540
	1985	0	119328	0	15944	0	0	0	2677	0	0	0	135272
	2000	0	133655	0	16614	0	0	0	2677	0	0	0	150269

* (11)=(01)+(03)+(05) * (12)=(02)+(04)+(06)

Depletion, with Figure IV-16, Assessed "1975" Streamflow Depletion. Certain subregions, such as those in southern Arizona, show a depletion greater than 100 percent. This means that these subregions are already overdrafting ground water to meet current offstream consumption. Many of the subregions discussed earlier as "under stress" for current conditions would be con-

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Table IV-12.—Natural water supply analysis (continued)

REGION		(13) INFLOWS ENTERING HYDRO UNIT (MGD)	(14) CURRENT STRMFLW AT OUTFLW PT (MGD)	(15)• TOTAL DEPLETIONS ABOVE INFLOW POINTS (MGD)	(16)• TOTAL DEPLETIONS WITHIN HYDRO UNIT (MGD)	(17)• NATURAL OUTFLOW AT OUTFLW PT (MGD)	(18)• NATURAL OUTFLOW WITHIN HYDRO UNIT (MGD)	(19) NAT FLOW DEPLETN ABOVE OUTFLW PT (15)+(16)/(17)	(20) NAT FLOW DEPLETN WITHIN HYDRO UNIT (16)/(18)	(21) DRAINAGE AREA ABOVE OUTFLW PT (SQ MI)	(22) DRAINAGE AREA WITHIN HYDRO UNIT (SQ MI)	(23) ESTIMATED RUNOFF ABOVE OUTFLW PT (17)/(21) (INCHES)	(24) ESTIMATED RUNOFF IN HYDRO UNIT (18)/(22) (INCHES)
1	"1975"	0	78180	0	481	78661	78661	1%	1%	71990	71990	23"	23"
	1985			0	647			1%	1%				
	2000			0	1063			1%	1%				
2	"1975"	0	79190	0	1843	80522	80522	2%	2%	104910	104910	16"	16"
	1985			0	2472			3%	3%				
	2000			0	3548			4%	4%				
3	"1975"	0	228010	0	4873	232544	232544	2%	2%	277200	277200	18"	18"
	1985			0	6778			3%	3%				
	2000			0	10059			4%	4%				
4	"1975"	0	72710	0	2598	75262	75262	3%	3%	113760	113760	14"	14"
	1985			0	3300			4%	4%				
	2000			0	4693			6%	6%				
5	"1975"	40800	178000	313	1798	180111	138998	1%	1%	203470	162660	19"	18"
	1985			647	2527			2%	2%				
	2000			1105	4332			3%	3%				
6	"1975"	0	40800	0	313	41113	41113	1%	1%	40810	40810	21"	21"
	1985			0	647			2%	2%				
	2000			0	1105			3%	3%				
7	"1975"	44100	121000	20393	1188	137549	76024	16%	2%	701360	190170	4"	8"
	1985			24530	1649			19%	2%				
	2000			25645	2734			21%	4%				
8	"1975"	361600	433000	34371	4027	460369	75015	8%	5%	1255890	103520	8"	15"
	1985			41032	4554			10%	6%				
	2000			45677	5511			11%	7%				
9	"1975"	0	6010	0	128	6138	6138	2%	2%	59370	59370	2"	2"
	1985			0	222			4%	4%				
	2000			0	465			8%	8%				
10	"1975"	0	44100	0	20393	61525	61525	33%	33%	511190	511190	3"	3"
	1985			0	24530			40%	40%				
	2000			0	25645			42%	42%				
11	"1975"	0	62600	0	10679	67694	67694	16%	16%	247540	247540	6"	6"
	1985			0	11679			17%	17%				
	2000			0	11998			18%	18%				
12	"1975"	0	28270	0	12964	35626	35626	36%	36%	181440	181440	4"	4"
	1985			0	12102			34%	34%				
	2000			0	12521			35%	35%				
13	"1975"	0	1230	0	4970	5309	5309	94%	94%	132790	132790	1"	1"
	1985			0	5084			96%	96%				
	2000			0	4801			90%	90%				
14	"1975"	0	10000	0	3956	13956	13956	28%	28%	113330	113330	3"	3"
	1985			0	4724			34%	34%				
	2000			0	5055			36%	36%				
15	"1975"	10000	1550	3956	10260	13351	-605••	106%	N/C	253890	140560	1"	0"
	1985			4724	10060			111%	N/C				
	2000			5055	9840			112%	N/C				
16	"1975"	0	2562	0	4106	5976	5976	69%	69%	142070	142070	1"	1"
	1985			0	4096			69%	69%				
	2000			0	4369			73%	73%				
17	"1975"	0	255270	0	13927	268523	268523	5%	5%	277340	277340	20"	20"
	1985			0	16665			6%	6%				
	2000			0	17279			6%	6%				
18	"1975"	0	47375	0	27310	68050	68050	40%	40%	176510	176510	8"	8"
	1985			0	28611			42%	42%				
	2000			0	30385			45%	45%				
19	"1975"	0	905000	0	58	905058	905058	<1%	<1%	586402	586402	32"	32"
	1985			0	207			<1%	<1%				
	2000			0	459			<1%	<1%				
20	"1975"	0	6747	0	606	7353	7353	8%	8%	6447	6447	24"	24"
	1985			0	637			9%	9%				
	2000			0	667			9%	9%				
21	"1975"	0	4851	0	343	5181	5181	7%	7%	3567	3567	31"	31"
	1985			0	374			7%	7%				
	2000			0	300			6%	6%				
NATION (1–18)	"1975"	0	1233357	0	120540	1330331	1330331	9%	9%	3047160	3047160	9"	9"
	1985			0	135272			10%	10%				
	2000			0	150269			11%	11%				

• (15)=(11)=(01)+(03)+(05)
• (16)=(12)=(02)+(04)+(06)
• (17)=(14)+(01)+(02)+(03)+(04)+(05)+(06)−(07)−(08)−(09)−(10)
• (18)=(14)−(13)+(02)+(04)+(06)−(08)−(10)
•• A NEGATIVE VALUE OF NATURAL OUTFLOW INDICATES THAT EVAPORATION AND PLANT TRANSPIRATION EXCEED RAINFALL IN THE REGION

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Table IV-12.—Natural water supply analysis (continued)

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Natural water supply — An analysis that estimates conditions in the so-called natural state, i.e., before human influence. However, it is not truly natural in that vegetation and runoff patterns have been altered by humans (see also "natural outflows").

Above inflow points — Term equivalent to "above outflow point" except it excludes the information for the given region or subregion.

above inflow points = above outflow point — within hydro. unit

Above outflow point — Describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion (within the hydro. unit), plus the sum of values for all upstream regions or subregions. This information represents the total load on the upstream river network.

At outflow point — Describes streamflow information. All streamflow is measured at the downstream edge of the subregions and regions. In many cases, this is the downstream portion of the major river draining the area, but for other (particularly coastal) subregions, the "outflow point" is truly the sum of outflows from all of the major streams and rivers draining the area.

Downstream subregion — The next subregion downstream from a given subregion. If no downstream subregion exists, a notation is included to indicate what is downstream, e.g., Pacific Ocean, Atlantic Ocean, Gulf of Mexico, Great Lakes, Canada, Mexico, or terminal lakes (closed basin).

Within hydro. unit — Refers to values within the appropriate hydrologic unit (region or subregion).

Note: numbers in parentheses refer to Table column headers.

(01) *Consumption above the inflow points* /1/ — Base conditions consumption for all upstream regions or subregions. This represents the consumptive load on the inflows entering the region or subregion. A value of zero indicates there are no upstream regions or subregions.

(02) *Consumption within the hydrologic unit* — Base conditions consumption for the region or subregion from Volume 3, Table II-4.

(03) *Net evaporation above the inflow points* /1/ — Net evaporation for all upstream regions or subregions.

(04) *Net evaporation within the hydrologic unit* — Net evaporation for the region or subregion from Volume 3, Table II-2.

(05) *Net exports above the inflow points* /1/ — Net exports for all upstream regions or subregions.

(06) *Net exports within the hydrologic unit* — Net exports for the region or subregion from Volume 3, Table II-2.

(07) *Net imports above the inflow points* /1/ — Net imports for all upstream regions or subregions.

(08) *Net imports within the hydrologic unit* — Net imports for the region or subregion from Volume 3, Table II-2.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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Table IV-12.—Natural water supply analysis (continued)

(09) *Ground-water overdraft above the inflow points* /1/ — Ground-water overdraft for all upstream regions and subregions.

(10) *Ground-water overdraft within the hydrologic unit* — Ground-water overdraft for the region or subregion from Volume 3, Table II-1.

(11) *Total depletions above the inflow points* — For natural supply analysis, depletions include all man-induced uses that result in decreased streamflow.

total depletions = consumption (01)
+ net evaporation (03)
+ positive net exports (05) where net imports is zero

(12) *Total depletions within the hydrologic unit* — Depletions include all man-induced uses that result in decreased streamflow for the region or subregion.

total depletions = consumption (02)
+ net evaporation (04)
+ positive net exports (06) where net imports is zero

(13) *Inflows entering the hydrologic unit* /1/ — Sum of flows for all streams and rivers entering a region or subregion. Equivalently, the inflow to a subregion is the sum of the outflows from all upstream subregions. A value of zero indicates the most upstream subregion of a river network.

(14) *Current streamflow* /1/ — Mean flow for "1975" from Volume 3, Table II-1, derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

(15) *Total depletions above the inflow points* /1/ — same as (11).

(16) *Total depletions within the hydrologic unit* — same as (12).

(17) *Natural outflow at the outflow point* (natural available streamflow) /1/ — Estimate of streamflow without artificial manmade constraints for comparison with current streamflow (Volume 3, Table II-5) and assessed streamflow (Volume 3, Table II-5). Natural flow indicates the average potential runoff available from precipitation before introducing human effects. It is not truly natural streamflow because vegetation and runoff patterns have been altered by man.

natural outflow = current streamflow (14)
+ total depletions (15) + (16)
− net imports (07) + (08)
− ground-water overdraft (09) + (10) where:

total depletions = consumption (01) + (02)
+ net evaporation (03) + (04)
+ net exports (05) + (06)

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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Table IV-12.—Natural water supply analysis (continued)

(18) *Natural outflow within the hydrologic unit* (natural available streamflow) — Estimate of average potential runoff available from precipitation in the region or subregion before introducing human effects. Equivalently, the portion of water supply contributed by the region or subregion.

natural outflow = current streamflow (14)
− inflows (13)
+ total depletions (16)
− net imports (08)
− ground-water overdraft (10) where:

total depletions = consumption (02)
+ net evaporation (04)
+ net exports (06)

(19) *Natural flow depletion above the outflow point* — Estimated loss to total natural outflow (natural available streamflow) from all offstream demands (consumption, evaporation, and net exports).

$$\text{natural flow depletion} = \frac{\text{total depletions (15) + (16)}}{\text{natural available streamflow (17)}}$$

(20) *Natural flow depletion within the hydrologic unit* — Estimated loss to regional or subregional natural outflow (natural available streamflow) from offstream demands (consumption, evaporation, and net exports) within the region or subregion.

$$\text{natural flow depletion} = \frac{\text{total depletions (16)}}{\text{natural available streamflow (18)}}$$

(21) *Drainage area above the outflow point* — Hydrologic area of the watershed in the region or subregion (22), plus the hydrologic area of all upstream regions or subregions, measured in square miles.

(22) *Drainage area within the hydrologic unit* — Hydrologic area of the watershed in the region or subregion, measured in square miles.

(23) *Estimated runoff above the outflow point* — Estimated runoff for the region or subregion (see 24), plus the estimated runoff for all upstream regions or subregions, converted to equivalent inches of rainfall.

$$\text{estimated runoff} = \frac{\text{natural available streamflow (17)}}{\text{hydrologic drainage area (21)}}$$

(24) *Estimated runoff within the hydrologic unit* — Estimate of potential rainfall which would reach the outflow point of a region or subregion from rainfall occurring in that region or subregion. Using natural outflow (18) and drainage area (22), this figure has been converted to equivalent inches of rainfall. Due to diverse sources of data used in the assessment process, these estimated runoff figures are provided only for comparison with other regions or subregions in the assessment.

$$\text{estimated runoff} = \frac{\text{natural available streamflow (18)}}{\text{hydrologic drainage area (22)}}$$

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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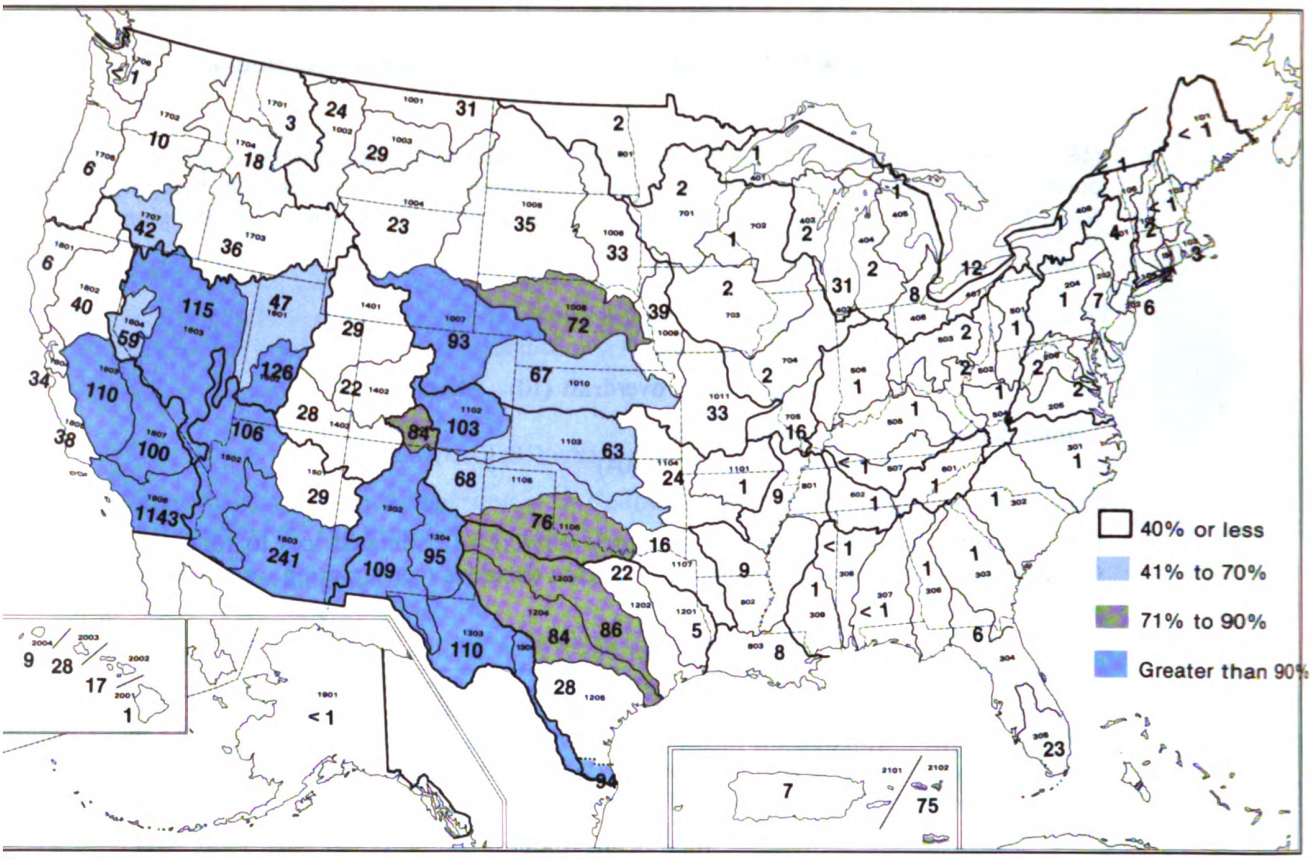

Figure IV-14: Natural flow depletion—"1975"

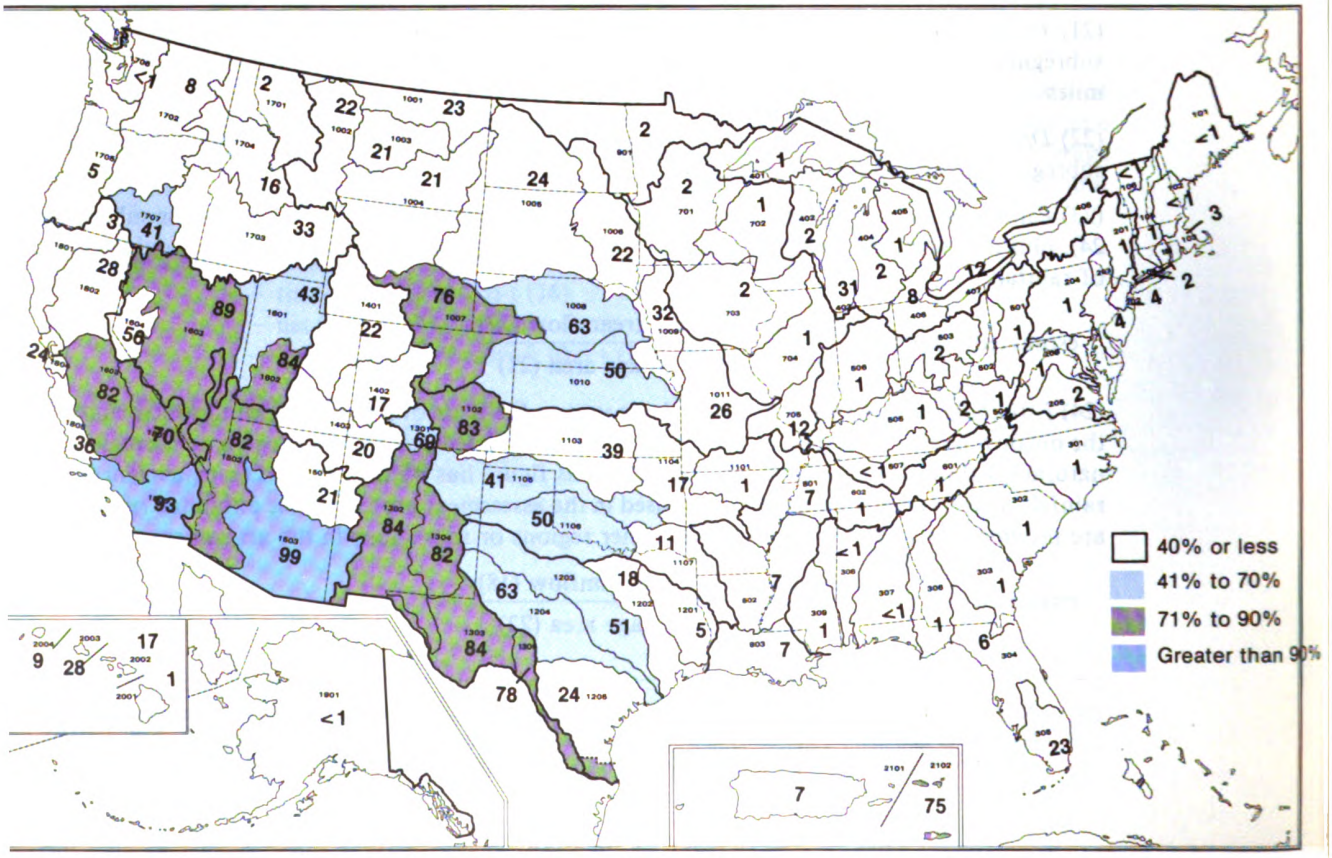

Figure IV-15: Current streamflow depletion—"1975" (base conditions)

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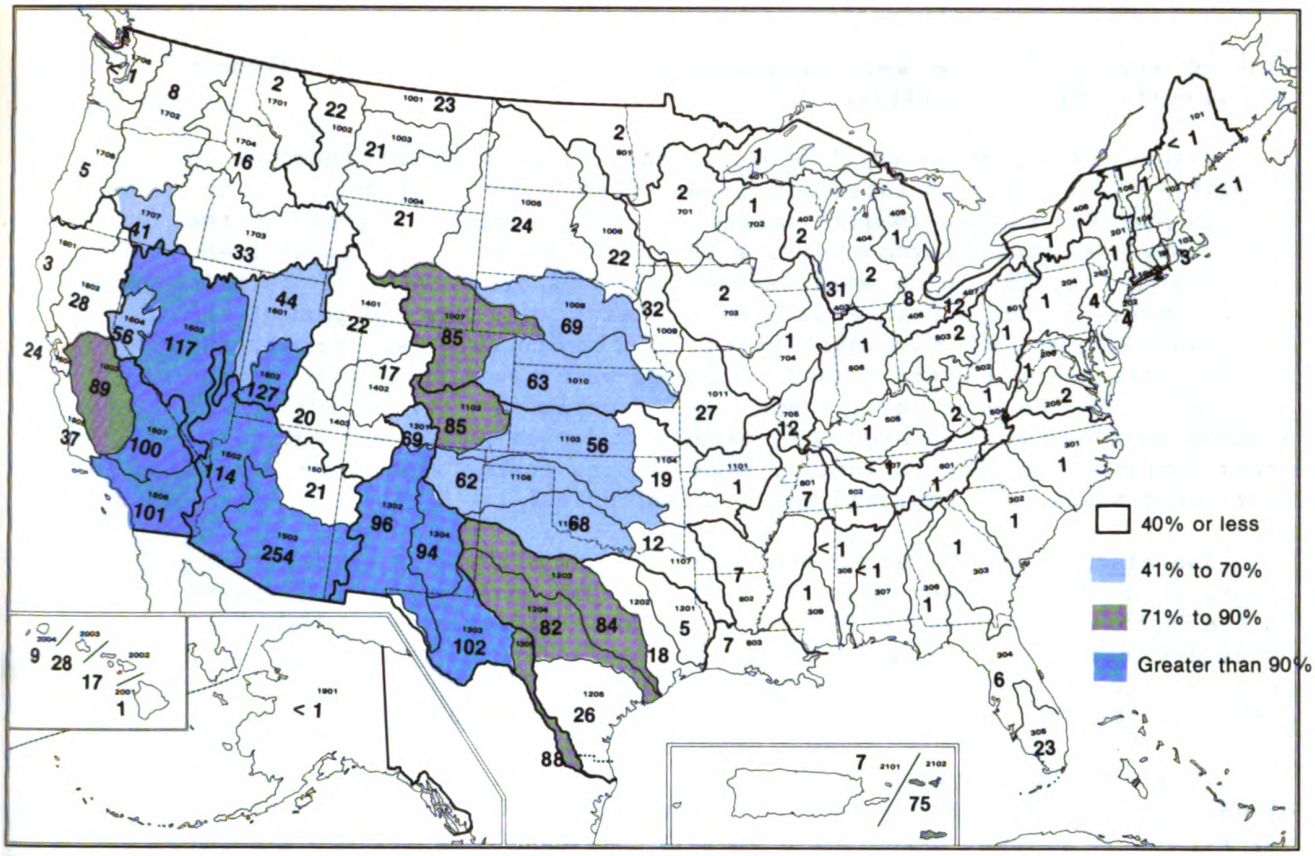

Figure IV-16: Assessed streamflow depletion—"1975" (base conditions)

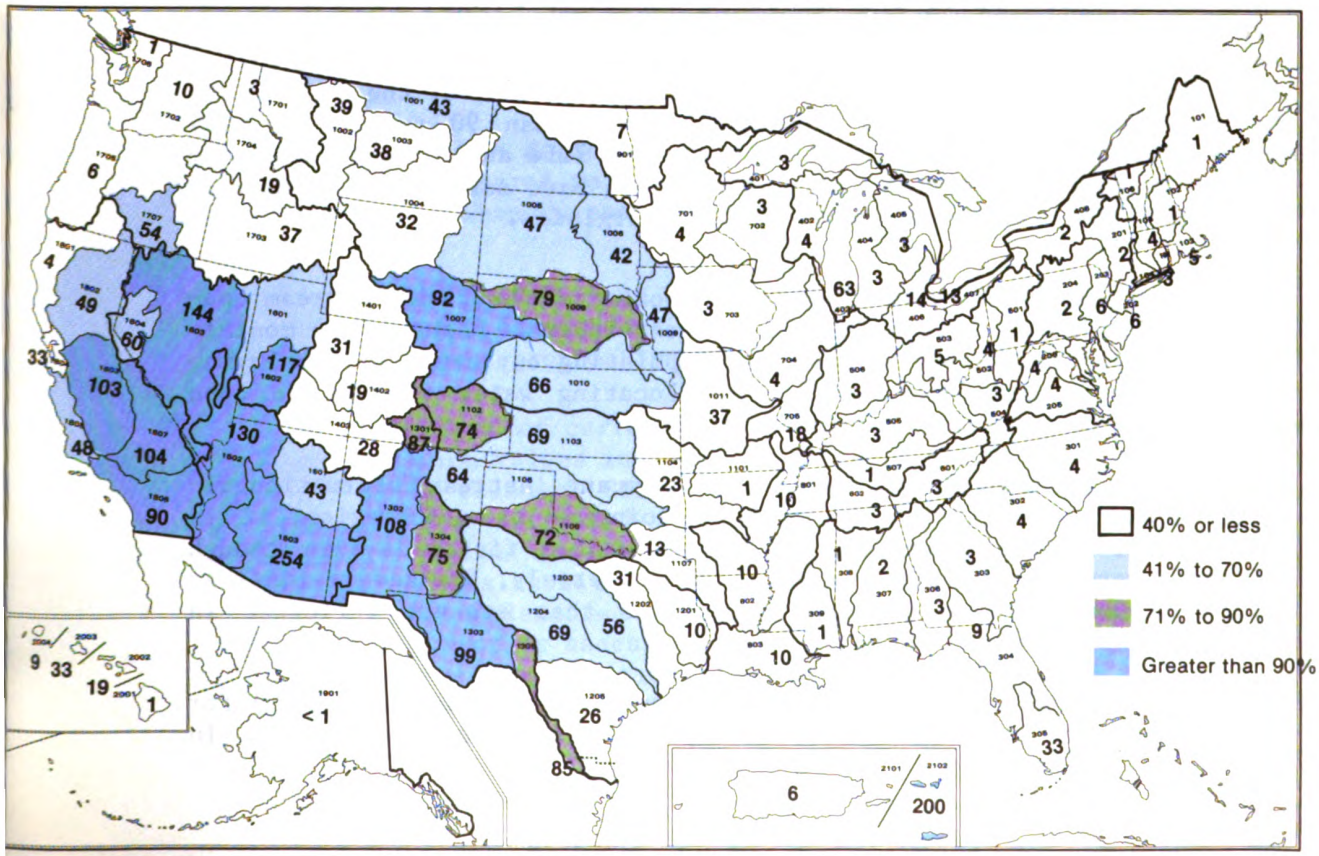

Figure IV-17: Assessed streamflow depletion—2000 (base conditions)

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sidered severe if there were not ground-water overdrafting to supplement normal surface-water supplies.

Figure IV-17, Assessed 2000 Depletions, shows a general increase in severity of stress from increased consumption. The headwaters of the Platte River and the San Joaquin Valley may be severely depleted by the year 2000. The primary force producing these increases is the significant increase in irrigation to meet assumed high export levels of certain agricultural products. However, the high plains of Texas and part of the Rio Grande Region should improve since irrigation consumptive use patterns are projected to lessen the demand on ground-water overdraft as a source of supply. For the most part, these reduced depletion levels reflect an assumed reduction of ground-water supplies from depletion of deep aquifers. Other contributing factors include high pumping costs, land constraints near urban areas, and improved water efficiencies.

The discussion this far has been restricted to average or normal conditions. The problem of severe or stressed instream environment seems to be in the Southwest. Figure IV-18, Dry Assessed 2000 Depletion, shows that under dry conditions, increased irrigation causes much higher depletions, particularly in Texas and the southern Great Plains, but the basic geographic pattern of areas with high depletion remains much the same.

It is informative from the viewpoint of instream values to consider areas where in a number of months the mean monthly depletions exceed the 40, 70, and 90 percent criteria. A summary of monthly depletions greater than the 40, 70, 90 percent depletion criteria is available in Volume 3, Table II-7, which shows the number of months in which these evaluation levels are exceeded in each subregion. There is already ("1975" assessed conditions) encroachment on optimum instream conditions (40 percent depletion) for most months throughout the West. In much of the arid West, the water supply is already depleted by more than 90 percent in many months. This means a loss of desirable aquatic life and attendant instream values. In southern Florida, large diversions have substantially reduced the famous "river of grass" known as the Everglades.

By the year 2000, given the projected offstream use, the instream conditions will worsen significantly in most basins. Perhaps the monthly analysis is most valuable as a means of pointing out areas for employing improved water management and for reallocating water storage to cope with short-term instream flow inadequacies.

Because the monthly and annual stream and instream information reflects conditions only at the outflow point(s) of a subregion, it is possible for tributary streams to support viable fisheries even though the mainstream is severely depleted, or, conversely, for severe instream flow problems to exist in some tributaries that are not reflected in the depletion ratios.

As discussed earlier, a set of instream flow approximations (IFA) for wildlife habitat maintenance was developed for the second assessment. In

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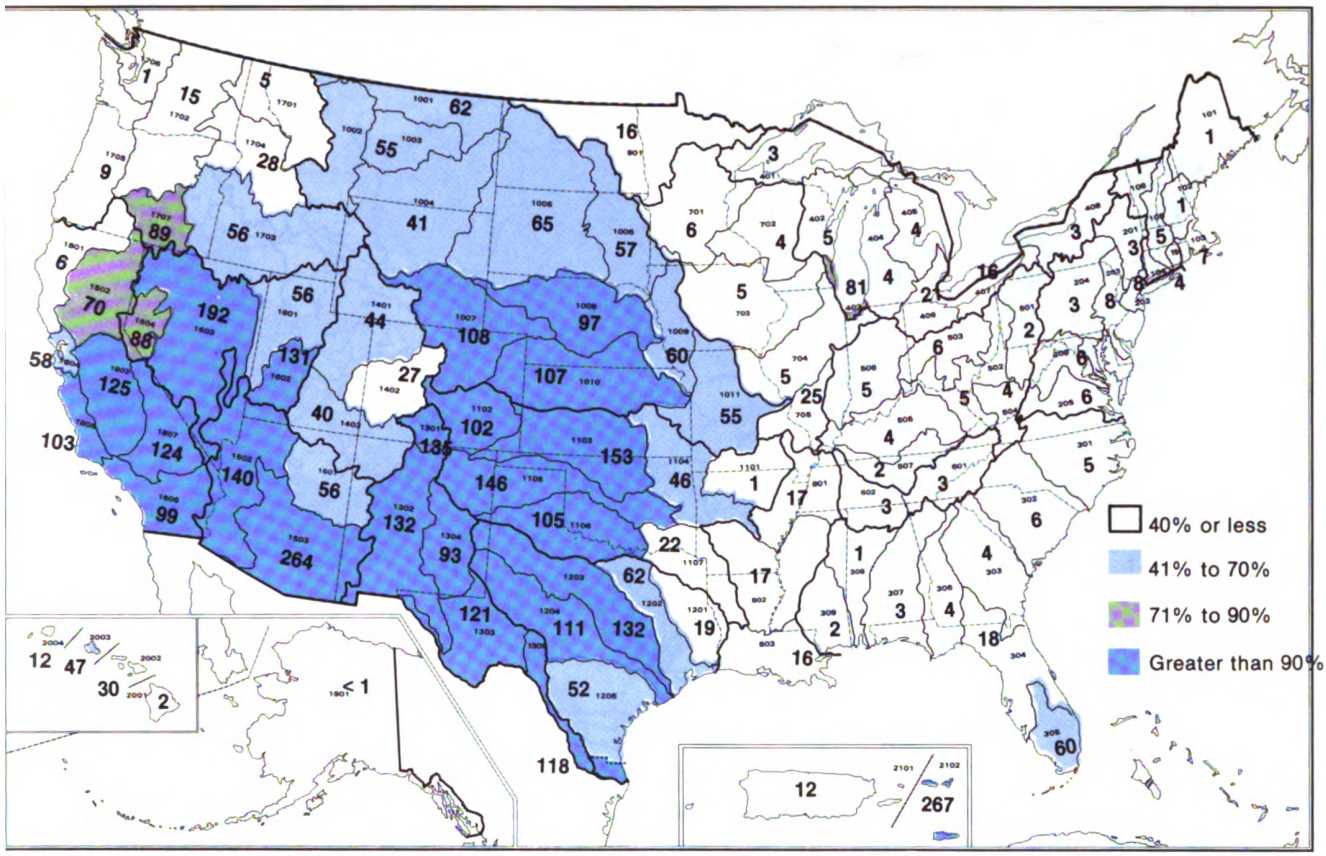

Figure IV-18: Assessed streamflow depletion—2000 (dry conditions)

addition to Tennant's depletion levels, the instream flow approximations can be directly compared to the assessed streamflow to determine conflicts. A conflict arises when the expected streamflow is less than the desired IFA.

Figures IV-19, IV-20, and IV-21 show those subregions where current and assessed annual streamflows are now and would be insufficient to meet the instream flow approximations for "1975" and 2000, respectively.

The comparison of current "1975" streamflow values with instream flow approximation values indicates that conflicts already exist in subregions in the southern Great Plains and the Southwest; moreover, by the year 2000 the estimated instream flow needs may not be met in the northern Great Plains and southern Florida. Some of the future instream-offstream conflicts would actually exist in "1975" if the stream supplies were not being supplemented through ground-water overdrafting. A comparison of the monthly assessed streamflows to the monthly IFA values shows how many months the streamflows will not meet the IFA's (Figure IV-22). The figure shows existing conflicts in the West, but also beginnings of problems in the East.

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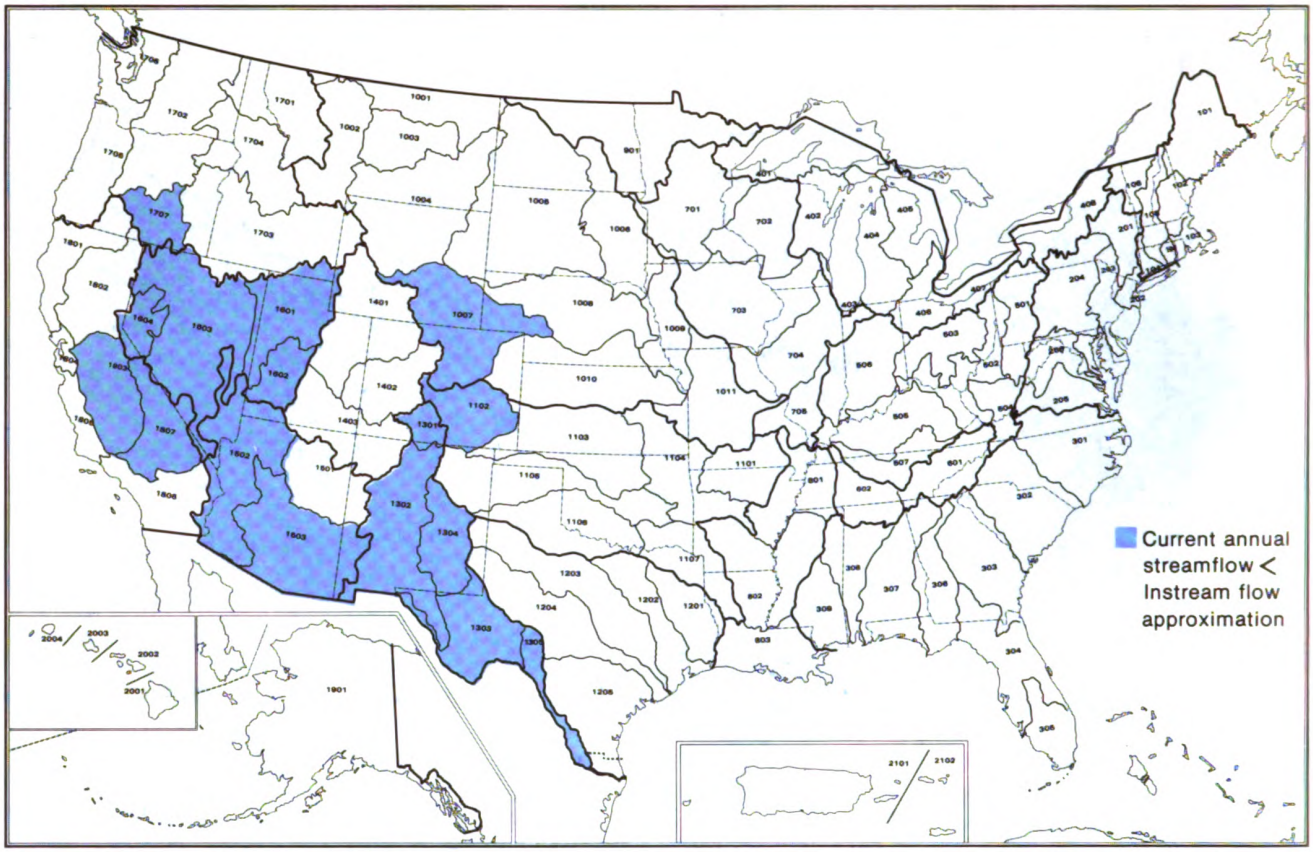

Figure IV-19: Comparison of instream flow with current streamflow—"1975" (base conditions)

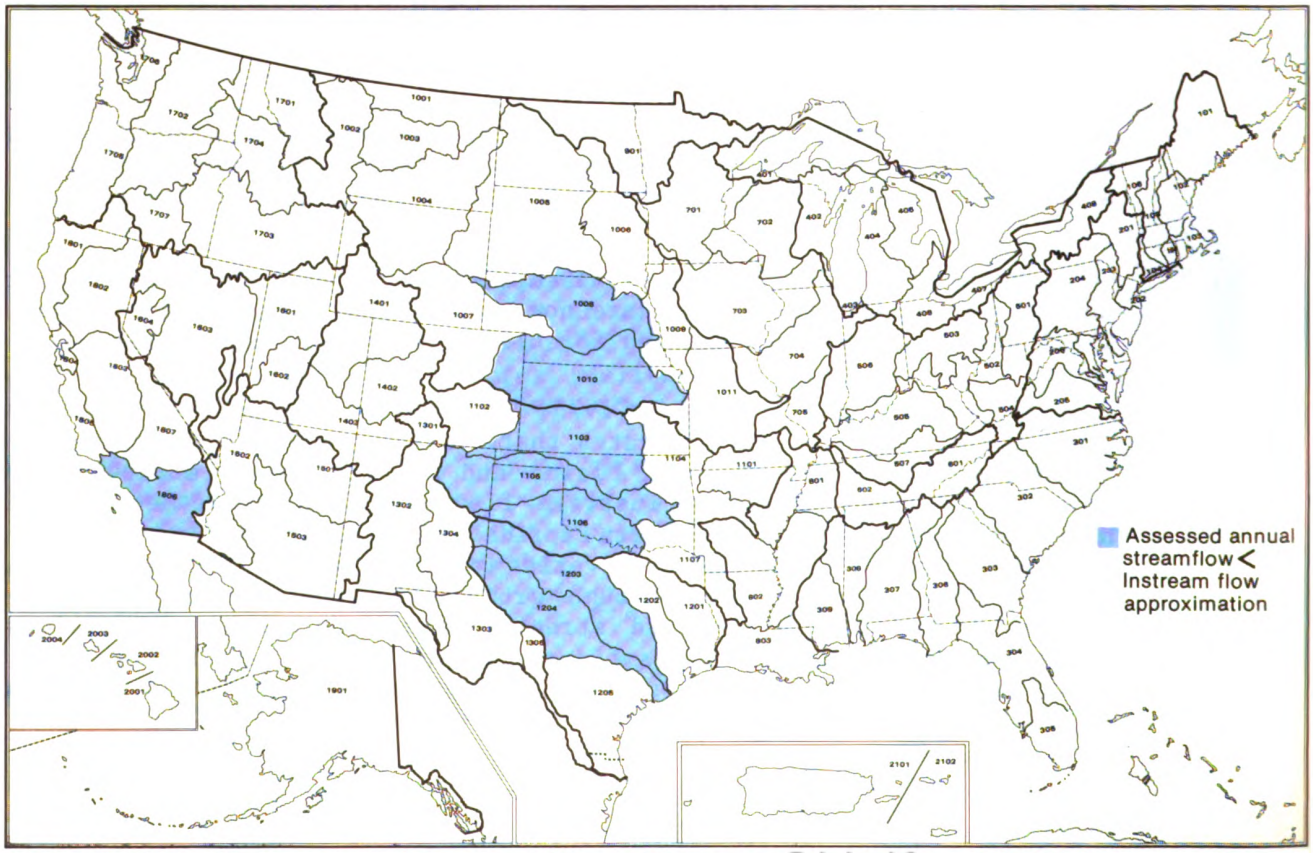

Figure IV-20: Comparison of instream flow with current streamflow—"1975" (base conditions)

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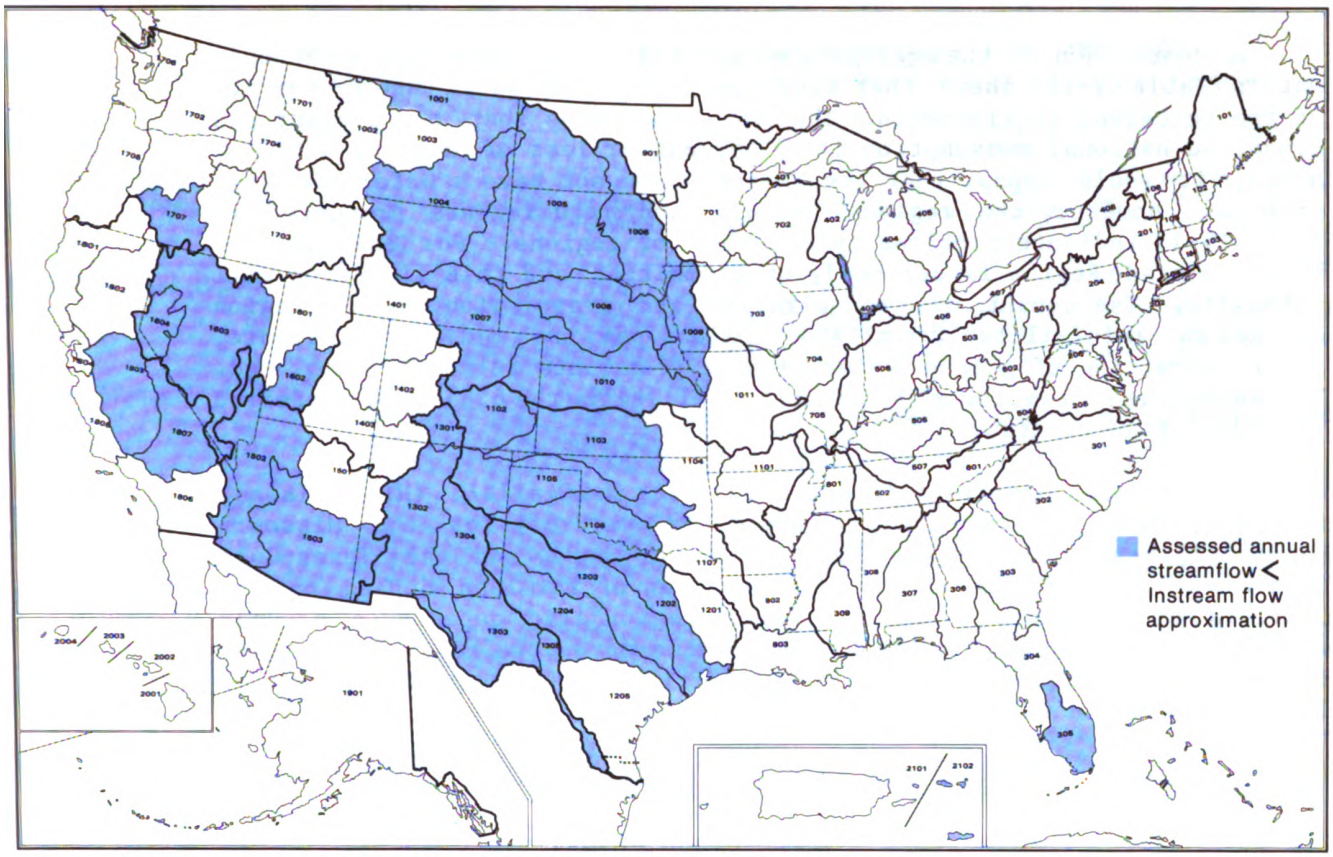

Figure IV-21: Comparison of instream flow with assessed streamflow—2000 (base conditions)

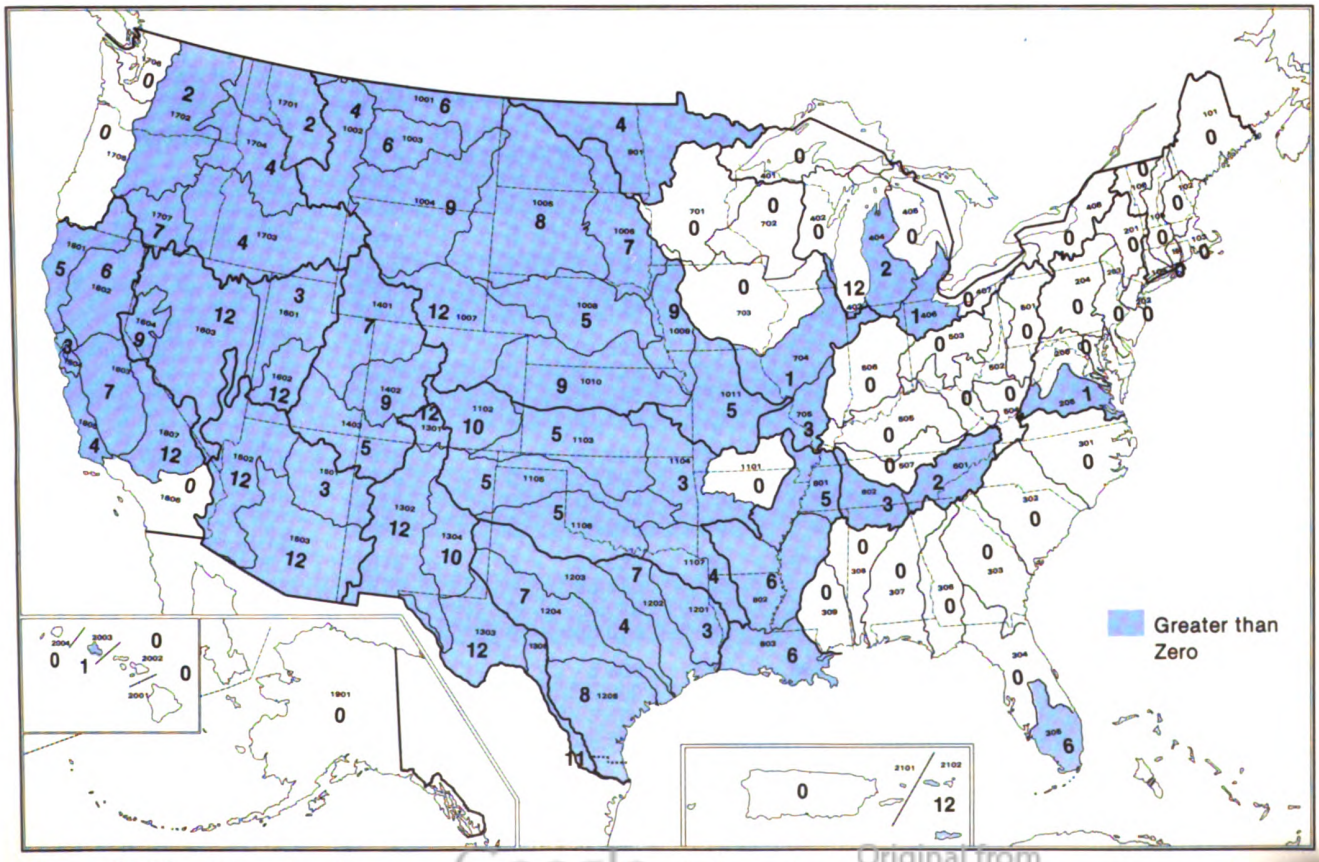

Figure IV-22: Months that assessed streamflow is less than IFA (base conditions)

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A comparison of the aggregate supply and demand data for the Nation's waters (Table IV-13) shows that there is sufficient water supply for all of the perceived requirements. The table indicates that the present and projected national consumption is 10 percent or less of natural outflow. Hence, it would appear that the Nation does not have a water shortage problem. However, the regional supply and requirements presented in Table IV-13 indicate problems in a number of regions. For example, the Lower Colorado Region is seriously overcommitted and this situation will intensify. The amount of transpiration and evaporation in that region exceeds the rainfall by 605 million gallons per day (mgd). Furthermore, the overdrafting of ground water presently amounts to about 2,415 mgd. The resulting streamflow of 1,550 mgd is well below the 6,854 mgd preferred for ideal fish habitat.

Ground-water overdraft is extensive over the Ogallala (High Plains) aquifer. Table IV-9 shows a ground-water overdraft for the Missouri Region (2,557 mgd), Arkansas-White-Red (5,457 mgd), and the Texas-Gulf (5,578 mgd). Approximately 10 million acres of farmland depend on the Ogallala for fresh water. The Rio Grande Region also depends on ground-water overdraft for much of its supply. Furthermore, the remaining streamflow projected for 1985 and 2000 is not sufficient to support the current level of fish and wildlife.

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Table IV-13.—Summary of fresh-water supply and use—"1975," 1985, 2000
(Data are in million gallons per day. Shaded areas reflect conditions without ground-water overdraft)

Water resources region and No.	Year[1]	Supply: Stream inflow[2]	Supply: Natural outflow[3]	Supply: Net imports	Supply: Ground-water overdraft	Use: Total consumption	Use: Net evaporation[4]	Use: Net exports	Remaining stream outflow	Instream flow approximation[6]
New England (1)	"1975"	0	78,661	0	0	481	0	0	78,180	
	"1975"	0	78,661	0	0	481	0	0	78,180	69,001
	1985	0	78,661	0	0	647	0	0	78,014	
	2000	0	78,661	0	0	1,063	0	0	77,598	
Mid-Atlantic (2)	"1975"	0	80,522	479	32	1,843	0	0	79,190	
	"1975"	0	80,522	479	0	1,843	0	0	79,158	68,840
	1985	0	80,522	479	0	2,472	0	0	78,529	
	2000	0	80,522	479	0	3,548	0	0	77,453	
South Atlantic-Gulf (3)	"1975"	0	232,544	0	339	4,867	0	6	228,010	
	"1975"	0	232,544	0	0	4,867	0	6	227,671	188,655
	1985	0	232,544	0	0	6,772	0	6	225,766	
	2000	0	232,544	0	0	10,053	0	6	222,485	
Great Lakes (4)	"1975"	0	75,262	19	27	2,598	0	0	72,710	
	"1975"	0	75,262	19	0	2,598	0	0	72,683	63,951
	1985	0	75,262	19	0	3,300	0	0	71,981	
	2000	0	75,262	19	0	4,693	0	0	70,588	
Ohio (5)	"1975"	40,800	138,998	0	0	1,798	0	0	178,000	
	"1975"	40,800	138,998	0	0	1,798	0	0	178,000	160,520
	1985	40,466	138,998	0	0	2,527	0	0	176,937	
	2000	40,008	138,998	0	0	4,332	0	0	174,674	
Tennessee (6)	"1975"	0	41,113	0	0	313	0	0	40,800	
	"1975"	0	41,113	0	0	313	0	0	40,800	38,480
	1985	0	41,113	0	0	647	0	0	40,466	
	2000	0	41,113	0	0	1,105	0	0	40,008	
Upper Mississippi (7)	"1975"	44,100	76,024	2,064	0	1,145	43	0	121,000	
	"1975"	41,543	76,024	2,064	0	1,145	43	0	118,443	110,750
	1985	37,428	76,024	2,064	0	1,604	45	0	113,867	
	2000	35,880	76,024	2,064	0	2,688	46	0	111,234	
Lower Mississippi (8)	"1975"	361,600	75,015	0	412	4,027	0	0	433,000	
	"1975"	353,586	75,015	0	0	4,027	0	0	424,574	359,033
	1985	346,966	75,015	0	0	4,554	0	0	417,457	
	2000	341,804	75,015	0	0	5,511	0	0	411,308	
Souris-Red-Rainy (9)	"1975"	0	6,138	0	0	112	16	0	6,010	
	"1975"	0	6,138	0	0	112	16	0	6,010	3,673
	1985	0	6,138	58	0	204	18	0	5,974	
	2000	0	6,138	641	0	446	19	0	6,314	
Missouri (10)	"1975"	0	61,525	411	2,557	15,469	4,924	0	44,100	
	"1975"	0	61,525	411	0	15,469	4,924	0	41,543	33,958
	1985	0	61,525	433	0	19,206	5,324	0	37,428	
	2000	0	61,525	0	0	19,913	5,595	137	35,880	
Arkansas-White-Red (11)	"1975"	0	67,694	128	5,457	8,064	2,615	0	62,600	
	"1975"	0	67,694	128	0	8,064	2,615	0	57,143	46,169
	1985	0	67,694	177	0	8,769	2,910	0	56,192	
	2000	0	67,694	200	0	8,887	3,111	0	55,896	
Texas-Gulf (12)	"1975"	0	35,626	30	5,578	11,259	1,705	0	28,270	
	"1975"	0	35,626	30	0	11,259	1,705	0	22,692	22,917
	1985	0	35,626	30	0	10,227	1,875	0	23,554	
	2000	0	35,626	30	0	10,529	1,992	0	23,135	
Rio Grande (13)	"1975"	0	5,309	234	657	4,240	730	0	1,230	
	"1975"	0	5,309	234	0	4,240	730	0	573	2,287
	1985	0	5,309	199	0	4,320	764	0	424	
	2000	0	5,309	199	0	4,016	785	0	707	

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Table IV-13.—Summary of fresh-water supply and use—"1975," 1985, 2000 (continued)
(Data are in million gallons per day. Shaded areas reflect conditions without ground-water overdraft)

Water resources region and No.	Year[1]	Stream inflow[2]	Supply			Use			Remaining stream outflow	Instream flow approximation[6]
			Natural outflow[3]	Net imports	Ground-water overdraft	Total consumption	Net evaporation[4]	Net exports		
Upper Colorado (14)	"1975"	0	13,956	0	0	2,440	711	805	10,000	
	"1975"	0	13,956	0	0	2,440	711	805	10,000	7,947
	1985	0	13,956	0	0	3,018	721	985	9,232	
	2000	0	13,956	0	0	3,232	728	1,095	8,901	
Lower Colorado (15)	"1975"	10,000	-605	0	2,415	4,595	1,202	4,463	1,550	
	"1975"	10,000	-605	0	0	4,595	1,202	4,463	[5]-865	6,864
	1985	9,232	-605	0	0	4,754	1,222	4,084	[5]-1,433	
	2000	8,901	-605	0	0	4,708	1,236	3,896	[5]-1,544	
Great Basin (16)	"1975"	0	5,976	101	591	3,779	327	0	2,562	
	"1975"	0	5,976	101	0	3,779	327	0	1,971	3,389
	1985	0	5,976	177	0	3,765	331	0	2,057	
	2000	0	5,976	251	0	4,036	333	0	1,858	
Pacific Northwest (17)	"1975"	0	268,523	47	627	11,913	2,014	0	255,270	
	"1975"	0	268,523	47	0	11,913	2,014	0	254,643	214,004
	1985	0	268,523	47	0	14,610	2,055	0	251,905	
	2000	0	268,523	47	0	15,196	2,083	0	251,291	
California (18)	"1975"	0	68,050	4,438	2,197	26,641	669	0	47,375	
	"1975"	0	68,050	4,438	0	26,641	669	0	45,178	32,607
	1985	0	68,050	4,069	0	27,932	679	0	43,508	
	2000	0	68,050	3,881	0	29,699	686	0	41,546	
Regions 1-18	"1975"	0	1,330,331	2,677	20,889	105,584	14,956	0	1,233,357	
	"1975"	0	1,330,331	2,677	0	105,584	14,956	0	1,212,468	1,035,221
	1985	0	1,330,331	2,677	0	119,328	15,944	0	1,197,736	
	2000	0	1,330,331	2,677	0	133,655	16,614	0	1,182,739	
Alaska (19)	"1975"	0	905,058	0	0	58	0	0	905,000	
	"1975"	0	905,058	0	0	58	0	0	905,000	859,000
	1985	0	905,058	0	0	207	0	0	904,851	
	2000	0	905,058	0	0	459	0	0	904,599	
Hawaii (20)	"1975"	0	7,353	0	0	605	1	0	6,747	
	"1975"	0	7,353	0	0	605	1	0	6,747	4,590
	1985	0	7,353	0	0	636	1	0	6,716	
	2000	0	7,353	0	0	666	1	0	6,686	
Caribbean (21)	"1975"	0	5,181	0	13	343	0	0	4,851	
	"1975"	0	5,181	0	0	343	0	0	4,838	3,706
	1985	0	5,181	0	0	374	0	0	4,807	
	2000	0	5,181	0	0	300	0	0	4,881	
Regions 1-21	"1975"	0	2,247,923	2,677	20,902	106,590	14,957	0	2,149,955	
	"1975"	0	2,247,923	2,677	0	106,590	14,957	0	2,129,053	1,902,517
	1985	0	2,247,923	2,677	0	120,545	15,945	0	2,114,110	
	2000	0	2,247,923	2,677	0	135,080	16,615	0	2,098,905	

[1] The second "1975" shows "1975" data without ground-water overdraft for a more direct comparison with the conditions for 1985 and 2000.

[2] Flow across international boundaries is not shown.

[3] Estimated water supply generated within each region. Negative values indicate that evaporation and plant transpiration are greater than rainfall in the region.

[4] From manmade reservoirs with storage capacities larger than 5,000 acre-feet and from farm ponds and lagoons. If precipitation exceeds evaporation value is zero.

[5] Negative values show the amount of excess water use without ground-water overdraft. Streamflow will be maintained to meet commitments to Mexico.

[6] U.S. Fish and Wildlife Service estimates for optimal fish and wildlife habitat conditions.

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Conclusion

Offstream uses (especially extensive development of irrigated agriculture) stress the stream ecosystems. When protection for aquatic ecosystems is lacking, these uses severely threaten fish and wildlife that depend on the river flow. While this analysis stresses the severity of the western water problems, it also indicates that instream flows are of concern in the East as well.

Implementation of multidisciplinary and multiagency efforts are required to:

1. improve the methods for collecting instream flow data
2. develop and correlate analytical techniques to systematically determine instream flow requirements for all instream uses
3. find solutions to the institutional problems encountered by those attempting to implement the recommendations.

Current and future planning and decisionmaking must include instream ecological values and must also provide and protect a supply of water sufficient to sustain these values.

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Water Quality

Introduction

Man's pollution of the water environment is one way in which he changes for the worse the world around him. Although to some degree, all organisms modify their environment, at times their habitat is altered so drastically that their own existence is put into jeopardy. Man differs in the extreme degree to which he can destructively modify his environment. While man also differs in his ability to evaluate the consequences of his actions, the tendency to view the environment within narrow boundaries -- such as a town or stretch of water -- often interferes with objective evaluation. Our technological society, however, has expanded its perspective on environmental problems and their control, bringing an increasing realization of the disturbing ramifications of environmental perturbation. To evaluate the disturbance to and prospects for water quality is the purpose of this chapter. Toward this end, the section will discuss three aspects of the water quality problem: (1) national patterns of water pollution; (2) sources of water pollution; and (3) control of water pollution.

The first part of this section discusses the types of pollutants that affect the health of human beings, plants, animals, and biological communities and the incidence and severity of these pollutants. Because pollution affects different water bodies in different ways (e.g., rivers do not assimilate pollution in the same way as lakes), the first part concludes with a discussion of the diversity of pollution's effects.

While the first part assesses national patterns of water quality, the second part analyzes the sources of water pollution. To a large degree, the legal control of pollution depends upon the nature of the source that discharges it. Sources of pollution have been defined as either point, such as municipal and industrial discharges, or nonpoint sources, those not readily identifiable. Polluted runoff is an example of a nonpoint source since atmospheric fallout, traffic residues, litter, and construction sites all contribute to the pollution that eventually reaches the water. The purpose of the second part is to characterize the importance of these pollutant sources. The analysis in that part is constrained, however, by available data. Because systematic national data are lacking, only estimates of biochemical oxygen demand (BOD) and total suspended solids (TSS) are available to compare the importance of point and nonpoint source pollutants. Ideally, a national assessment should be based, not on specific pollutants or classes of pollutants, but rather on categories of effects that are produced. But such information is even more limited.

The third part on contol of water pollution discusses the control of both point and nonpoint sources. The debate over costs of regulation and the risks of less stringent regulations is increasingly focusing on certain issues such as the pretreatment of industrial wastes and the control of toxics.

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For this section, every attempt was made to employ and contrast information from a variety of sources. For example, the Council on Environmental Quality provided the displays of mean levels and annual violation rates for a number of different pollutants. The Environmental Protection Agency supplied trend data on these parameters from the STORET data base. The Water Resources Council supplied estimates of pollutant sources which formed the basis for the map displays in the second part. Finally, much of the cost information comes from publications of the Bureau of Economic Analysis, U.S. Department of Commerce. Since the issues of water quality are varied and complex, this chapter can only superficially analyze a subject so large in scope.

National Patterns of Water Pollution

The basic concept of pollution stems from its Latin root, polluere, meaning to soil or defile. This early definition included only the physical aspects of pollution -- impurity or foulness. Today pollution may be diverse and complex. For example, thermal pollution does not defile or degrade the water according to the early meaning of pollution. In a modern context, pollution encompasses anything that changes the natural quality of water.

Pollutants fall into four major categories: (1) chemical, (2) biological, (3) physical, and (4) physiological. Within these categories, the types of measurements are manifold and the criteria are not always well defined. Indeed, the effects of pollution are increasingly complex.

(1) Chemical materials discharged into water may be either organic or inorganic. Undesirable inorganic materials include heavy metals or other toxic substances and soluble salts that change the pH of water. Organic compounds in water can deplete oxygen and harm biota by accelerating bacterial growth, which uses up dissolved oxygen for oxidation. Organics of particular concern are pesticides and other toxic or hazardous substances.

(2) Biological contamination was the center of early systematic and scientific investigations of water pollutants. The paramount danger from this source is the threat to public health. Vectors of waterborne diseases include: bacteria, viruses, protozoa, and the helminths. Some bacteria-caused diseases are cholera, typhoid fever, and bacillary dysentery. Infectious hepatitis and poliomyelitis are diseases transmitted by waterborne viruses. Amoebic dysentery is a disease caused by a protozoan, and schistosomiasis is caused by the helminths.

(3) Physical pollutants are varied: discoloration, turbidity, temperature, suspended solids, foam, and radioactivity. Some, like color, though not harmful, are undesirable for uses such as drinking water. Others, heat being one, seriously affect living organisms. Each species tends to have its own range of favorable temperatures. Thermal pollution can disrupt the temperature range natural to a given species. The effects of thermal pollution may be lethal or, at sub-lethal levels, can alter a species' life span, activity, and reproduction. The tremendous growth in cooling water for electrical generating stations has increased the awareness of how heat can pollute water.

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(4) Physiological pollution is a special problem for drinking water. Although science has advanced methods of detection, extremely small quantities of some pollutants can be tasted or smelled. For example, chlorophenols can be tasted at extremely low concentrations. Fish that absorb or ingest such pollutants may be eliminated as a food source because of their tainted odor or taste.

The following discussion will consider several specific groups of pollutants of special concern today.

Toxic Chemicals

Concern over toxic substances in the environment has greatly increased in recent years. Their manufacture, disposal, and transportation have become the center of legislation and regulation. Many believe that toxic pollutants represent the most devastating threat to water quality and public health. Some chemicals that are essential to life in certain quantities may be toxic in greater quantities; yet the balance between these extremes is not always known. Moreover, each year man synthesizes many new chemicals.

The number of chemical compounds in existence today is in the millions and those in commerce, in the thousands. With ongoing research and development, over a thousand new chemicals are developed each year in response to the public demands for new and better synthetic products. The sheer numbers involved have resulted in inadequate data on the effects of these compounds.

Many of these toxic substances are extremely persistent and often accumulate in bottom sediments of streams and rivers, which can cause death, reproductive failure, or other damage to fish and wildlife. But much has yet to be learned about the extent and the effects of toxic pollutants on natural populations and human health. The danger is that: large amounts of accumulated toxic material could be introduced into the human food supply; or this toxic material might perturb the ecosystem because of the sudden or gradual removal of populations essential to the system. Toxics in concentrations below currently detectable limits may have sub-lethal effects that can become apparent only after long periods of observation.

Heavy Metals

The serious pollutants in aquatic environments are those that: (1) reach the system in large amounts, (2) are toxic, (3) concentrate within an organism to a level greater than that in the environment, and (4) persist for long periods of time. Heavy metals, by these criteria, are an important problem in the quality of the Nation's waters. These elements are termed "heavy" partly because of their comparatively high density and partly because of their moderate chemical activity as compared to the alkaline earth elements. They are considered here as one group of toxic pollutants.

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One source of information on the severity of these problems is an annual report by the States that describes current water quality and identifies important problems within each State. This annual report is required by the Clean Water Act (Public Law 95-217) as an inventory of water quality problems. Toxic metal pollution was cited by 35 of the 45 States that reported water quality problems to EPA in the 1976 National Water Quality Inventory. In another study done by the National Commission on Water Quality, 12 of the 41 sites analysed had a major problem from heavy metals. The National Commission on Water Quality was established by Congress to make a thorough study of what effects might accompany the achievement of the mandated water quality goals. The 1975 draft report of this temporary commission serves as another source of information on national water problems.

Generally, the problem is widespread because of our manifold use of heavy metals and because of the diverse methods by which they are transported to the receiving water. Mercury, for example, is a ubiquitous material. It is found frequently in nature and is in demand by various industries. It is employed in dental supplies, mechanical devices and instruments, electrical processes, paints, agriculture, pharmaceuticals, plastics, and synthetic products. In 1974, the U.S. demand for mercury was approximately four and one half million pounds. Industrial discharge and urban storm-water runoff transport heavy metals to water in heavily populated regions. In other areas, mining, soil erosion, and atmospheric fallout of air pollutants contribute large amounts.

Because of the vapors emitted in its liquid metallic elemental form, mercury has traditionally been considered a public health threat in media other than water. Mercury in water has been a concern only in the last two decades. In the 1950's, the danger of mercury in water presented itself in Japan, where fishermen and their families around Minamata Bay suffered a neurological illness that was eventually traced to the consumption of fish containing high concentrations of the element. Later studies proved that micro-organisms could convert any form of mercury to the toxic methyl mercury form. Since then, other pollutants such as cadmium have been identified as pervasive toxics with neurological effects.

Fish exposed to concentrations of mercury in water accumulate the pollutant in tissue and pass the pollutant on through the food chain. This concentration of mercury in the food chain is called "biomagnification." Toxic materials present in low concentrations can be accumulated and "magnified" in higher levels of the food chain since larger numbers of lower level organisms are consumed by the organisms in higher levels. The result is a higher concentration of toxic material per unit of body weight. Given the persistence of mercury, its slow dissipation from sediments, and the ability of organisms to absorb and concentrate it, an aquatic habitat thus contaminated could continue to be polluted for as long as 10 to 100 years after the discharge has ceased.

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Figures IV-23 through IV-24 indicate the nationwide extent of mercury pollution. The first map (Figure IV-23) shows the annual percentage of "violations" for mercury;* in other words, the percentage of measurements taken throughout the year that exceed a reference level (0.5 micrograms per liter). For 1976, no one area exceeded the criterion all of the time, but many areas exceeded the reference level up to 50 percent of the year.

To show trends in mercury pollution, Figure IV-24 compares available data from 1967-69 to 1973-75.** Each map provides a different perspective on that pollutant--one map gives problem areas for a given year,*** the other shows the increase or decrease between the two periods. Many areas have worsened, but unfortunately, the data are inadequate to characterize the Nation as a whole. In fact, the predominant white areas have insufficient data to estimate any change.

Another heavy metal with acute lethal toxicity is zinc. In contrast to mercury, widespread violations are occurring with this pollutant. Figure IV-25 shows five areas that were above the reference level for over 99 percent of the measurements during 1976. Because the reference level was low (50 micrograms per liter), the map to some degree overstates the threat from zinc. Unfortunately, trend information for zinc from STORET is available for only two States, Colorado and Minnesota. A few other areas have sufficient data, but they are scattered and do not provide enough information to gain a clear indication of change over time.

To illustrate the extent of pollution from heavy metals in the United States, Figures IV-26, IV-27, and IV-28 show concentrations of copper, cadmium and lead, respectively. These maps only reinforce what the State reports to EPA and the National Commission on Water Quality site studies have indicated -- heavy metals pollution is a significant problem. Concentrations are in micrograms per liter.

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* Violation is not used here in a legal sense. The standard in the exhibit serves only as a reference to indicate the proportion of all measurements above this benchmark.

** Unlike the NASQAN maps, this exhibit is derived from data contained in the EPA STORET system. STORET was developed to be a repository and a uniform reporting format for water quality data. The data within STORET from sampling stations, have increased to over 200,000. According to EPA, these trend data are derived from comparable stations and periods of record.

***Although the NASQAN station may not report violations (it monitors an entire drainage area) STORET stations within the same drainage area may report a number of violations.

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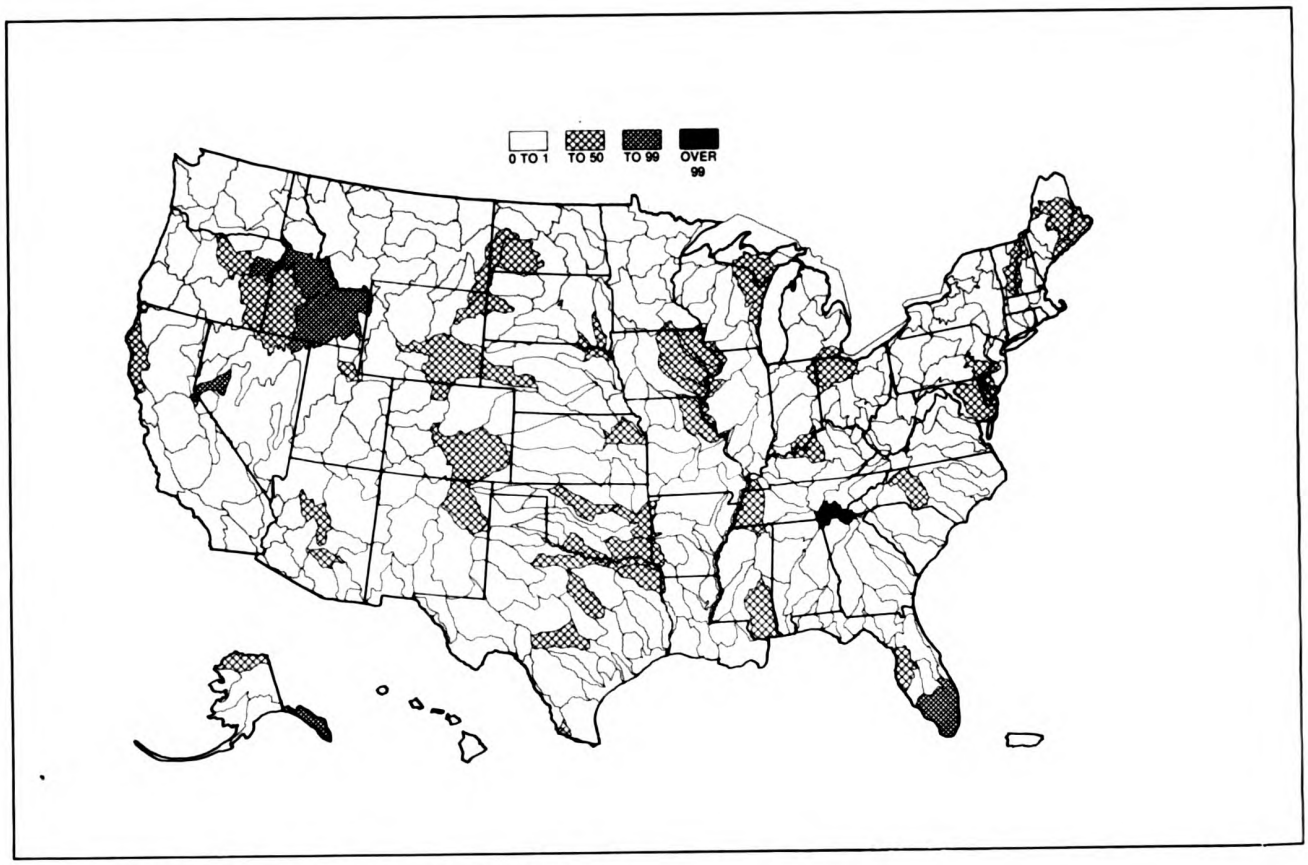

Figure IV-23: Annual violations of mercury use

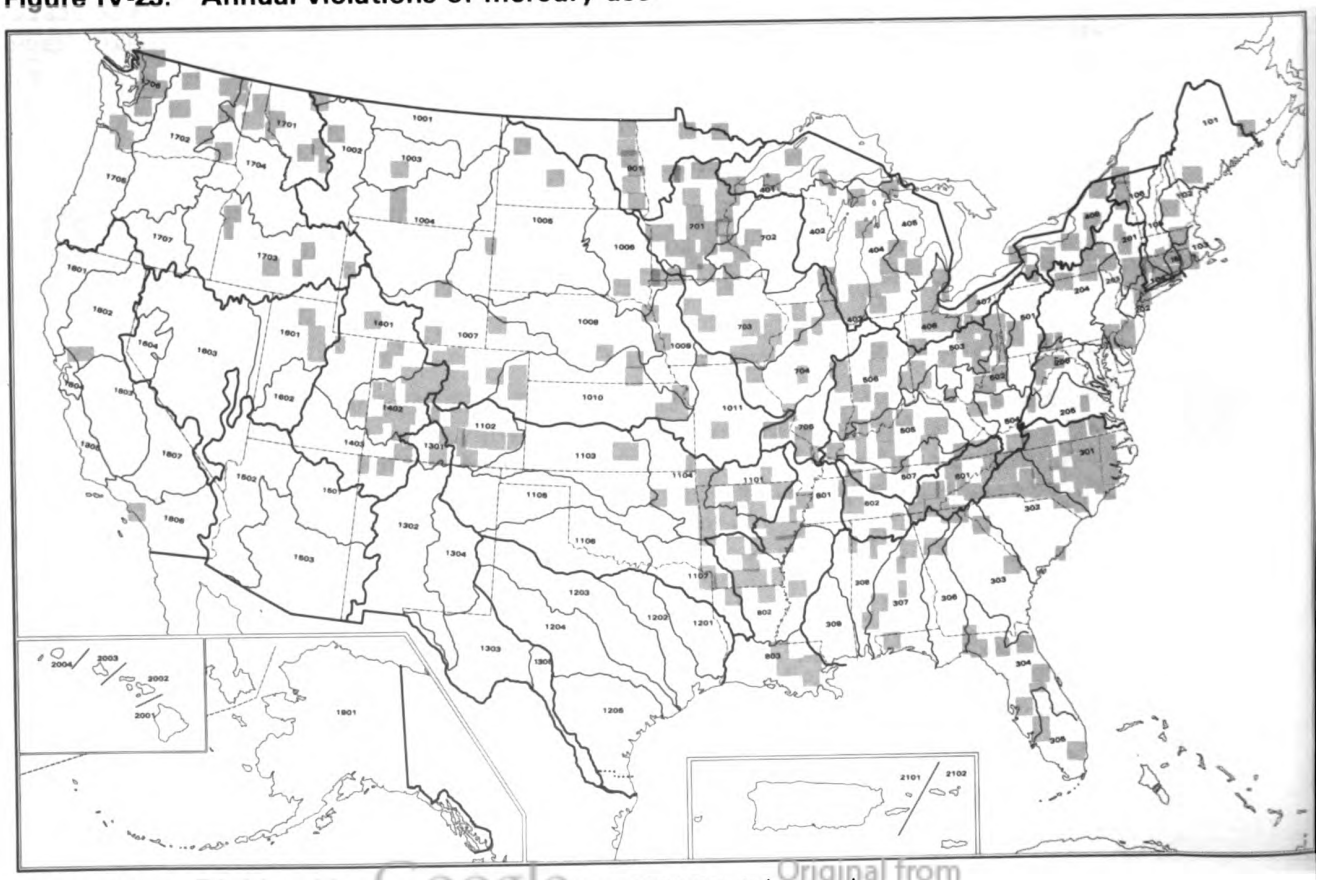

Figure IV-2[illegible] Trends in mercury—1967-69 to 1973-75

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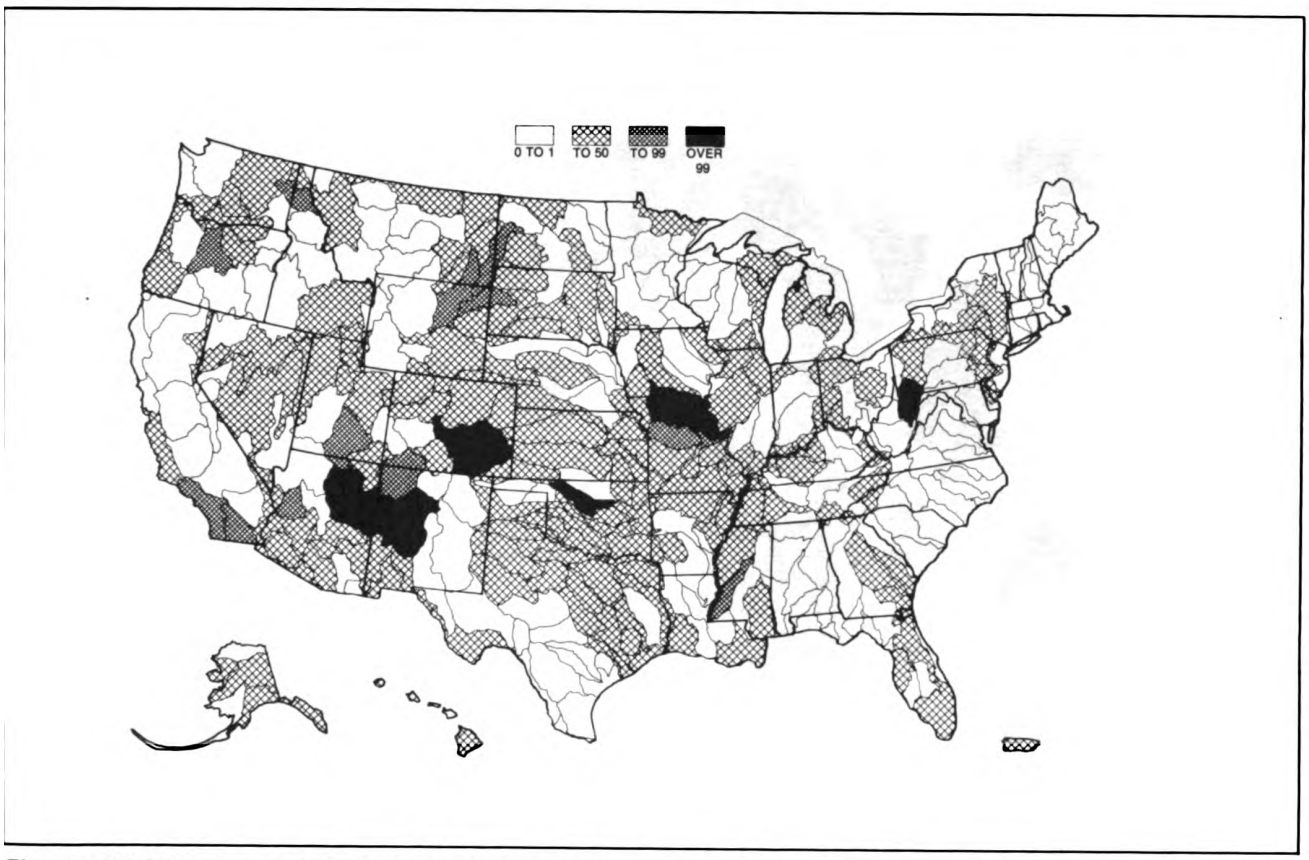

Figure IV-25: Annual violations of zinc use

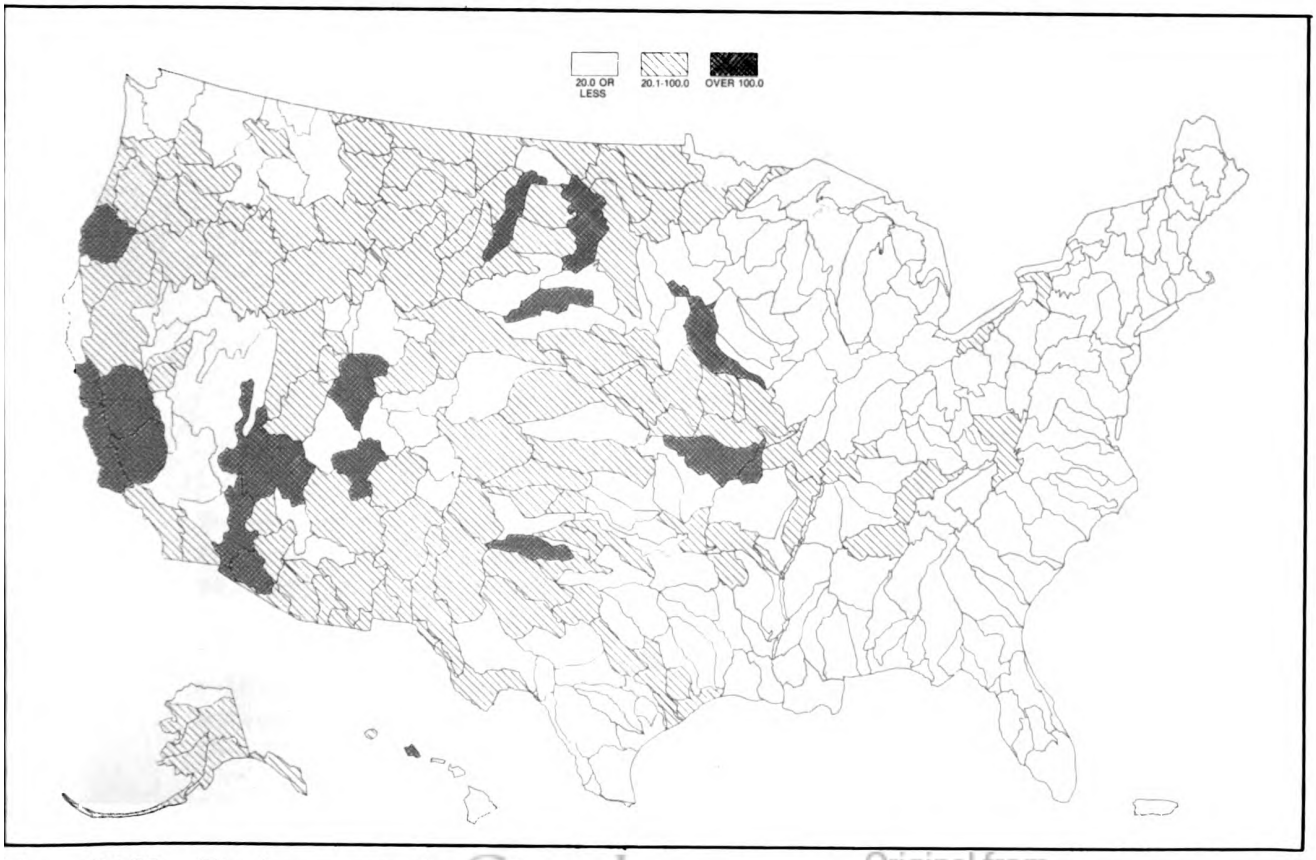

Figure IV-26: Total concentrations of copper

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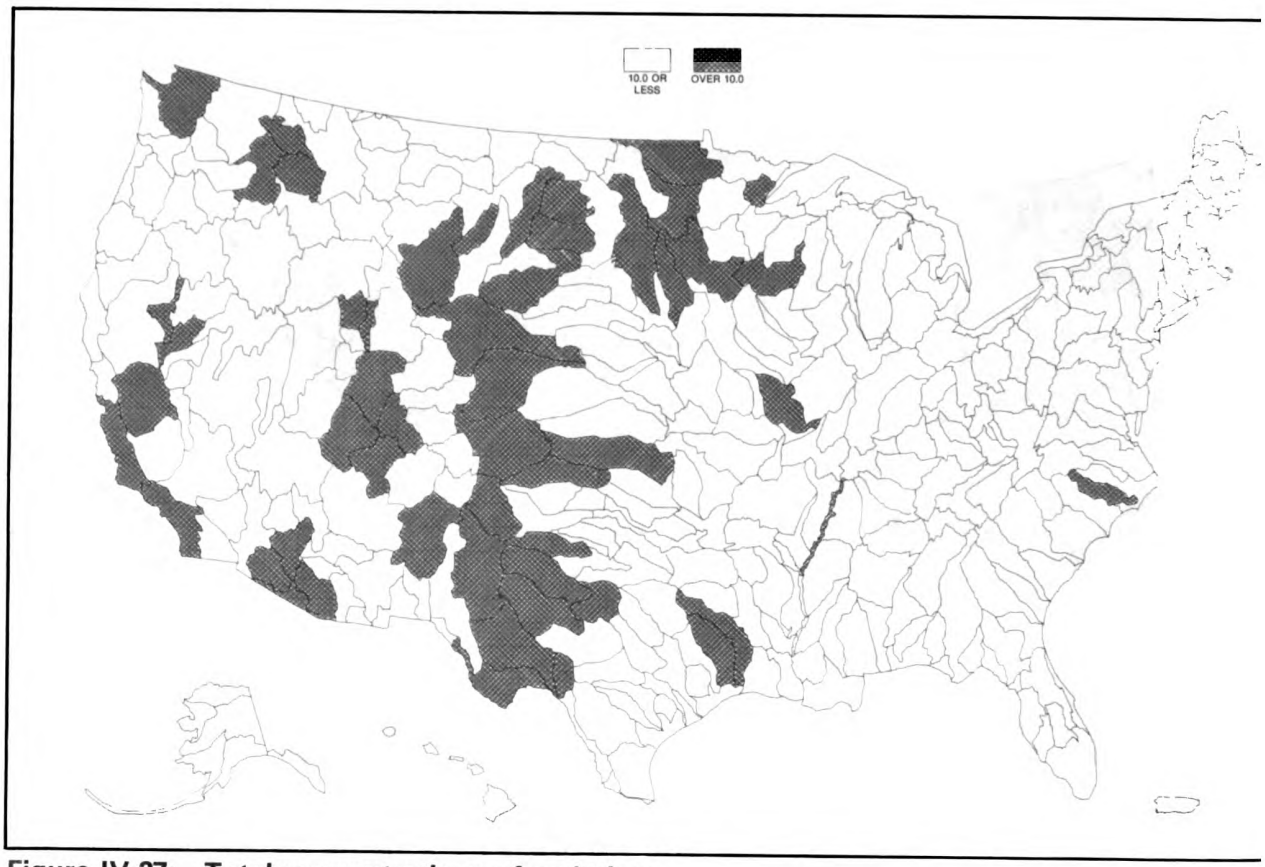

Figure IV-27: Total concentrations of cadmium

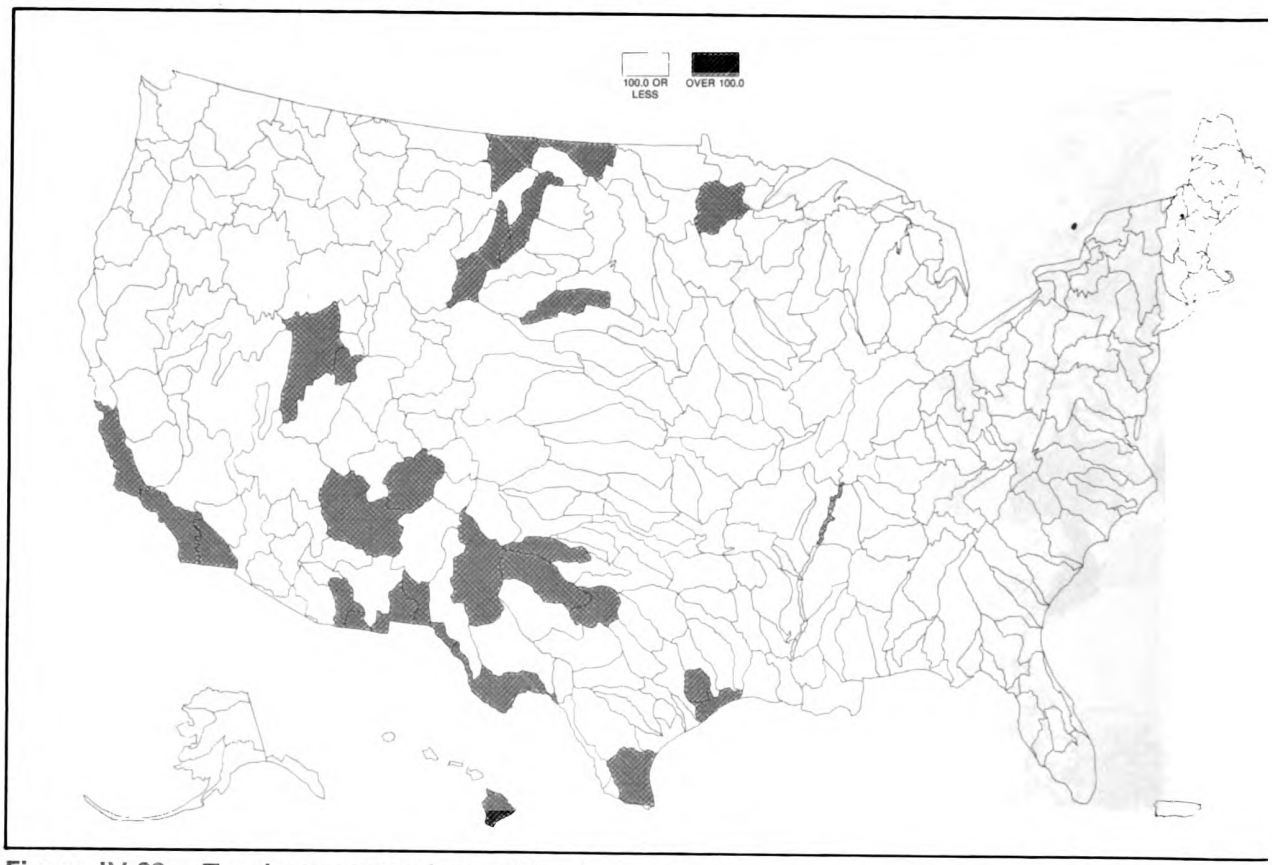

Figure IV-28: Total concentrations of lead

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Pesticides

Over 1,000 basic chemical compounds are now used as pesticides in the United States. Annually, these active materials are mixed into over a billion pounds of pesticides and over 40,000 formulations for use as insecticides, rodenticides, fungicides, herbicides, and plant growth regulators. Pesticides also have toxic effects, depending on the type used, the application, and the transport characteristics of the area. The hazards of pesticides in water include:

- o In aquatic biota accumulation of pesticide residues to lethal levels or accumulation in the food chain
- o Reduced productivity of biota
- o Interactions with other pollutants (e.g., increased temperatures may increase the DDT absorption in fish several fold).

Among the more alarming effects of some pesticides are their suspected teratogenic, mutagenetic, and carcinogenic consequences.

Over a billion pounds of synthetic organic pesticides are used each year in the United States. If this quantity were blanketed uniformly over the Nation's 3.6 million square miles, about 275 pounds of active pesticide ingredients would be deposited annually on each square mile of land. However, pesticide use is concentrated in agricultural areas and not evenly distributed across the United States. These pesticide residues pollute receiving waters through four principal means:

- o The atmosphere - pesticides are often introduced to the environment by a spray that settles by gravity
- o Sediment runoff - most of the pesticide residues in aquatic systems are washed from cropland in runoff or come from irrigation water. Another related source is urban runoff, since surburban populations use these substances for weed control
- o Effluent - some residues originate from industrial sources or from domestic sewage
- o Accumulation - because of low solubility in water and high solubility in the oils of body tissue, levels accumulate in aquatic biota, thereby working up the food chain.

Because of their prevalence, persistence, ease of transport to and passage through aquatic systems, coupled with their toxic effects, pesticides significantly threaten water quality.

Pesticide pollution is a widespread problem. Eighteen States in their submissions to Congress reported pesticide contamination of water quality. Moreover, in the site studies of the National Commission on Water Quality, 14 of the 41 sites had major problems from pesticides. One highly publicized

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incident of pesticide pollution involved the unlawful discharge of kepone, a criminal case resolved in October of 1976, with a total 8.85 million dollar fines levied against Allied Chemical Corporation and Life Science Products. Though high, this dollar amount does not represent a full assessment of damages.

The control of pesticides is primarily directed to the manufacture and distribution of these substances. The Federal Insecticide, Fungicide, and Rodenticide Act as amended, prohibits any person from holding for sale or distribution into interstate or intrastate commerce any pesticide that is not registered in compliance with the Act. The law also prohibits any person from using any registered pesticides in a manner inconsistent with its labeling.

A number of pesticides have been suspended, cancelled, or restricted in use. DDT, endrin, chlordane, dieldrin, and aldrin are examples. How effective have these restrictions been in improving the quality of the receiving waters? Much remains unknown about the fate of restricted pesticides. Aquatic contamination with DDT and its metabolites can be expected to remain for a considerable time. Because much of the contamination is associated with aquatic sediments, the ultimate fate of DDT will depend on what happens to these sediments. For example, DDT-laden sediments can be overlayed with fresh uncontaminated sediments and later be resuspended. But recent evidence supports the conclusion that pesticide levels have been reduced as a result of pesticide restrictions. A Canadian study has reported that in Lake St. Clair, residues of DDT, HEOD, and PCB declined between 1970 and 1974; this coincided with restrictions on these materials. The study did not, however, discuss the longer-term effects of these compounds on biota.

In contrast to the Canadian study, a recent study by the Council on Environmental Quality (CEQ) supports the conclusion that use of restricted pesticides may continue.* The CEQ has concluded:

> The most significant finding of the study was the prevalance of several cancelled or restricted pesticides in water samples. Even though sales of dieldrin were greatly restricted by EPA in 1973 and its major uses were suspended in 1974 because of its carcinogenic properties, dieldrin residues were still often detected in 1976. Dieldrin was detected in 21 percent of all water samples taken last year in the three-state study areas, and the detection rate for the Houston area was 68 percent.

CEQ concluded: "These high rates of detection, especially for dieldrin, raise the question whether these chemicals are being used extensively despite regulations." If so, what are the sources of these restricted

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* Council on Environmental Quality, Recent Trends in Pesticide Residue in Streams in Texas, Louisiana, and Oklahama (draft), 1977.

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materials? Although available information indicates the positive effect of bans on pesticide use, some restricted use of pesticides may continue. Since these substances have demonstrated serious adverse environmental effects, their continued use, despite legal restriction, is alarming.

Other Toxics

Although the many toxic substances cannot be dealt with in depth in this chapter, they should be mentioned because they are important. The most commonly described industrial chemical compounds that contribute to water pollution are cyanides, phenols, and polychlorinated biphenyls. Of these toxics, six states reported problems with cyanides, 11 with phenols, and seven with PCB's.

Threats from these substances vary. For example, standards for cyanide are based upon toxicity to fish, not to man. In reasonable doses in man, cyanide can be readily converted to less toxic forms; however, cyanide in fish can be very toxic at low concentrations.

The effects of phenols vary with the particular chemical form and the general nature of the total waste. For man, phenols affect the taste and odor of drinking water and fish. Phenolic pollution may be produced through chlorination of public water supplies and treated sewage. Phenolic compounds in waters chlorinated for disinfection may form chlorophenols.

The term PCB refers to a family of organic chemicals--polychlorinated biphenyls--that has been produced and marketed in this country for 45 years. PCB, one of the most stable organic compounds known, accumulates in the tissues of many organisms. The PCB problem has been demonstrated in many areas of the United States. Several years ago, prohibitively high levels were found in the oysters of Escambia Bay, Florida. Early in 1976, the Hudson River was closed to commercial fishing because of PCB contamination. For the same reason, portions of the Great Lakes fisheries have been closed. Fish in Georgia, South Carolina, Kentucky, and Idaho have been found to contain high levels of PCB. Because of their persistence and long-term toxicity, PCB's have become an increasingly publicized concern. EPA has estimated that free PCB's available through air and water dissipation have amounted to 150 million pounds since 1932; other estimates place the figure at 180 million pounds. Although these compounds have been restricted, their presence in the environment remains significant.

Bacteriological Contaminants

The diseases transmitted by human fecal matter include typhoid fever, hepatitis, dysentery, encephalitis, poliomyelitis, psittacosis, and tuberculosis. Concentrations of fecal coliform bacteria are used as an indicator of potential human health hazard in surface and ground waters. While these particular bacteria are not harmful, they do provide a comparatively simple-to-obtain indication of the degree to which human and animal fecal matter, which can transmit disease bacteria and viruses, are present in the water.

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The many point and nonpoint sources of bacteria include municipal treatment plant effluents, combined sewer overflows, urban feedlot and agricultural runoff, septic fields, and natural sources such as migrating waterfowl that congregate in large numbers at certain waterbodies. For most areas of the country, however, the major problems arise from urban centers. These problems are exacerbated by streamflow variations that affect the dilution of sanitary waste loads.

Seasonal effects, however, may vary in importance according to the type of surrounding land use. From its National Water Quality Surveillance System, an EPA analysis of data showed that during the summer months (where lower flows and higher temperatures are common), 71 percent of the stations below municipal areas had severe problems and another 25 percent had intermittent problems; in rural areas only 16 percent of the stations had severe problems and another 34 percent had intermittent problems (Figure IV-29).

The National Commission on Water Quality reported that municipal point source discharges were the major source of bacteria in 32 of the 34 sites with significant problems. Urban runoff and combined sewer overflows contributed to the problem in nine of these segments, while agricultural sources were major contributors in two sites and moderate contributors in 16 sites.

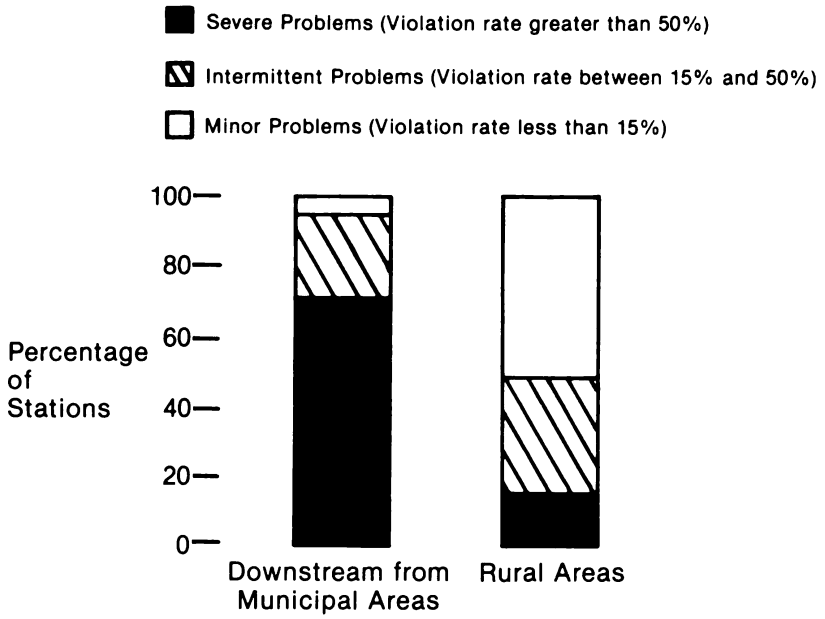

Figure IV-29: Violations of criteria for fecal coliform bacteria

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While municipal sources may contribute most to the bacteria problem on the national level, certain areas of the country are more affected by other sources. The central States report that feedlots and agricultural runoff are their major sources of bacteria. Resort areas with no central sewer systems often have problems with leachates from septic fields that contaminate surface and ground waters. This is a particular problem in areas such as the Colorado mountains where the soil is not suitable for septic systems.

In many coastal areas around the country, bacterial contamination has curtailed shellfish harvesting. The National Commission on Water Quality reported that 14 of its 16 estuarine study sites included areas closed to shellfish harvesting for health reasons. In the State water quality reports to Congress, almost all of the Northeastern and Middle Atlantic States describe areas where shellfish acreage has been closed to harvesting because of bacterial contamination from sewage discharges, combined sewer overflows, and urban and agricultural runoff. In 1975, the EPA New England regional office estimated that the total potential value for shellfish areas closed by pollution in New England exceeded $15 million per year.

Bacteriological contamination of fresh waters is, however, the most widely reported problem across the country. The National Commission on Water Quality found that 34 of the 41 sites studied had major problems with bacteriological contamination. The State water quality reports to Congress almost all reported some significant problems from bacteria. For example, Illinois reported that at 98 percent of its sampling stations the bathing water criteria were exceeded at least once. Kansas was another State reporting severe problems from bacteria.

Figures IV-30 through IV-32 present a national overview of fecal coliform bacteria from two perspectives: (1) the annual "violation" rates for 1975 and 1976, and (2) trends in measured levels by a comparison of interval 1967-69 data to 1973-75 data.

In the darkest areas of Figures IV-30 and IV-31, bacterial contamination is greatest. The figures show fecal coliform pollution, which is a measure statistically related to the presence of pathogens in the water. They indicate the percentage of measurements above the criterion for swimming waters (200 cells per 100 milliliters) since the number of coliforms permitted in water depend upon the purpose for which the water is to be used. As can be seen, most areas of the country have violations at least part of the time. On the whole, however, bacteriological pollution has been reduced. From the second perspective, Figure IV-32 shows that 59 percent of the areas with available data had some improvement in water quality in 1973-75 as compared with the years 1967-69, although this does not mean that the problem has been removed.

The trends in reduction are expected to continue, according to the National Commission on Water Quality. Only four of the 34 sites with major identified problems should continue to have major problems from this source after all sewage treatment plants achieve secondary treatment. Moreover, the State water quality reports to Congress cite numerous examples where this form of pollution has been reduced.

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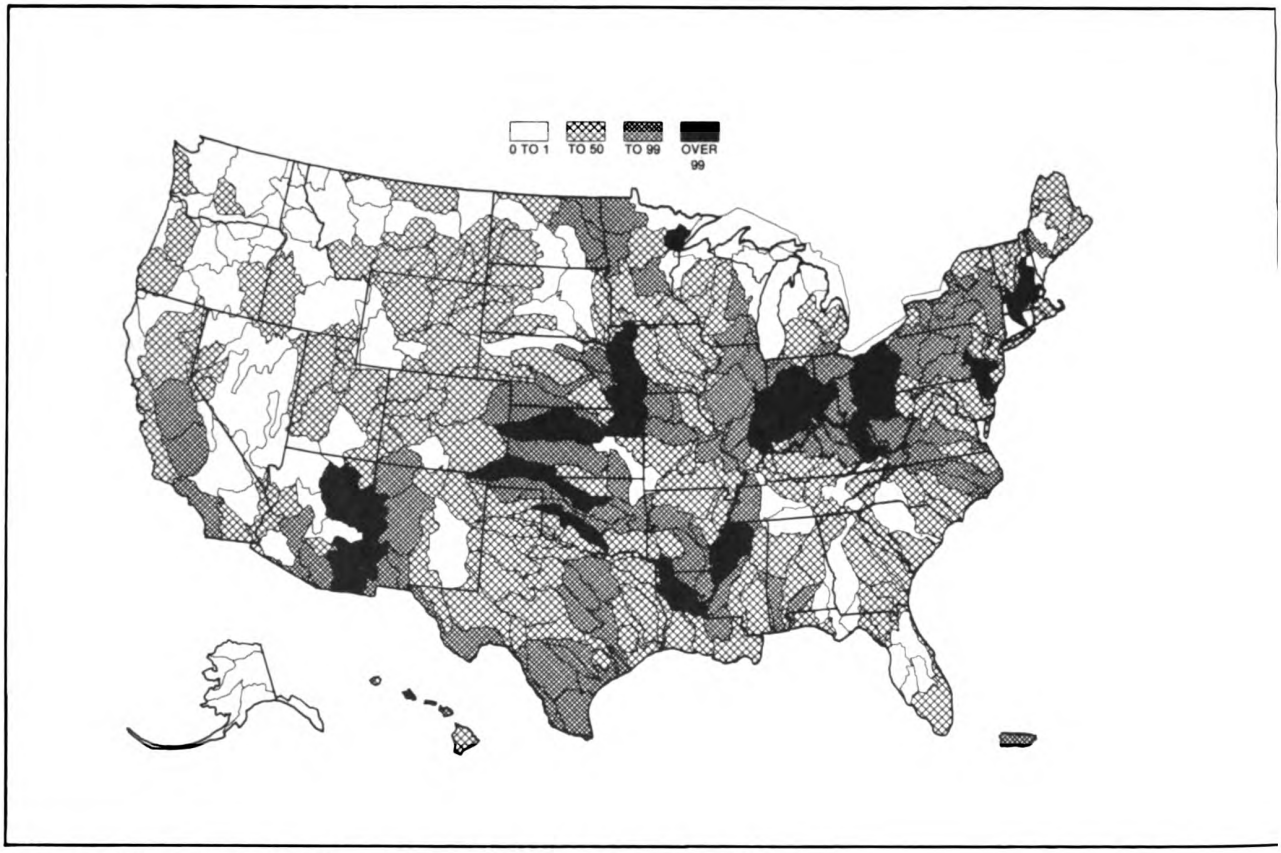

Figure IV-30: Fecal coliform bacteria violation rates, 1975

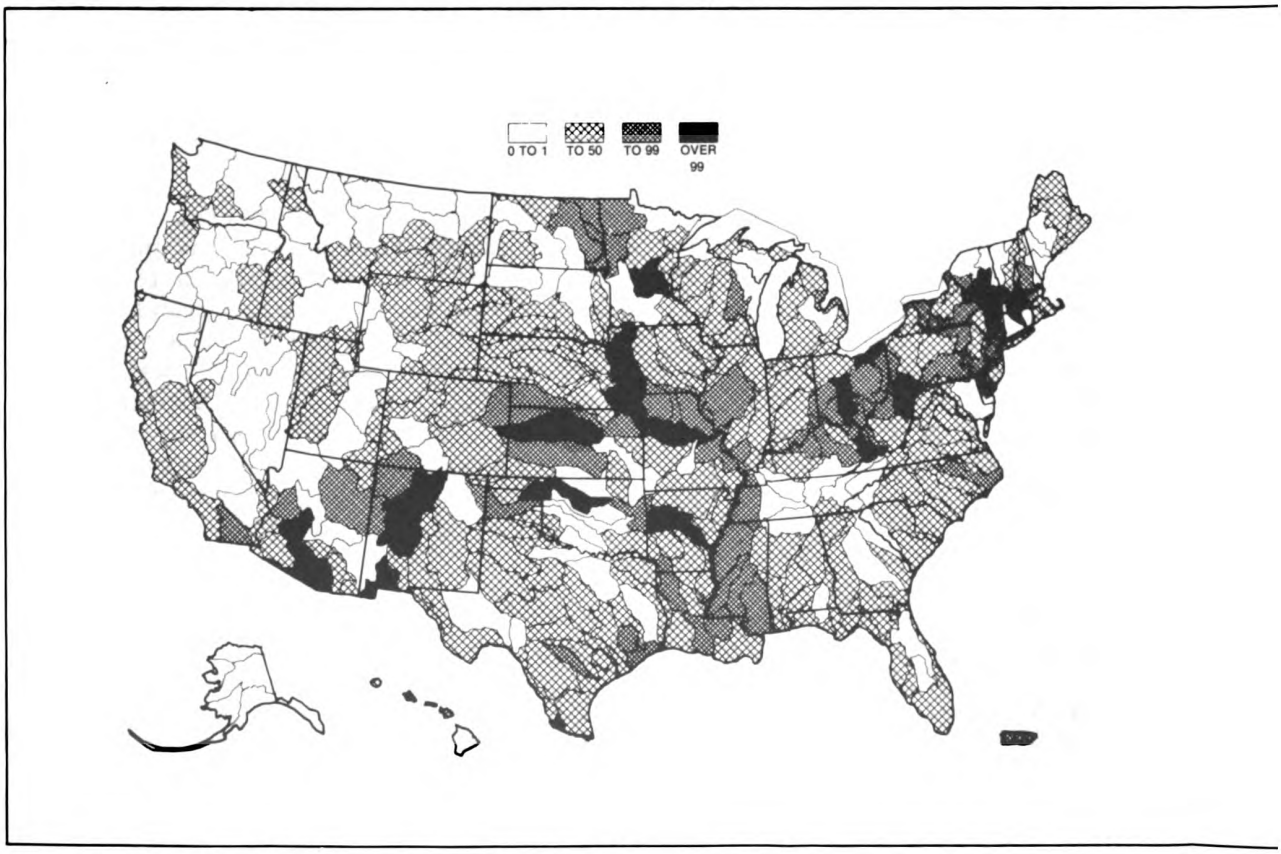

Figure IV-31: Fecal coliform bacteria violation rates, 1976

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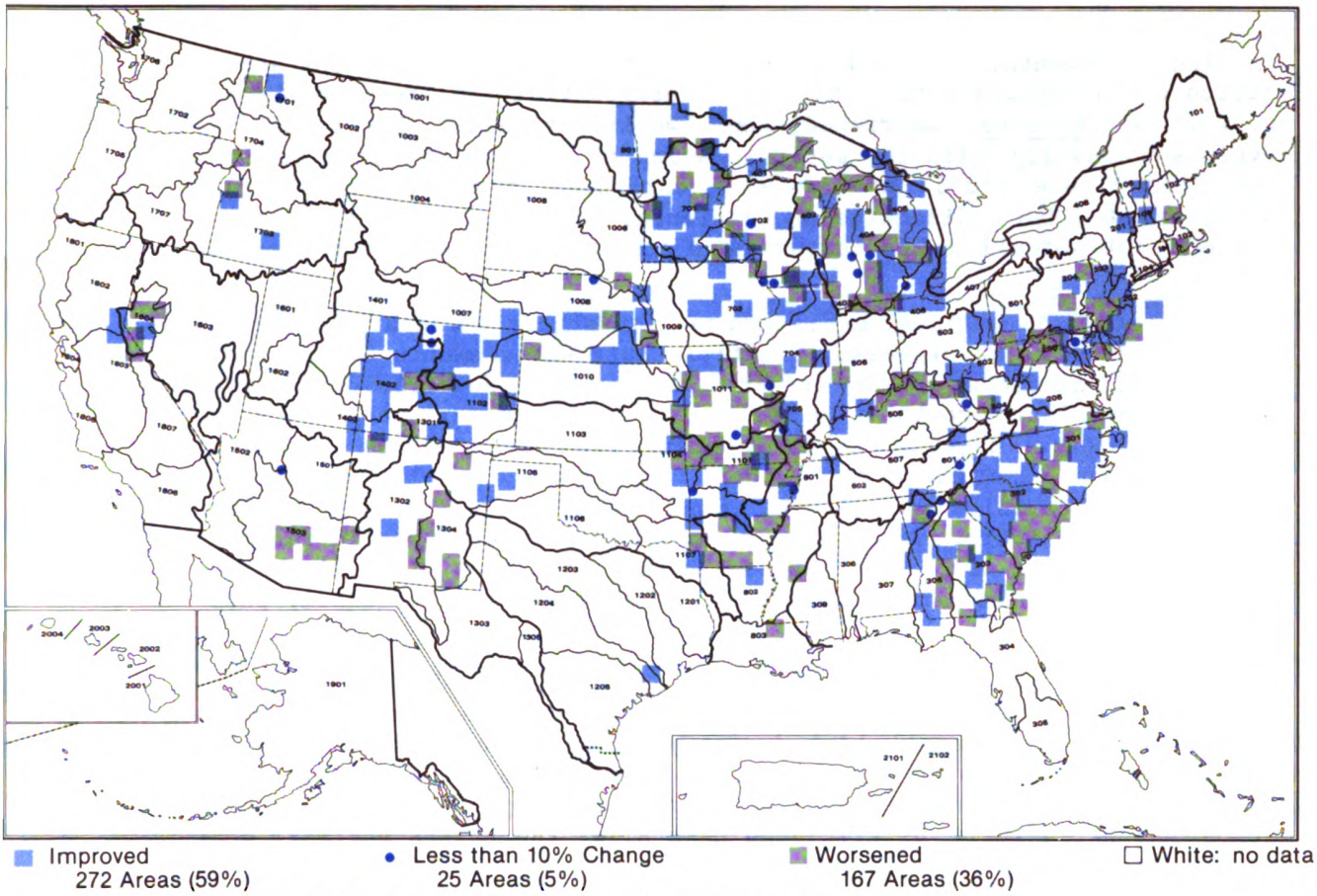

Figure IV-32: Trends in fecal coliform bacteria

Nutrients

The discharge of materials that fertilize or stimulate excessive or undesirable forms of aquatic growth can create significant problems in receiving water systems. Overstimulation of aquatic weeds or algae can:

- Be esthetically displeasing
- Cause a reduction of dissolved oxygen and an increase in CO_2
- Reduce the assimilative capacity of the water
- In extreme cases, interfere with small boat navigation and other recreation uses of the water body.

The problems from excessive nutrients can be severe, causing surface scum, foul odors, and in some cases, the killing of fish when oxygen is depleted.

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The fundamental problem from the discharge of nutrients is the acceleration of eutrophication. This term derives from two Greek morphemes: eu, well and trophos, nourished, thus "well-nourished." Eutrophication develops naturally with the geologic aging of a body of water such as a lake (see Figure IV-33). As a lake ages, enrichment by nutritive materials is increased. Man's discharge of nutrients, however, speeds the process from one that normally takes centuries to one that takes only a few years.

In general, a nutrient is defined as a substance necessary for growth or reproduction of an organism. Multiple nutrient elements are present; the limiting nutrient is the one in the lowest concentration required to stimulate plant growth. Two principal nutrients are phosphorus and nitrogen. Loads of these two enter waterways from many sources including: sewage treatment plant discharges, runoff from urban and rural areas containing organic material, agricultural runoff and irrigation return flows containing fertilizers, leachates from septic fields, atmospheric fallout, and some industrial waste discharges. Sewage treatment plant discharges and agricultural runoff are major sources of nutrients, particularly phosphorus.

EPA analyses show that phosphorus concentrations in streams below municipal areas are generally high during low-flow periods, which indicates that in heavily populated areas, point source discharges are a principal source of phosphorus. In the Great Lakes area, where problematic eutrophication has extensively deteriorated Lake Erie, the States estimate that approximately 50 percent of the phosphorus loadings in their waterways are from sewage treatment plants, and that half of this phosphorus loading comes from phosphate detergents. These estimates were largely confirmed when the State of Indiana reported that stream loadings of phosphorus had been reduced by 25 to 30 percent after a statewide ban on phosphate detergents had been implemented.

The largest total contributor of nutrients is agriculture. Fertilizer is the main source although not all nutrients from agricultural runoff come from fertilizer. Leaching of residues, natural background levels, and rainfall itself are other sources. As shown in Figure IV-34, nutrient concentrations in streams are generally higher in agricultural areas. Further, the National Eutrophication Survey found that runoff from agricultural lands carried more than twice as much nitrogen (Figure IV-35) and almost four times as much phosphorus (Figure IV-36) as did runoff from forest lands. Nutrient concentrations in the agricultural runoff were even more pronounced, since forested areas generally have higher rainfall. Concentrations are in milligrams per liter.

An indication of the widespread nature of nutrient problems comes from two reports: (1) the National Commission on Water Quality found 22 of its 41 sites had major problems, (2) the State reports to Congress in 1976 showed greater emphasis on nutrients. In fact, Vermont, Maryland, and Florida indicated that excessive nutrients were their most serious water quality problem. The above mentioned figures show that nutrient enrichment problems are geographically diverse.

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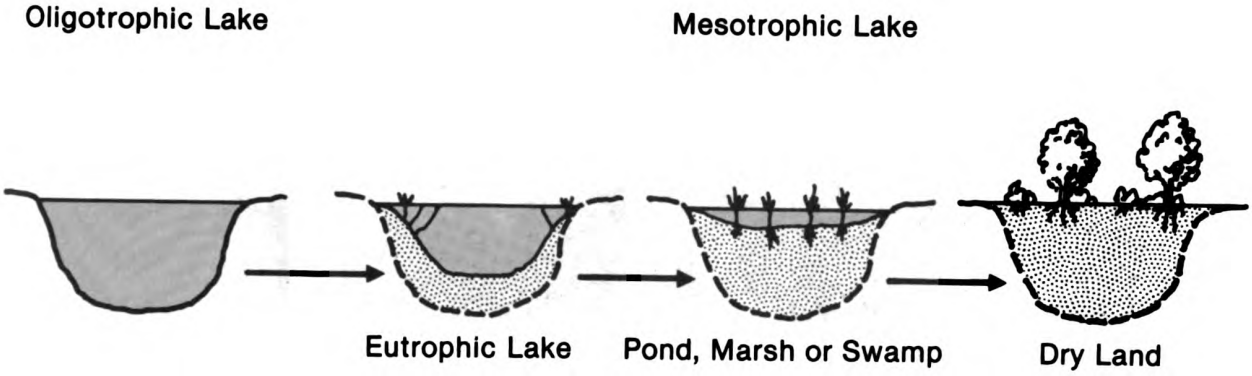

Figure IV-33: The natural eutrophication process

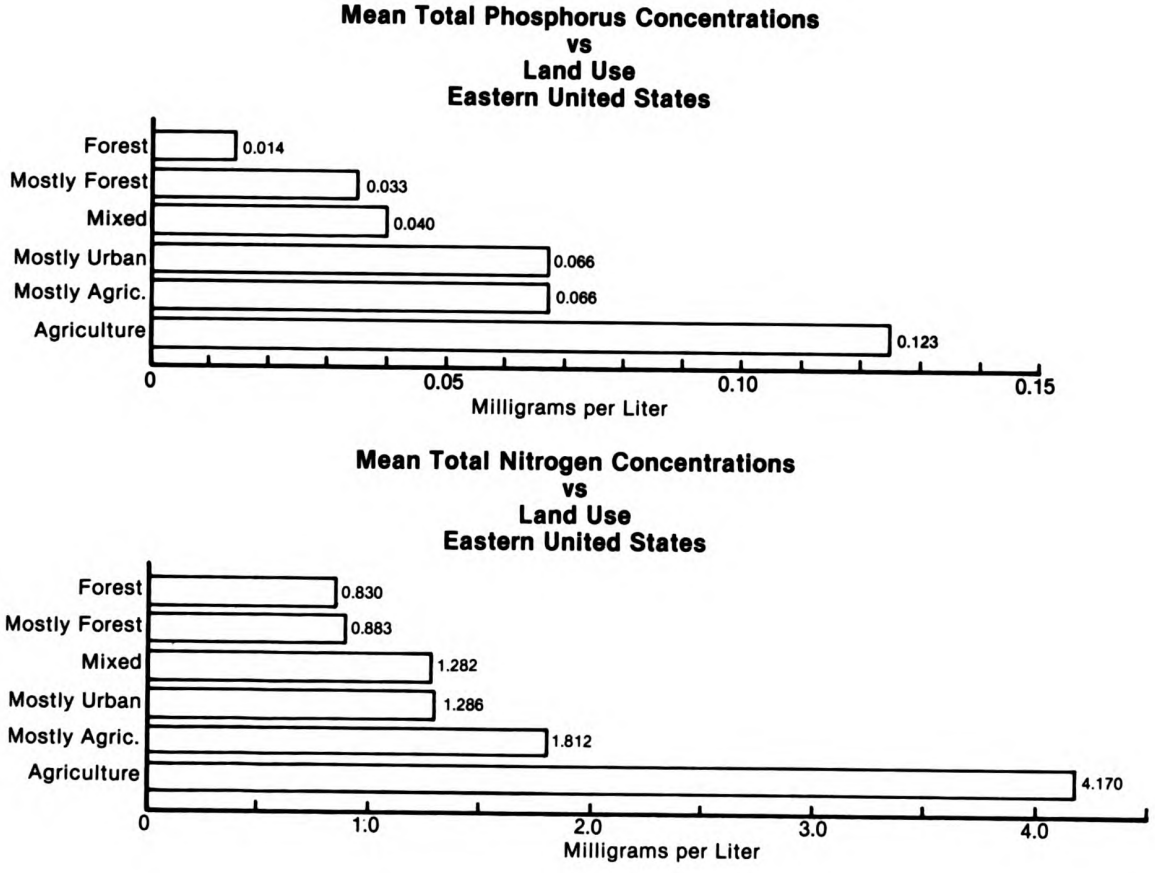

Figure IV-34: Mean total phosphorus and nitrogen concentrations vs land use (Eastern United States)

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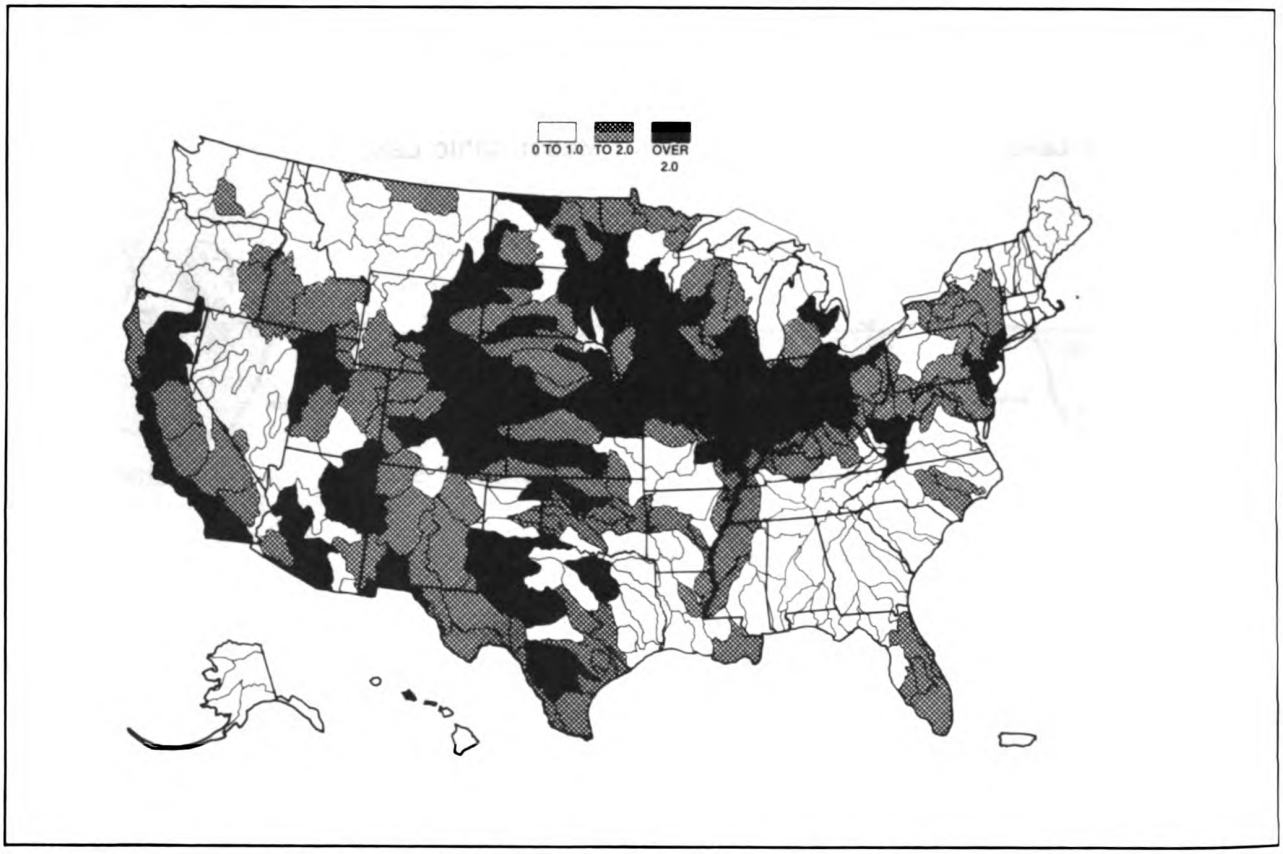

Figure IV-35: Geographic distribution of nitrogen concentrations

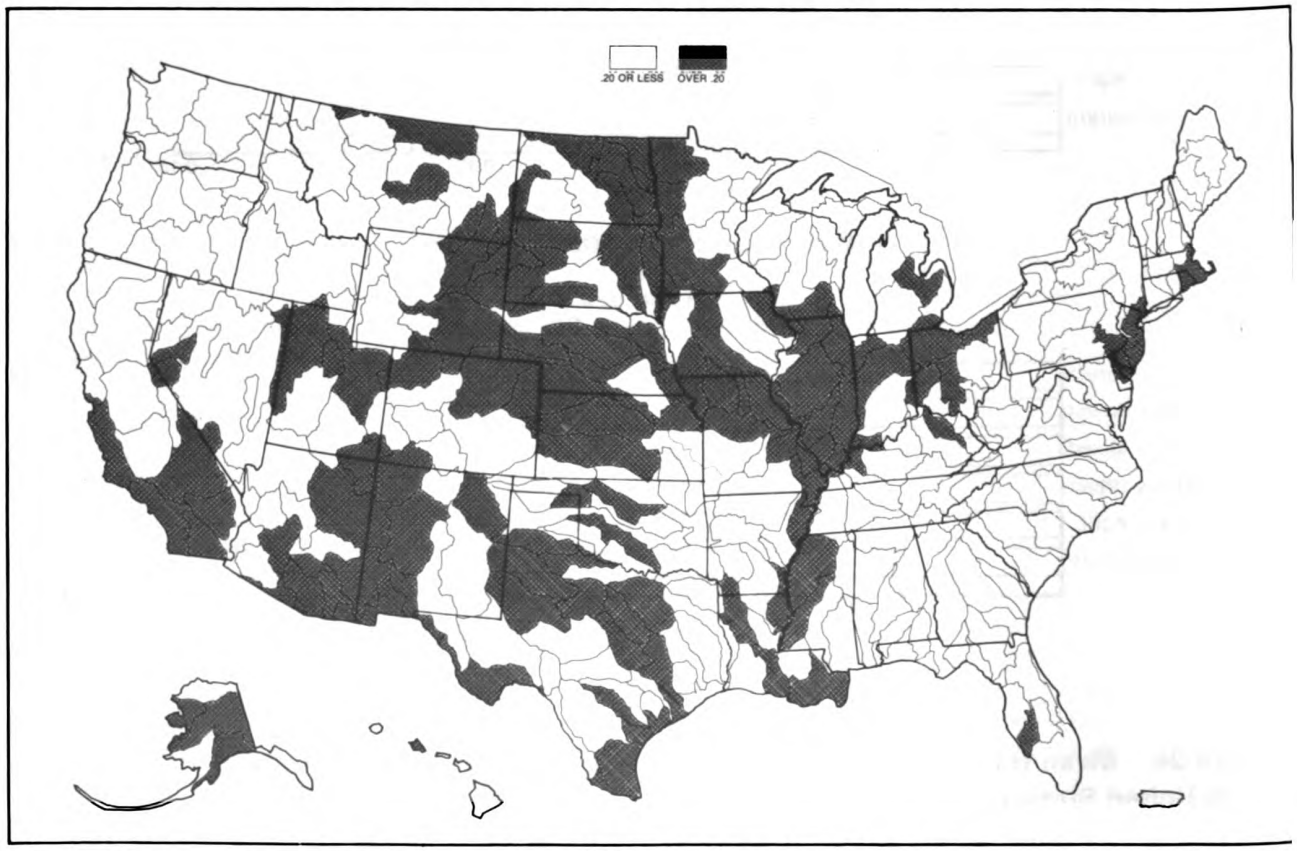

Figure IV-36: Geographic distribution of phosphorous concentrations

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Physical Pollutants

Suspended Solids

Suspended solids consist of silt particles, organic matter, plankton, and other substances found in the water column. These particles affect the beneficial use of water in several ways:

- They reduce light transmission through the water and thereby inhibit the growth of underwater plants that are the primary food source for aquatic life
- They interfere with nursery grounds or other habitats of aquatic life
- Organic suspended solids settle to form oxygen-demanding sludge deposits
- High levels cause esthetic degradation
- They create a taste and odor problem for potable water supply.

By far the largest source of suspended solids is sediment runoff. Although this runoff may occur naturally, it is aggravated by man's activities, primarily agriculture, forestry, mining, and construction. The rate of erosion will depend upon the particular land use as well as the natural conditions prevailing.

Erosion from agricultural lands is an especially significant problem because large quantities of fertilizers, herbicides, and pesticides are washed into the streams along with the soil particles. But erosion in mining areas is another significant source of suspended solids because of the runoff from exposed surface areas, disposal piles, and related construction areas. The regions most affected are the coal mining areas near the Appalachian and Rocky Mountains and other areas where minerals mining is extensive, such as the iron ore mines in Minnesota.

Forestry activities that contribute to erosion include the construction of logging roads, log transport, and clear cutting operations. These activities are found primarily in the Southeast and in the Northwest. Other significant sources of suspended solids include dredge and fill operations, wave turbulence in estuaries, and urban runoff.

According to the recent State reports to Congress, almost every State has some problem with suspended solids from agricultural sediment runoff. STORET data indicate that, on the whole, the levels of this pollutant have not improved.

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Dissolved Solids

Salinity is the concentration of dissolved mineral salts in water. While geographic variations in salinity levels are largely natural, human activity can have a significant influence, particularly in areas where water is scarce.

Excess mineralization can have a number of adverse effects. Human health is affected by excessive flourides, which cause mottling of dental enamel, and by high sodium intake, which is associated with coronary problems. Other effects include objectionable taste in drinking water, corrosion of metals, damage to fabrics being washed, health effects on livestock, and damage to crops being irrigated. While fish and other aquatic life generally adapt to high background salinity levels, abrupt changes may be lethal. The most widespread economic effects result from irrigation waters high in dissolved solids. For example, it has been estimated that for each milligram per liter increase in salinity in the lower Colorado River, there is an annual economic cost of approximately $230,000.

Salinity problems are generally found in two types of geographic areas: coastal areas where sea-water intrusion may occur, and arid areas in the West and Southwest where the fresh-water supply is insufficient to dilute the salt loadings from natural sources and from irrigation return flows.

In coastal areas the major source of salinity is sea water that enters surface waters during low-flow periods or seeps into ground-water storage areas that have been depleted of fresh water. Sources of salinity in inland problem areas are mineral salts in surface runoff and ground-water inflow; other sources may be mineral springs and irrigation return flows. Irrigation return flows contribute high salinity loads because crops utilize much of the irrigation water but leave the dissolved salts in the remaining water. In the West the deep percolation of this irrigation water in contact with mineral formations constitutes another source.

In the Colorado River Basin the natural sources account for about two-thirds of the total annual salt loadings while irrigation return flows account for almost all of the remainder. Municipal and industrial sources account for only a very small percentage of total Colorado River salt loadings.

Methods currently used to alleviate salinity levels are: importation of less saline waters from alternative sources; the interception, impoundment, and evaporation of mineral springs; diversion of runoff and streams around areas of salt pickup; improvement of irrigation conveyance facilities; improvement of irrigation and drainage practices; and desalinization of water supplies at points of use. Increased consumptive use, particularly for irrigation, further reduces streamflows, which means that salt loadings will have to be considerably reduced even to maintain current salinity levels.

Nationally, one of the most severe problems is the intrusion of salt water into fresh ground-water aquifers. Almost all coastal areas that consumptively use ground water face this problem to some extent, since the

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depletion of ground water allows salt water to intrude the aquifers. The following excerpt from the California Annual Water Quality Inventory, one of the State reports to Congress required by the Clean Water Act, indicates how severe the problem can be:

> One of the more serious water quality problems affecting California coastal areas is the insidious intrusion of salt water into fresh-water aquifers. Heavy reliance on ground-water pumping in coastal basins has resulted in numerous instances of reversal of hydraulic pressure gradients and the subsequent inland movement of ocean waters, spoiling what were once high quality fresh-water aquifers. The problem is widespread along the California coast, although it has received attention along the southern California bight.

Excess salinity is also considered the most serious water quality problem in several of the western and southwestern States that make extensive use of their water resources for irrigation. All eight inland study sites where the National Commission on Water Quality found major salinity problems are located in these regions*.

While severe salinity problems are generally located in areas where natural conditions are a major factor, certain other areas, such as the area around the Great Lakes, have increasing chloride levels from heavy concentrations of industrial discharges. The Indiana Harbor Ship Canal in particular has high chloride levels, and Lake Erie has had a long-term increase in salinity. While the chloride levels in Lake Erie are not yet a significant problem, the trend should be noted to ensure that the situation does not worsen to the point where conditions begin to affect fish and aquatic life or human water uses.

Temperature

Thermal pollution can be a significant source of either physical, biological, or chemical harm to aquatic organisms. Temperature affects nearly every physical property of concern in water quality management, including density, surface tension, gas solubility, and gas diffusion. Of these, oxygen solubility is probably the most important; a lower solubility induced by higher temperatures, if combined with an organic effluent and a resulting increased bacterial rate, can deplete dissolved oxygen below fish survival levels. Moreover, temperature has a profound effect on biological activity. Shifts in temperature change the distribution of organisms that are active in waste assimilation. These shifts may dramatically alter the waste assimilation rates. For more complex organisms such as fish, thermal pollution affects activity and reproduction. Temperature affects not only the rate, but also the extent of the chemical action.

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* U.S. National Commission on Water Quality, "Water Quality Analysis and Environmental Assessment, Technical Report," Public Law 92-500: Vol. I, PB 252-167-01-02.

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The two primary dischargers of heat are the steam electric power generation and manufacturing industries. As shown in Table IV-14, these industries discharged a total of about 8.7×10^{15} Btu of heat to the Nation's surface waters in "1975." Of this total, 66 percent is attributed to cooling of electric power generation facilities, whereas, the remaining 34 percent is attributed to the cooling in manufacturing processes using energy.

By the year 2000 about a five-fold increase is projected for the electric power heat dissipation cooling requirements. Due to the provisions in the Clean Water Act and the lack of heat sinks (rivers and lakes) large enough to dissipate the heat, by 2000 most of the waste heat will be discharged to the air by cooling towers or cooling ponds. Therefore, by year 2000 the amount of total heat discharged to the Nation's fresh surface waters is projected to decrease by 51 percent, while the heat discharged to saline waters increases by about 77 percent. A similar expectation holds for the manufacturing industries. The implementation of the provisions of the Clean Water Act will decrease the amount of heat discharged by a factor of ten.

In sum, by the year 2000, 98 percent of the heat discharged to the Nation's fresh and saline waters is projected to come from electric power generation facilities, and 39 percent of those discharges are projected to enter fresh surface-water resources. Regional variations in the heat discharges occur, however. For example, the largest expected decrease in heat discharges is in the industrial Northeast.

Table IV-14.—Heat generated and discharged to the nation's fresh and saline surface waters

	"1975"		1985		2000	
	Btu's x 10^{15}	Percent of total discharged	Btu's x 10^{15}	Percent of total discharged	Btu's x 10^{15}	Percent of total discharged
Electric power generation:						
Heat generated	11.0	-	24.3	-	57.1	-
Heat discharged to water	5.7	66	7.8	98	7.4	98
(Fresh)	(3.9)	(45)	(3.9)	(49)	(2.8)	(37)
(Saline)	(1.8)	(21)	(3.9)	(49)	(4.6)	(61)
Manufacturing:						
Heat discharged to water	3.0	34	0.2	2	0.2	2
(Fresh)	(2.2)	(73)	(0.2)	(2)	(0.2)	(2)
(Saline)	(0.8)	(27)	(0)	(0)	(0)	(0)
Total heat discharged	8.7	100	8.0	100	7.6	100
(Fresh)	(6.1)	(70)	(4.1)	(51)	(3.0)	(39)
(Saline)	(2.6)	(30)	(3.9)	(49)	(4.6)	(61)

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Radioactive Materials

Some mention should also be made of radioactive materials in the aquatic environment. When radioactive materials enter surface waters, they are diluted and dispersed by the same forces that mix and distribute other soluble or suspended materials. But it is very difficult to compare radioactive contamination with other pollutants. Each radioisotope tends to take a characteristic route and has its own rate of movement through various temporary reservoirs. The route taken by tritium is different from that of other radioisotopes. Tritium and strontium 90 picked up in the water molecule cannot be removed by conventional waste treatment practices.

The radioisotopes present in aquatic ecosystems can irradiate aquatic organisms in many different ways:

1. Radioisotopes that tend to remain in solution, or at least suspended in the water, are assimilated more readily by aquatic organisms than the radioisotopes that settle out.

2. Radioisotopes present on or fixed to sediments are significant to aquatic life, particularly to benthic organisms in the vicinity of existing major atomic energy plants.

3. Radioisotopes attached to the outer surfaces of organisms are of greater significance to micro-organisms than to shellfish or fish.

It is, however, difficult to measure the amount of radiation absorbed by aquatic organisms because they are simultaneously irradiated by radioisotopes within their body, on the surface of their body, in other organisms, in the water, and in sediments. Exposure thus depends on an organism's position in relation to the sediments and to other organisms, and to movement of some species in and out of the contaminated area. The principal danger from this type of pollution is that radioactive material will reach man through the food chain.

Conclusions - The Diversity of Effects

The severity of water pollution depends on the type of pollutants in question. However, equally important is the nature of the water receiving the pollution. The receiving waters vary in their ability to assimilate waste, to cleanse themselves. As a concluding note to this section, it is important to stress not only what pollution is, but, how it affects the receiving water.

Receiving waters may be classified as:

- Fresh-water streams and rivers
- Tidal rivers and estuaries
- Lakes and reservoirs
- Harbors and oceans.

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Each of the above has its own characteristics of mixing. In fresh-water streams and rivers a one-directional flow predominates. The river flow or advection is, therefore, the principal mass transport mechanism. Estuaries differ, however. An estuary is that portion of a coastal river where the tidal action from the ocean is the significant transport mechanism. Estuaries have two broad sections: the tidal river portion where the water body ebbs and flows but is entirely fresh water, and the lower estuaries portion where sea salt makes a significant incursion. Both advection and dispersion are important in estuaries. Thus, tidal flows cause a vertical mixing, which makes flows in estuaries more complex in mixing characteristics.

Lakes and reservoirs may also be exceedingly complex in their flow regime. Since no dominant mechanism generally determines the advective flow or mixing (in contrast to rivers and estuaries), the effects of waste loads on lakes and reservoirs are difficult to describe. The lack of these forces sometimes allows stratification to occur.

In these different receiving water systems, the reactions of pollutants will also vary. The types of reactions may be grouped into two categories according to their reaction:

- o Conservative: those that persist in the water column (e.g., certain dissolved solids)
- o Nonconservative: those that decay slowly (e.g., toxic materials) or rapidly (e.g., BOD or biochemical oxygen demand*).

Nonconservative substances can also affect reactions such as BOD on oxygen depletion.

What occurs when a waste is discharged to a receiving water body? Figure IV-37 provides an example of BOD in a river where a hypothetical discharge of organic material has been made at day 0 and mile 0 on the river. Before discharge, oxygen in the stream is approximately 7 parts per million (ppm) and the BOD is approximately 2 ppm -- values which could be expected in a relatively unpolluted river. When the waste is discharged, BOD rises to 20 ppm at time 0 and subsequently falls to a value near that before the waste discharge. Dissolved oxygen accordingly decreases to a minimum and then recovers. With the influx of a waste load, the bacterial growth rate is accelerated and as the dissolved oxygen process goes on, the food is "used up" and BOD declines. Unlike BOD and other traditional pollutants, toxics will persist, especially if mixing forces are not great.

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* The aerobic decomposition of organic matter lowers the concentration of dissolved oxygen in the water. Biochemical oxygen demand (BOD) is a measure of the potential rate of degradation and of oxygen utilization. Thus, the addition of organic substrate increases the BOD. The actual load of organic matter can be inferred by calculation, given the rate of oxygen demand.

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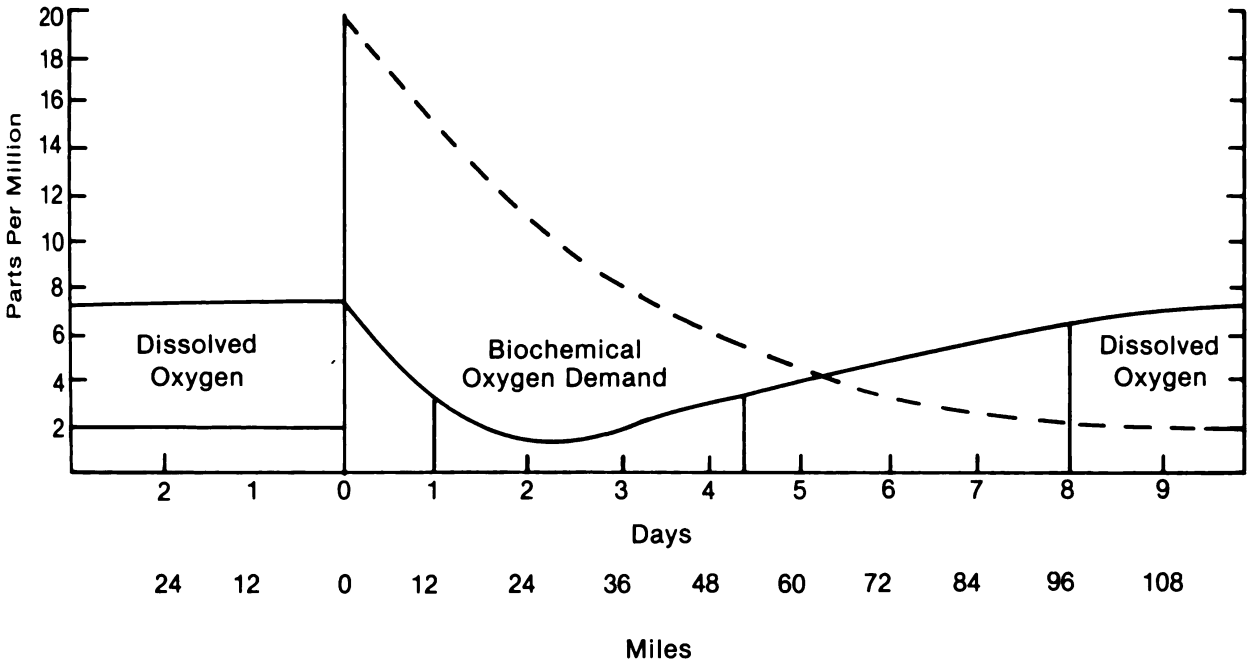

Figure IV-37: Representative inflow of BOD load in a stream

Sources of Water Pollution

The previous part on water quality problems emphasized selected pollutants and partially analyzed their instream effects. Only limited attention was given to the sources of these pollutants. This part examines pollutant sources. Unfortunately, little information exists to characterize adequately pollutant generation by source on a nationwide basis, particularly with diffuse sources.

In general, the sources of pollution are either point or nonpoint, depending on whether the means of discharge is from a discrete conveyance such as a pipe, or generated at and transported over a wide area such as agricultural runoff. The definition of the pollutant source determines the legal means of control available. The Clean Water Act (Public Law 92-500) requires the identification, monitoring, and control of water pollution. In the case of point sources, the Federal and State laws require that technology-based effluent limitations be reached by specified dates. For nonpoint sources, no Federal requirements are analogous to the effluent limitations for point sources. Instead, EPA addresses nonpoint sources through the State and areawide planning mandated by Section 208 of the Clean Water Act.

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Point Sources

The distinction between point and nonpoint sources of pollution is not always clear. Point sources are generally described as those that discharge to the receiving waterbody through a discrete pipe or ditch. However, this definition encompasses a wide range of discharges since runoff from almost any type of area can eventually reach the receiving waterbody by some type of culvert, ditch, or gully. Therefore, in this discussion, point sources are defined as industrial discharges (including large feedlot discharges but not including discharges from other agricultural activities or from mining and forestry areas), municipal sewage treatment plant discharges, and combined sewer overflows.

Industrial Discharges

Pollution problems associated with industrial discharges include oxygen depletion, excess suspended solids, oil and grease, heavy metals, and toxic chemicals. Thermal pollution and pH problems from point sources are also generally attributed to particular types of industrial effluents. For example, cooling-water discharges from electric powerplants can elevate receiving-water temperatures to levels that significantly affect the aquatic life.

Across the country, the effect of industrial discharges on water quality varies in both type and extent. The Northeast and Great Lakes areas are the most affected by industrial discharges, as would be expected. In these two areas, almost 88 percent of the basins were noticeably affected by industrial discharges as compared to about 65 percent for the rest of the Nation (Table IV-15). By contrast, in the Southwest, only 23 percent of the basins were affected by industrial discharges.

Municipal Discharges

Municipal discharges adversely affected water quality in 89 percent of the basins across the country (Table IV-15). As would be expected, the more heavily populated regions generally had a higher percentage of basins affected, although even in the sparsely populated Southwest, 64 percent of the basins had some problems from municipal discharges. Most of these problems arose from inadequate treatment or overloaded treatment plants. The States expected that most problems would be resolved as construction grant funding became available to upgrade treatment facilities.

Combined Sewers

Combined sewers overflow when excessive rainfall runoff is added to normal sewage flows in systems where storm and sanitary sewers are combined. The resulting overflow produces a direct untreated discharge containing pollutants from both the sewage (principally bacteria, excess nutrients, and oxygen-demanding loads) and the urban runoff (principally suspended

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Table IV-15.—Point sources of pollution
(percentage of basins affected[a], by type of point source)

Area (number of basins)	Industrial	Municipal	Combined sewer overflows
Northeast (40)	95	95	60
Southeast (47)	74	91	17
Great Lakes (41)	80	95	37
North Central (35)	74	86	0
South Central (30)	70	100	0
Southwest (22)	23	64	0
Northwest (22)	55	73	14
Island (9)	89	100	0

[a]In whole or part.

Source: Environmental Protection Agency.

solids, heavy metals, oil, and grease). These discharges can severely degrade water quality.

Combined sewers are generally located in older cities, so problems from combined sewer overflows are found primarily in the Northeast and Great Lakes areas. Almost half of the basins in those two areas have problems from combined sewers, as compared to only 8 percent for the rest of the country. Some Northeast and Great Lakes States report that combined sewers represent a serious water quality problem.

Another way to compare the importance of municipal point sources with industrial point sources is the National Residuals Discharge Inventory (NRDI). Figures IV-38 and IV-39 present NRDI data for BOD and total suspended solids (TSS) on a nationwide basis. Even a cursory examination of these maps reveals that at present, publicly-owned treatment works are the predominant influences on BOD, while the reverse is true for TSS. Only in Texas and some parts of the mid-Atlantic coast do the municipal sources account for over half the TSS discharge from point sources. For BOD, some areas estimate that over 90 percent of the point source discharge comes from the treatment works, which is a striking contrast to the foregoing.

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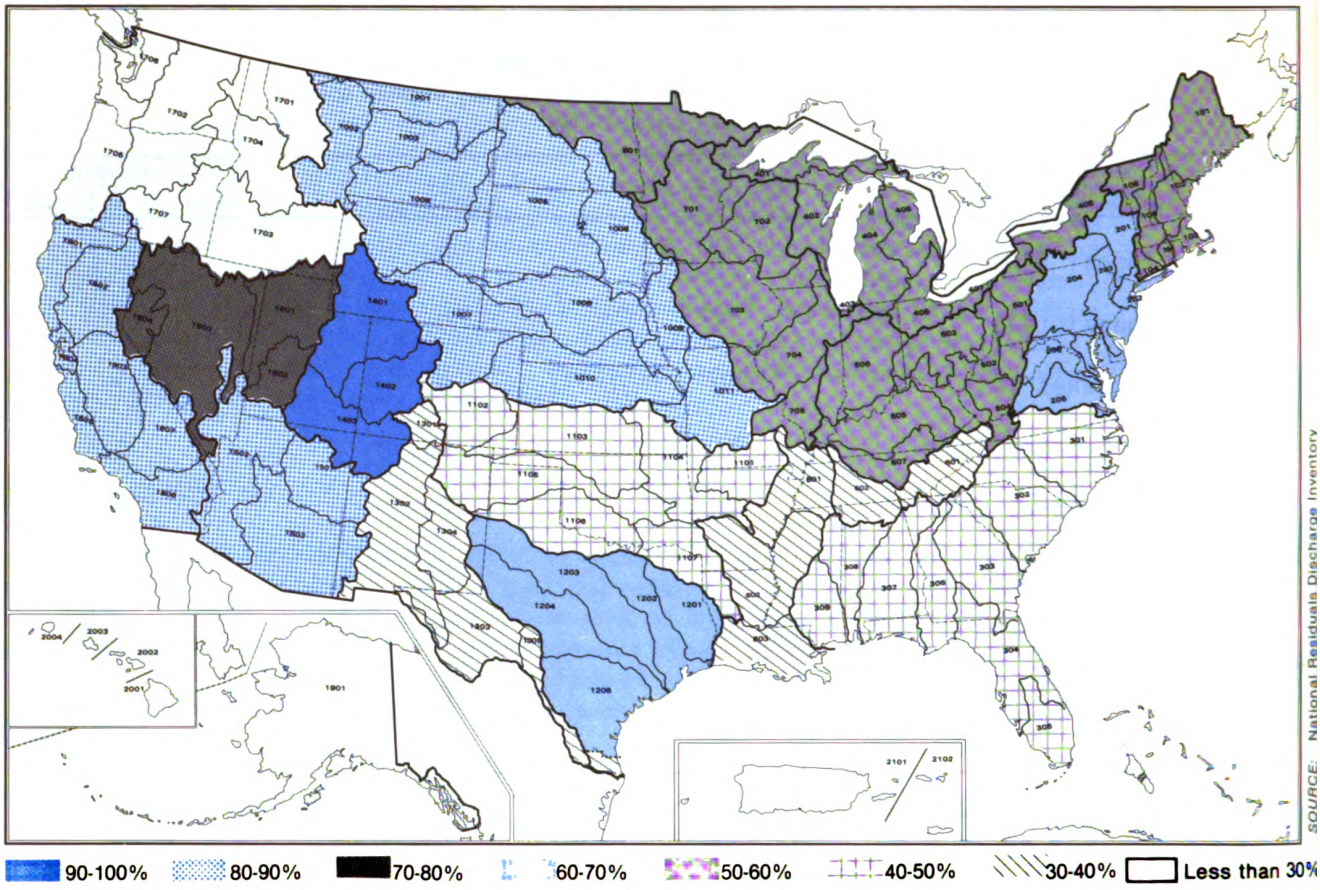
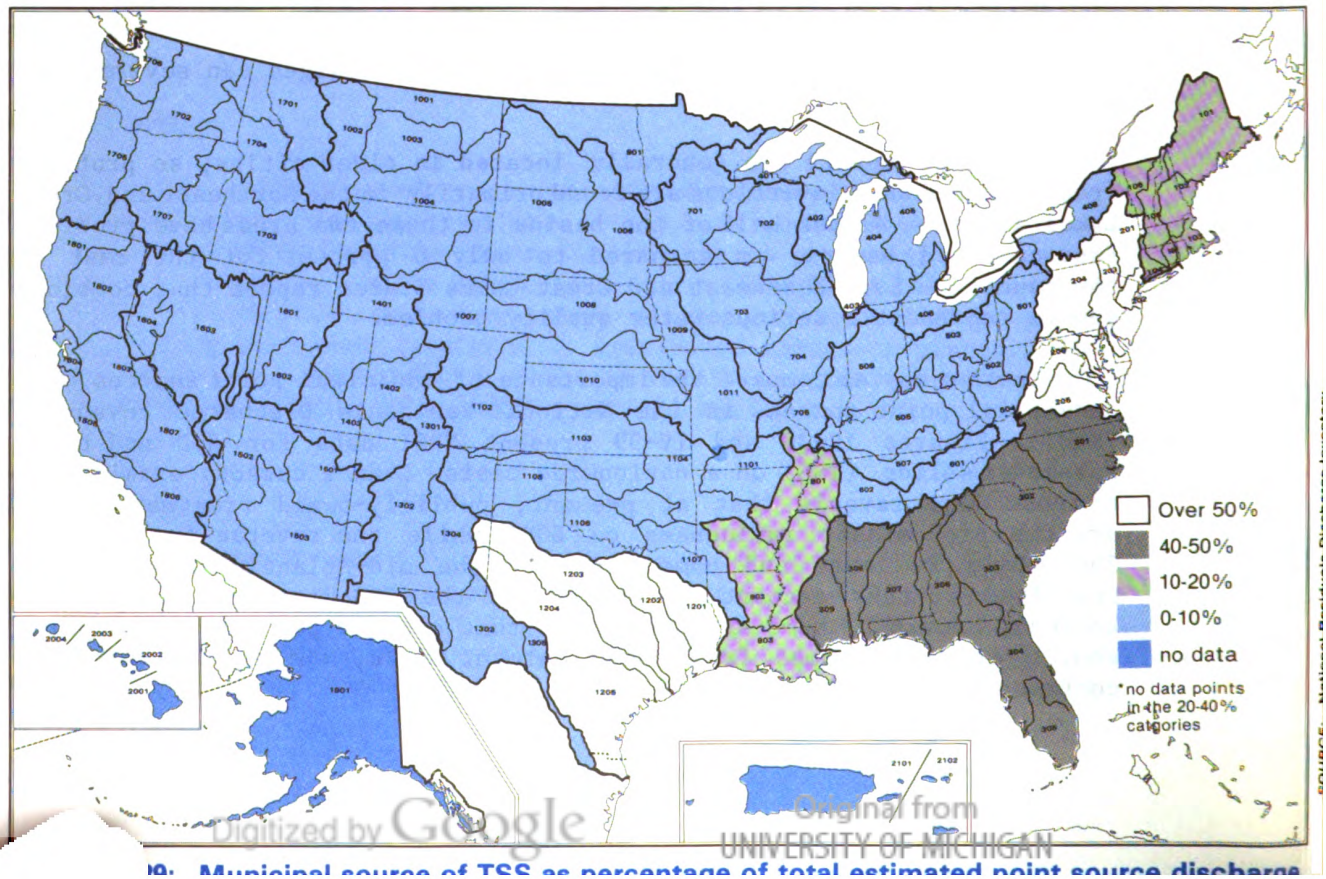


Figure IV-38: Municipal source of BOD_5 as percentage of total estimated point source discharge



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9: Municipal source of TSS as percentage of total estimated point source discharge

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Nonpoint Sources

The effects of nonpoint or diffused sources of pollution on water quality conditions are not as well understood and documented as are point source effects. Even the definition of nonpoint sources is not always clear. For example, for purposes of issuing discharge permits, several States refer to problems such as urban runoff, agricultural return flows, and runoff from mines as point rather than nonpoint sources. In this section, agriculture, urban runoff, hydrologic modification, forestry, mining, and solid waste disposal are discussed as nonpoint sources.

Agriculture

Agricultural activities are the most widespread causes of nonpoint source problems. They affect well over half of the basins in each geographic area (Table IV-16). The most affected areas are the North Central, South Central, and the Southwest (Figure IV-40). A total of 83 percent of the basins in these three areas are affected, as compared to 58 percent for the rest of the country.

Pollution from agricultural activities can come from runoff or from irrigation return flows. Runoff generally increases levels of bacteria, suspended solids, nutrients, and pesticides, while irrigation return flows primarily increase dissolved solids, nutrients, and pesticides.

Urban Runoff

Urban runoff is cited as a primary cause of water quality degradation in heavily populated areas. Almost every type of pollutant is found in urban runoff, the most severe being suspended solids and toxics, particularly heavy metals. Bacteria, oxygen-demanding loads, nutrients, and oil and grease are other pollutants frequently mentioned in discussions of urban runoff.

Across the Nation, 52 percent of the basins are affected by urban runoff (Table IV-16). As would be expected, the highest percentage of affected basins (70 percent) is in the densely populated Northeast, while the lowest percentages are in the Southwest and Northwest (23 percent).

Hydrologic Modification

Hydrologic modification causes problems when alterations in streamflow patterns adversely affect water quality. These modifications are generally in the form of streambed channelization and dam construction.

Streambed channelization is done to maintain navigation channels, to reduce flooding potential, or to facilitate irrigation flows. The channelization can produce high levels of suspended solids and excessive sedimentation which destroy aquatic habitats. This problem affects many streams in the Lower Mississippi River Basin (Figure IV-41).

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Table IV-16.—Nonpoint sources of pollution
(percentage of basins affected[a], by type of nonpoint source)

Area (number of basins)	Urban runoff	Construction	Hydrologic modification	Forestry	Mining	Agriculture	Solid waste disposal	Individual disposal
Northeast (40)	70	15	20	10	20	55	35	63
Southeast (47)	57	2	21	30	15	62	9	40
Great Lakes (41)	54	7	2	15	41	59	15	39
North Central (35)	54	6	3	6	40	89	9	29
South Central (30)	50	0	23	13	53	87	13	40
Southwest (22)	23	0	18	5	36	73	0	35
Northwest (22)	23	23	23	27	23	55	9	32
Islands (9)	67	67	22	0	0	78	22	89

[a]In whole or part.

Source: Environmental Protection Agency.

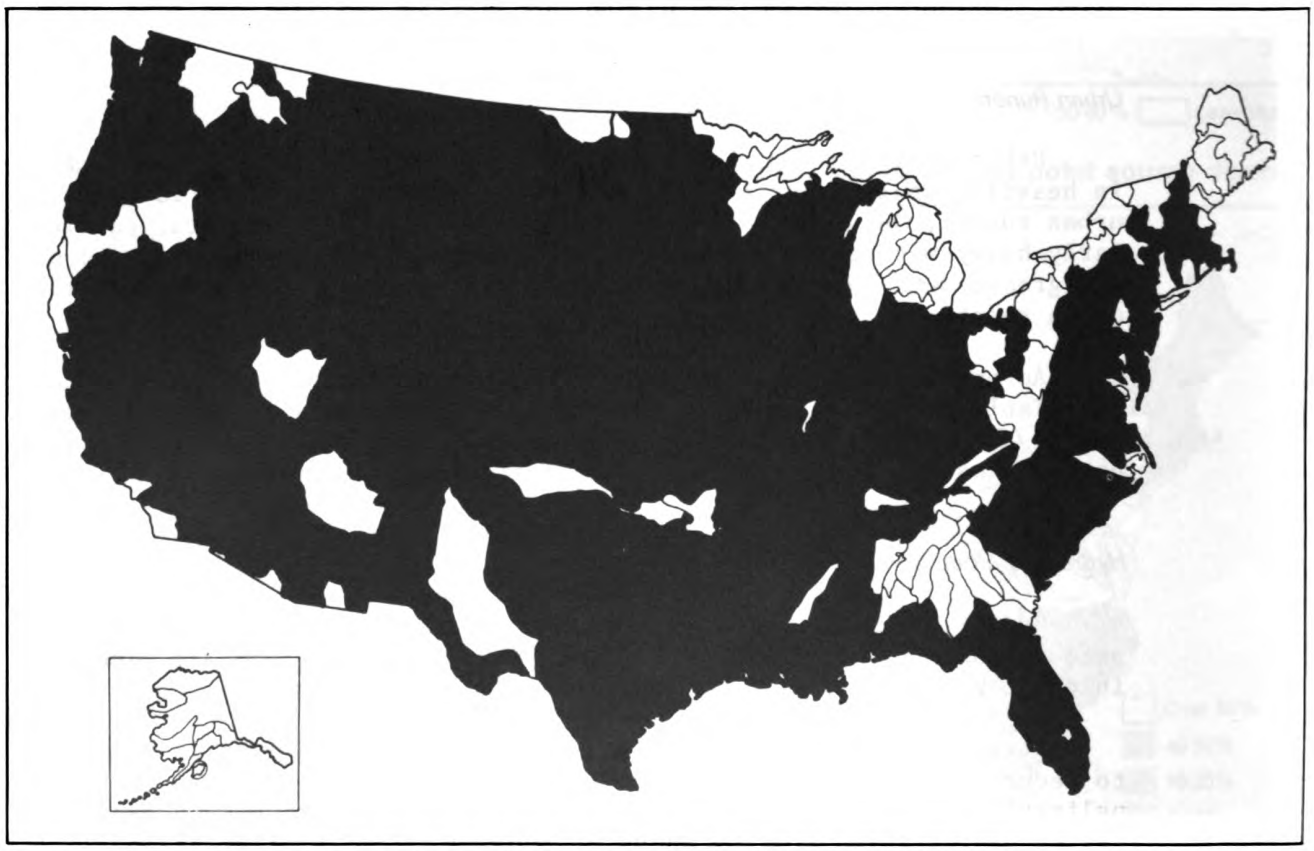

Figure IV-40: Basins affected by pollution from agricultural activities

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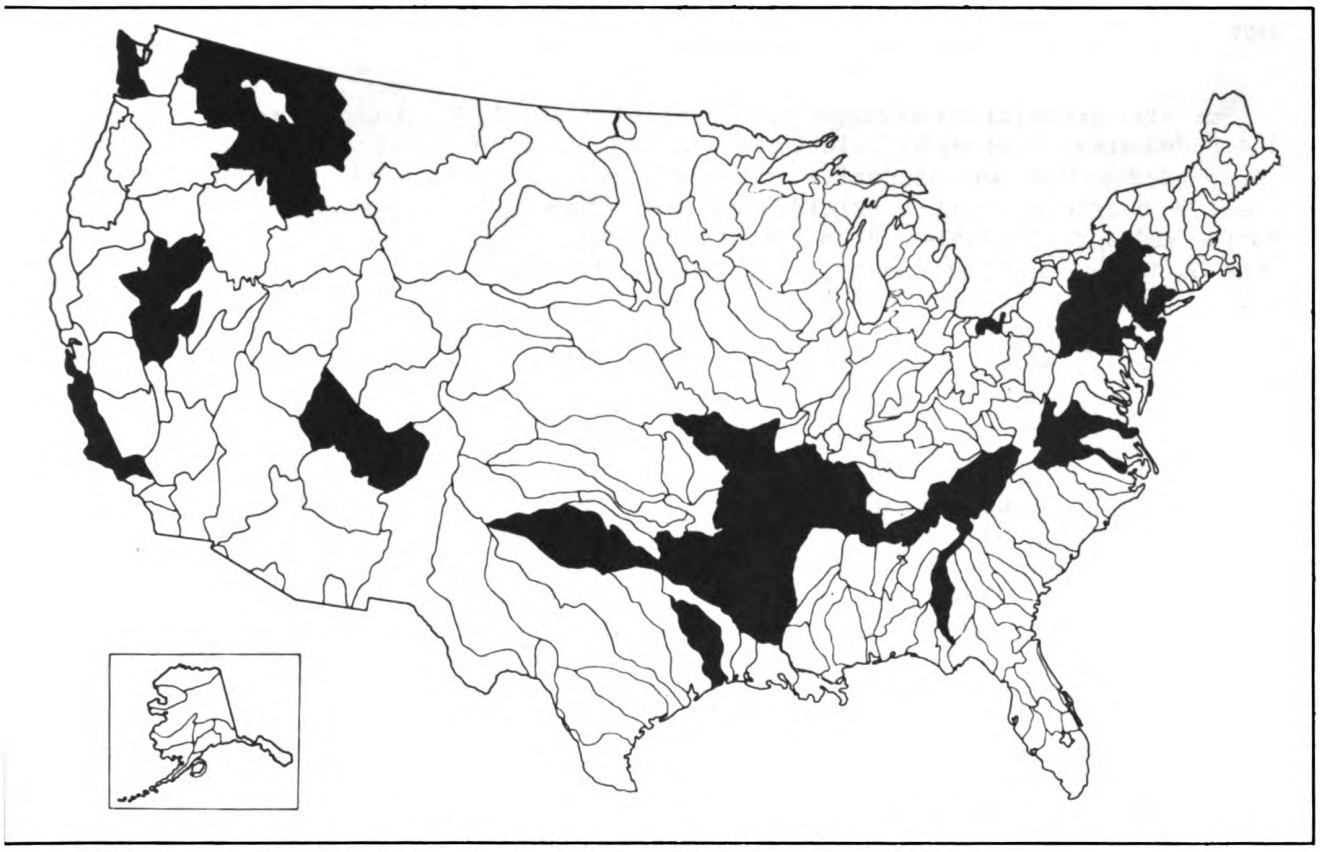

Figure IV-41: Basins affected by hydrologic modifications

Dam construction can be both beneficial and detrimental to water quality. On the positive side, dam impoundments act as retention basins where excess suspended solids and nutrients can settle out, thereby reducing the levels of these pollutants in downstream waters. Dam impoundments can also regulate streamflow and maintain the minimum flow level needed to assimilate downstream waste loads. This flow regulation is not, however, an alternative to adequate waste treatment.

On the other hand, dams can cause serious water quality problems in two ways. First, water descending over the dam spillways can become supersaturated with dissolved gases (oxygen and nitrogen) that cause the fatal gas bubble disease in fish. This problem is of particular concern in the Snake and Columbia Rivers in the Pacific-Northwest Region where dams also act as barriers to the migratory runs of salmon and other fish (Figure IV-41). Second, water released from the lower portions of many reservoirs contains high levels of nutrients and suspended solids and low levels of dissolved oxygen and low temperatures caused by stratification of the water in the reservoir. These problems are in addition to the eutrophication from nutrient buildup that often occurs within the reservoir.

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Forestry

Forestry activities can cause severe erosion problems. Logging roads and denuded areas on steep hillsides cause runoff, which produces high levels of suspended solids and excessive sedimentation. Oxygen-demanding loads, excessive nutrients, and pesticides can also be carried along with the runoff. Widespread problems from forestry activities are found primarily in the Southeast and Northwest (Table IV-16, Figure IV-42).

Mining

Thirty percent of the Nation's river basins are affected by runoff or drainage from active or abandoned mines (Table IV-16, Figure IV-43). Abandoned mines cause the most severe control problems in most areas, although the extent and type of problem varies considerably with geographic region. In the Ohio River Basin of the Great Lakes area, mining is principally for coal. The most severe impact of coal mining is acid mine drainage, which is caused by exposed sulfur-bearing rock reacting with air and water to form sulfuric acid. This acid leaches or runs off into nearby streams. Erosion from coal mining also causes excess suspended solids.

In the North Central, South Central, and Southwest areas, heavy metals from ore mining are the principal pollutants. Oil and gas extraction often causes salinity in the South Central areas. Coal mining affects the water in the North Central area.

Solid Waste Disposal

Surface- and ground-water pollution from solid waste disposal generally arises from runoff or leaching of toxic materials such as heavy metals and PCBs from landfills or dumps. This problem can be potentially critical because a ground-water aquifer, once polluted by a persistent toxic material, may take decades or even centuries to purge itself. Abandoned disposal sites pose a significant problem in this regard because of their potential for releasing hazardous substances into the aquatic environment through leaching and runoff.

Pollution from individual disposal systems has been widely reported by the States, with 43 percent of the basins across the country affected (Table IV-16, Figure IV-44). In most cases, problems arose from inadequate or malfunctioning septic systems in rural or recreation areas. The leachate from these systems contaminated surface waters or ground waters. Overcrowding and soil conditions not suitable for septic systems also contributed to the problem. The major pollutants associated with individual disposal problems are bacteria and, to a lesser extent, excess nutrients.

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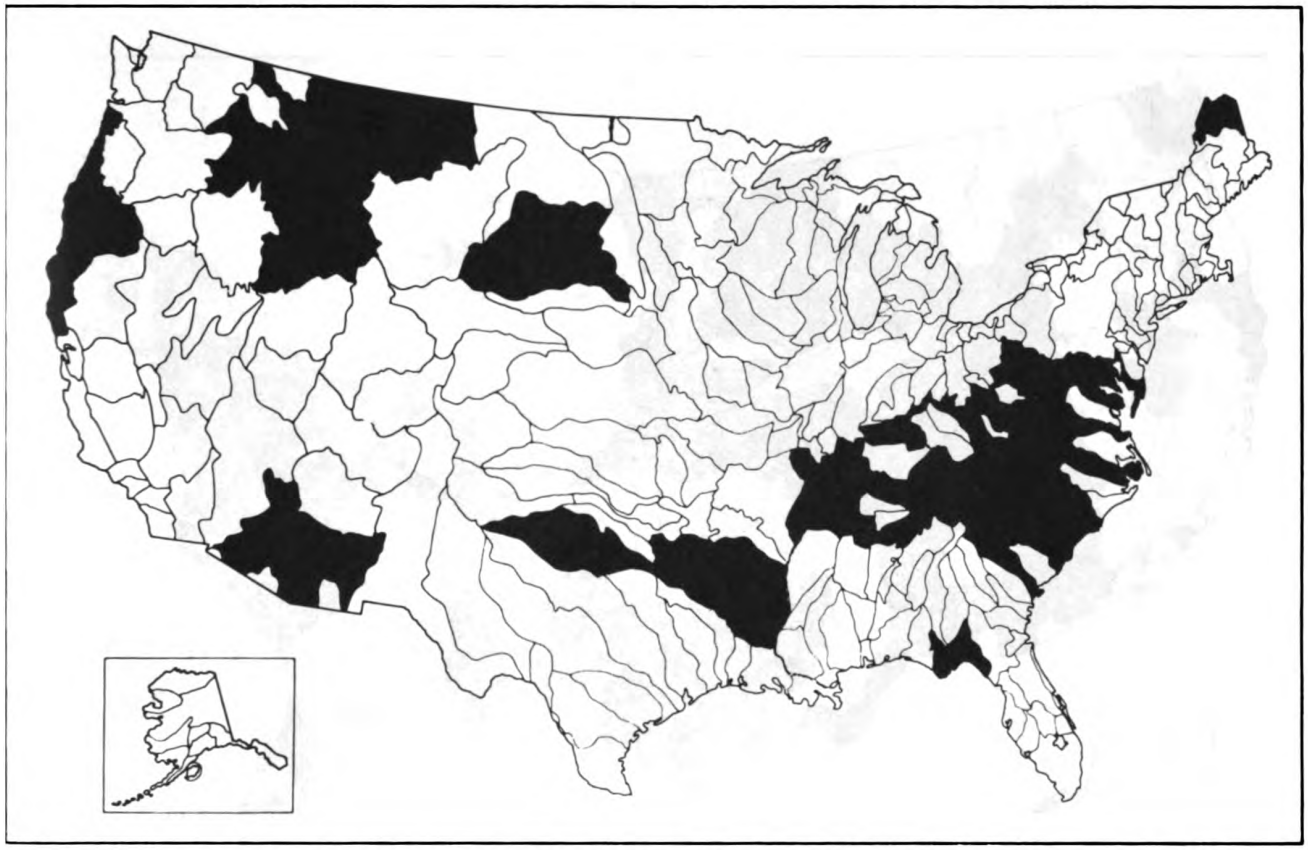

Figure IV-42: Basins affected by pollution from silvicultural activities

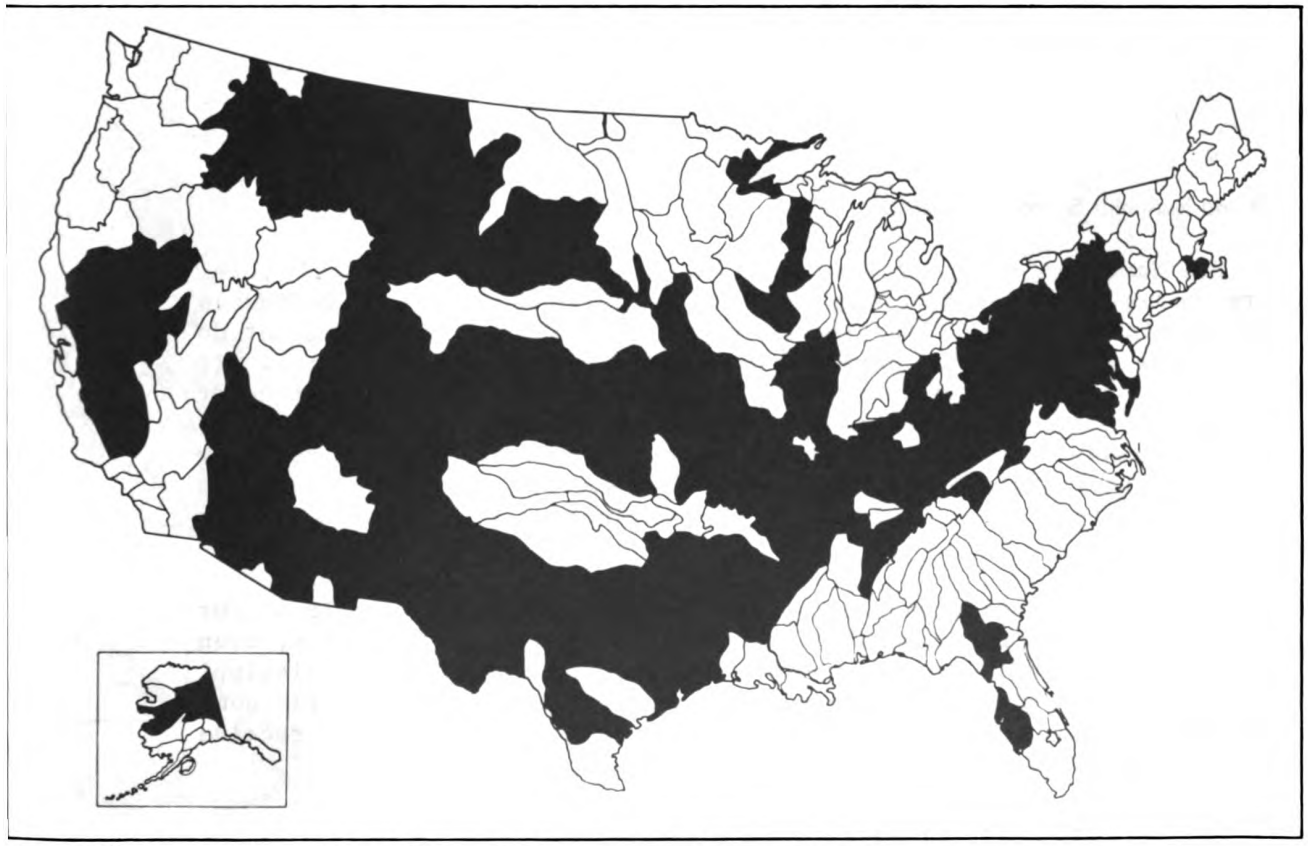

Figure IV-43: Basins affected by pollution from mining activities

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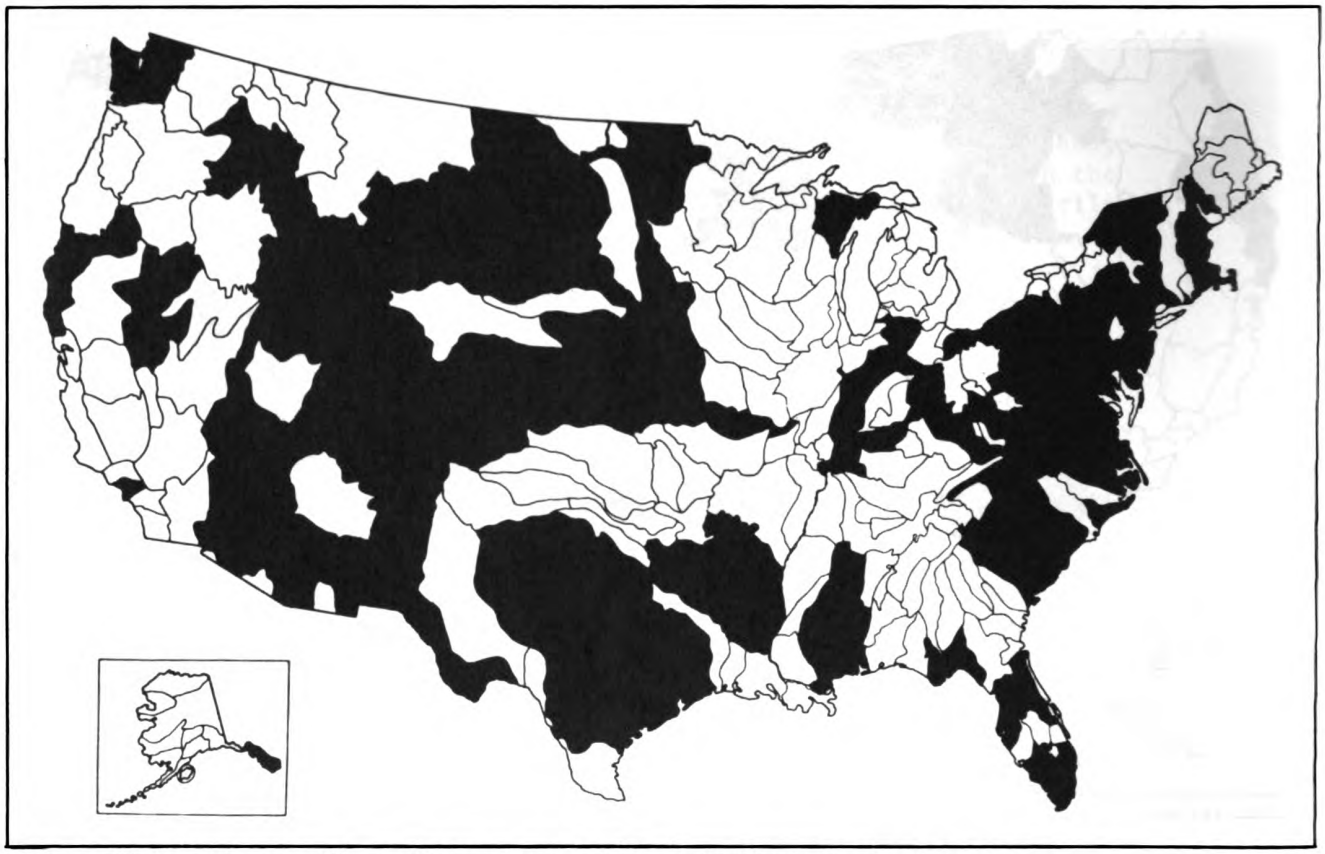

Figure IV-44: Basins affected by pollution from individual disposal systems

Point and Nonpoint Source Comparison

How important are point sources as a group to the total pollution discharge to receiving waters? Figures IV-45 and IV-46 show National Residuals Discharge Inventory (NRDI) estimates for BOD and TSS, respectively, but do not include estimates for other important pollutants such as toxics. It should be noted that the nonpoint source fraction has been estimated for only agricultural and urban runoff. Moreover, these should be viewed as only coarse approximations since there is little information on the severity or geographical distribution of these diffuse sources. Thus, point sources are compared to a rough estimate of only argicultural and urban nonpoint sources.

These data present another stark contrast between BOD and TSS. For most of the Nation, BOD discharges currently come from point sources, even though for a few regions such as the Missouri and Upper and Lower Mississippi the BOD from nonpoint sources predominates. TSS problems generally come from nonpoint sources. A large portion of the Nation appears to receive less than 10 percent of the TSS discharge from point sources.

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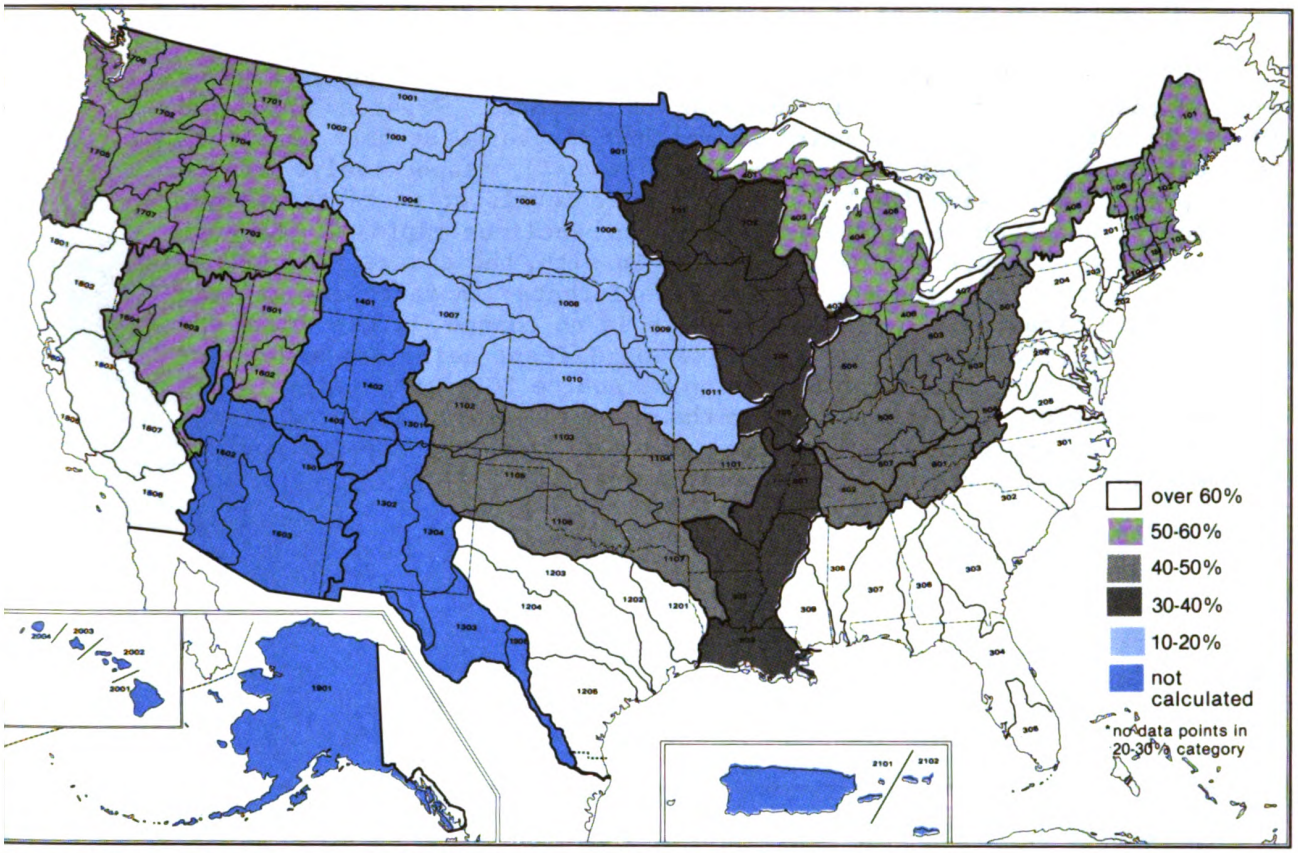
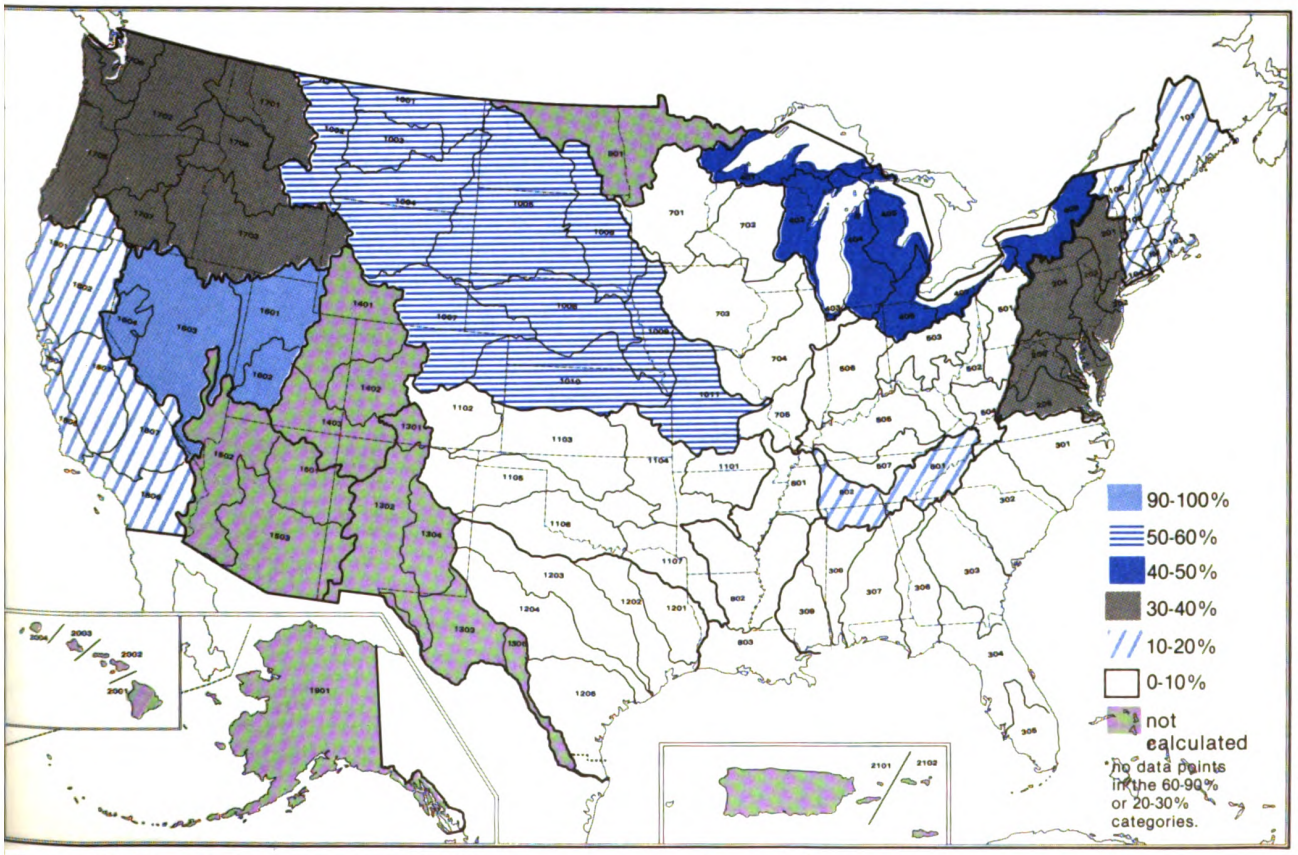


SOURCE: National Residuals Discharge Inventory

Figure IV-45: Point sources of BOD as percentage of total discharge



SOURCE: National Residuals Discharge Inventory

Figure IV-46: Point sources of TSS as percentage of total discharge

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With higher levels of treatment for point sources, what will point sources contribute to the discharge of pollutants? Figures IV-47 and IV-48 present estimates for point source BOD discharge at best practical technology (BPT) and best available technology (BAT), respectively. Figure IV-49 presents the same for TSS. With higher levels of waste treatment, the proportionate share of the point sources declines rapidly. Because the point source contribution is low to begin with, the change from BPT to BAT gains little with respect to these pollutants; in fact, one map can present both treatment levels since there is no change larger than the categories selected in the display. Some significant gains are made, however, from the application of BAT to point source BOD, especially in the Texas-Gulf Region. In others, such as the Missouri Region, advanced treatment causes no appreciable differences in the proportion of point sources in the total discharge, on the basis of these data.

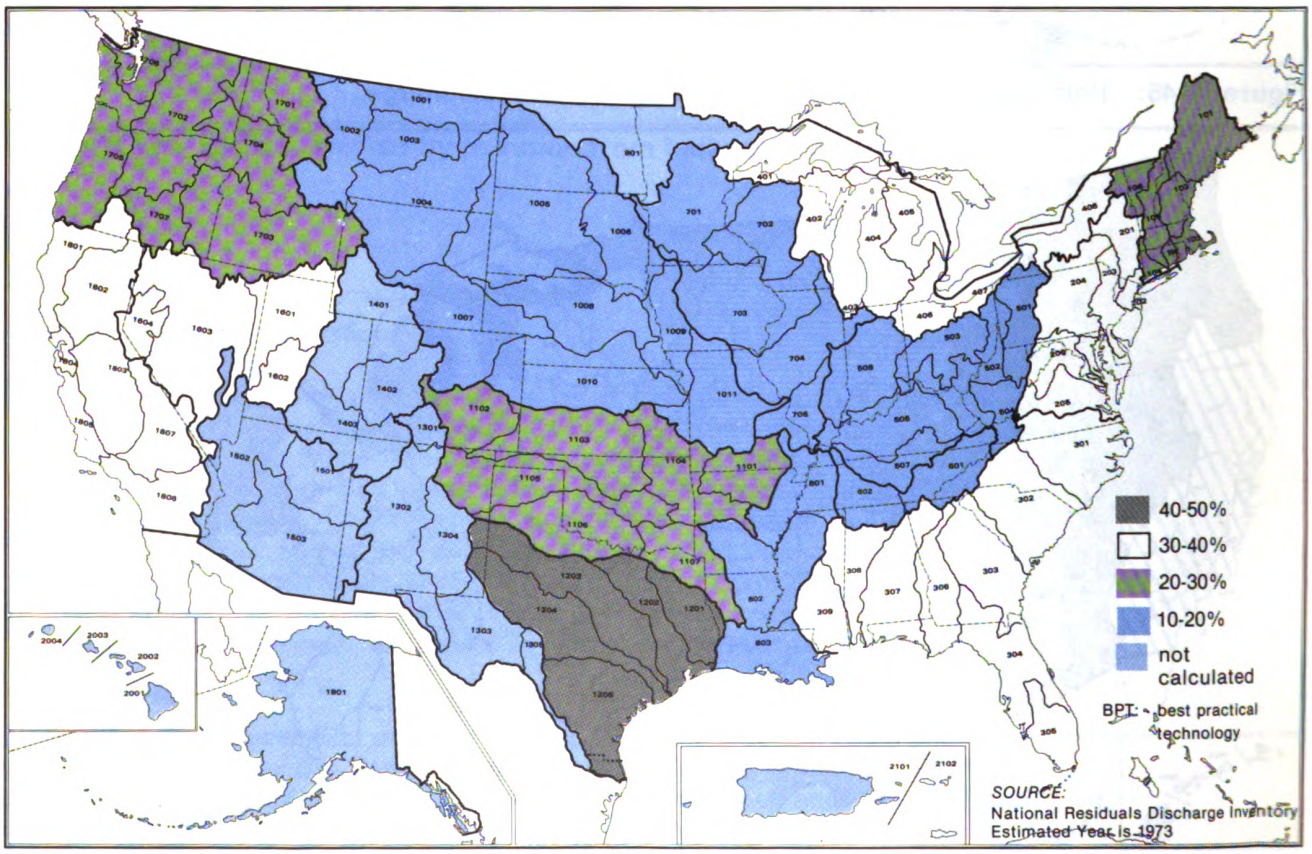

Figure IV-47: Point sources of BOD_5 as percentage of total estimated discharge: BPT

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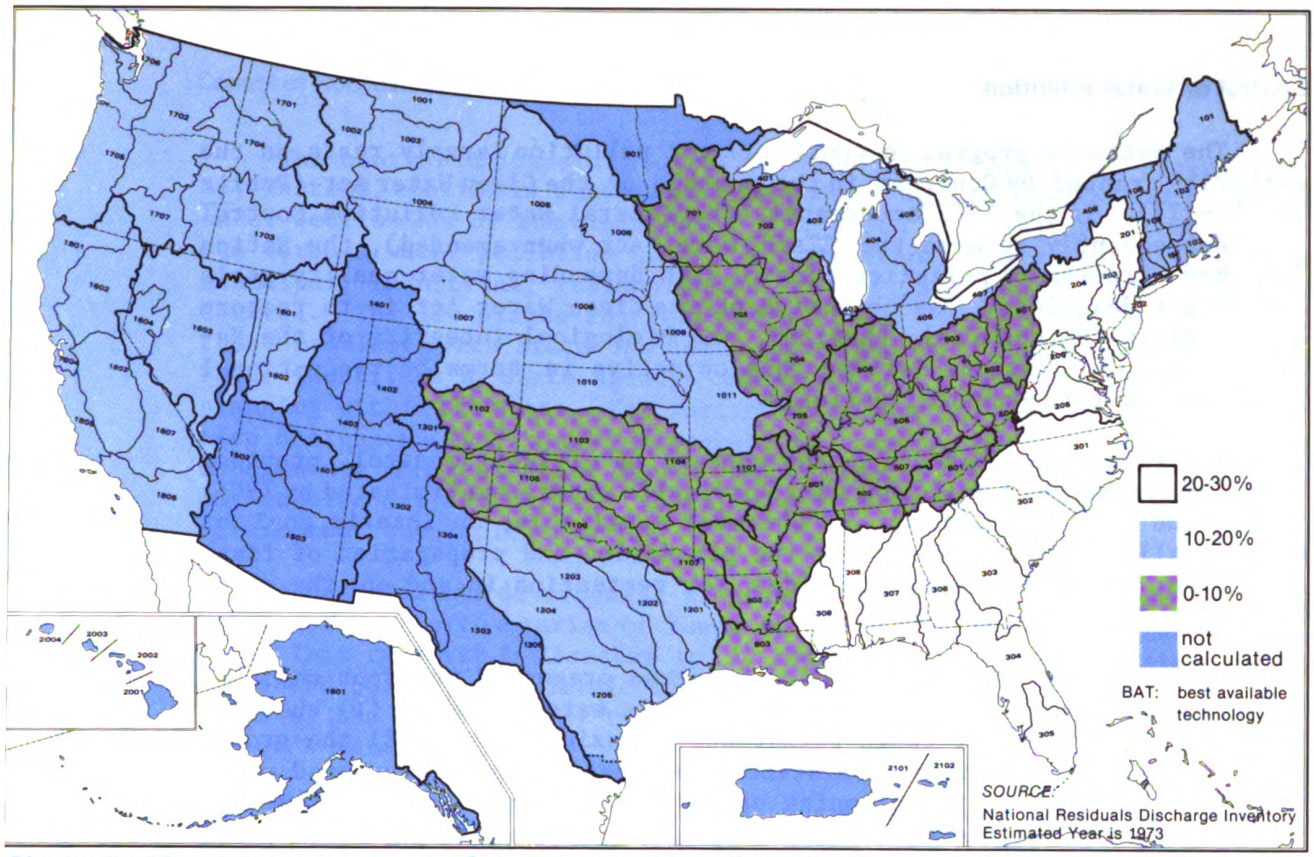

Figure IV-48: Point sources of BOD as percentage of total estimated discharge: BAT

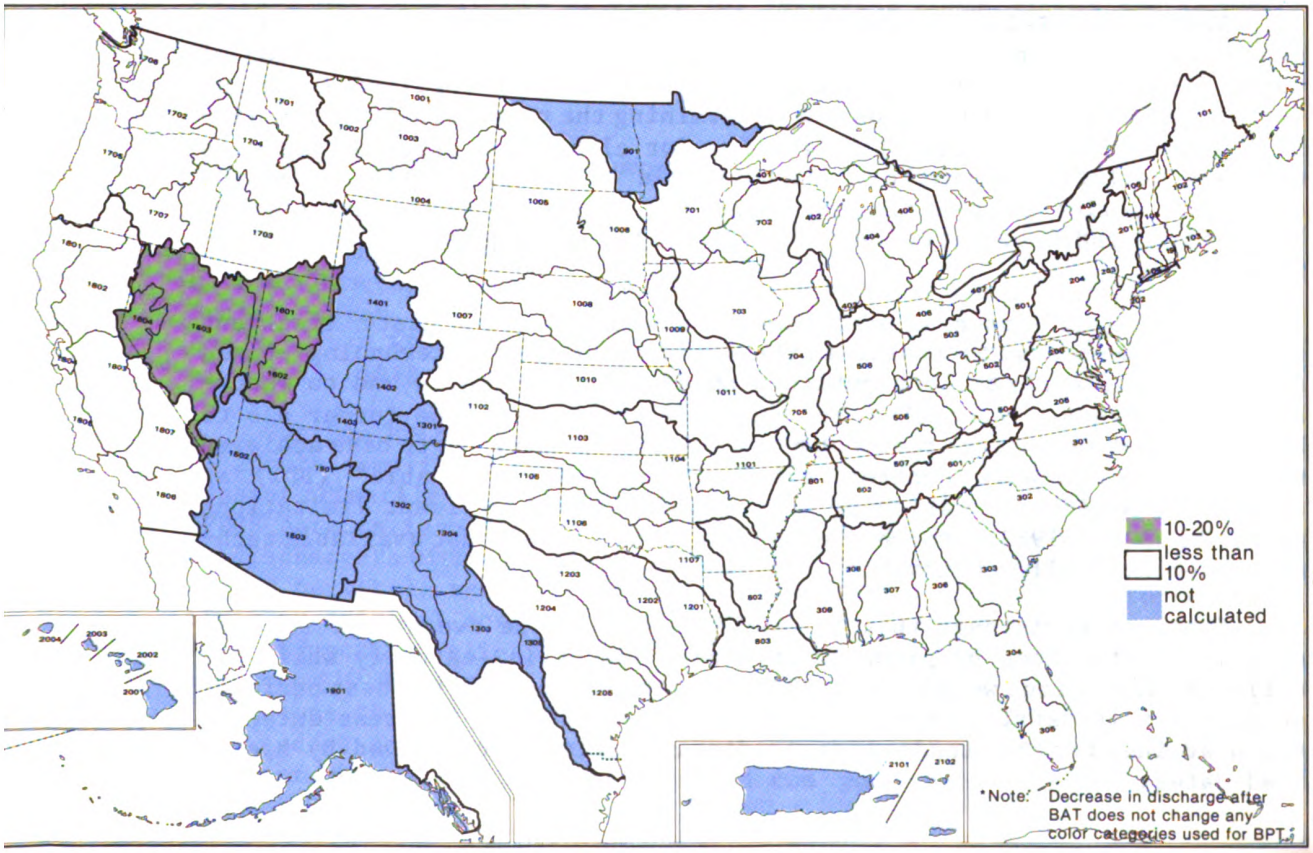

Figure IV-49: Point sources of TSS as percentage of total discharge: BPT and BAT

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Control of Water Pollution

The Nation's program to control water pollution largely rests on the authority granted by Congress in the passage of the Clean Water Act (Public Law 95-217). In the 1972 amendments (the Federal Water Pollution Control Act, subsequently renamed the Clean Water Act when amended), the Nation launched a program of pollution control with demanding water quality goals and strict deadlines. The objective of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Congress defined this objective in terms of two national goals and four fundamental policies.

The first goal, based upon the concept of effluent control, provides that the discharge of pollutants into navigable waters be eliminated by 1985. The second goal, requires, ..."wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983."

In addition to these two goals, Congress presented the four national policies that are the framework of the Nation's water program: (1) the prohibition of discharge of toxic pollutants in toxic amounts, (2) the provision for Federal financial assistance to construct publicly owned waste treatment works, (3) the planning process for areawide waste treatment management, and (4) the establishment of a major research and development program to develop the technology needed to eliminate pollutant discharges.

Various provisions of the Act concern toxic substances. The preventive approach of Section 307(a) focuses on the regulation (or prohibition) of toxic discharges. Section 311 concerns the response to a spill--designating certain substances as hazardous and determining the responsibility and liability for spills. Section 115 provides for cleanup of existing residues of toxic pollutants in harbors and navigable waterways. These provisions for toxic pollution control have been the source of much controversy, litigation, and legislative amendment since the passage of the 1972 amendments.

The Federal financial assistance to publicly owned waste treatment works is a mechanism to assist in the achievement of the technology-based standards that apply to both publicly owned treatment works and to industrial discharges. According to the 1972 amendments, the former was to have achieved secondary treatment by 1977 and the latter was to have achieved the "best practicable control technology currently available" (BPT) as defined by the Administration of EPA. A second set of effluent limitations was to be met by 1983 through the application of the "best available technology economically achievable" (BAT).

Congress envisioned that BPT would represent the average of the best existing performance by plants within each industrial category while BAT effluent limitations would be established with reference to the best performance in any industrial category. In the 1977 amendments, Congress extended the deadlines for the standards, providing criteria to be achieved by specified dates.

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Control of Nonpoint Sources

The control of nonpoint sources does not have a regulatory program per se; instead, control is achieved through water quality management planning under Section 208 of the Clean Water Act, which is designed to coordinate the various water pollution control and abatement requirements, including municipal, industrial, residual waste, runoff, and ground-water pollution control. The law places the responsibilty for implementing solutions to these problems with State and local governments. The governor of each State identifies a State agency to conduct and coordinate water quality planning within the State. For particularly complex problem areas, he may also designate a local agency to prepare an areawide plan for water quality management. The lead State agency that organizes the overall State effort may involve any appropriate local, State, or Federal agency in the plan development and implementation.

The research and development program, set forth in Title I of the Clean Water Act sets forth a series of funds relating to different purposes of the Act. This research is directed to (1) obtaining the necessary data to permit sound policy, (2) developing the control technology to achieve the goals of the Act, and (3) training the human resources necessary to the Nation's water pollution control effort.

On the whole, the Clean Water Act is a major piece of legislation for water pollution control, but it is not the only governing legislation. Others include: the Safe Drinking Water Act (Public Law 93-523), the Ocean Dumping Act (Public Law 92-532), the Resources Conservation and Recovery Act (Public Law 94-580), and the Toxic Substances Control Act (Public Law 94-469).

Control of Point Sources of Water Pollution

Section 402 of the Clean Water Act establishes the National Pollutant Discharge Elimination System (NPDES), which requires all point sources to obtain a discharge permit. NPDES is administered by EPA or by an EPA-approved State program. As of July 1, 1978, over half of the U.S. jurisdictions had received EPA approval to administer NPDES within their boundaries. As of July 1, 1978, EPA and the approved States have issued 52,517 permits.

Section 309 of the Clean Water Act provides for enforcement mechanisms to ensure compliance with the requirements of the NPDES program. These consist primarily of: (1) notices of violation issued to dischargers with NPDES permits issued by approved States, (2) administrative orders issued to dischargers with EPA-issued permits (and to some dischargers with State-issued permits), and (3) referral of cases to United States Attorneys for civil or criminal action. Section 309 authorizes the EPA Administrator to seek injunctive relief, and provides for the imposition of civil penalties of up to $10,000 per day of violation. Section 309 also provides for criminal fines of not less than $2,500 nor more than $25,000 per day of violation and/or not more than one year imprisonment for first offenders, and fines of up to $50,000 per day and two years imprisonment for second

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offenders. Section 301 is the basic statement of policy. This section establishes the technological standards to be met by publicly owned treatment works and industry.

How has this enforcement program been carried out? Figure IV-50 provides an overview of the EPA enforcement program. The exhibit shows the emphasis placed on administrative or informal resolution of violations, under the provisions of Sections 301 and 309 of the Clean Water Act. In particular, it is interesting to compare on a nationwide basis all penalties levied under the authority of Sections 309 and 301 of the Act up to 1977. What is surprising is the regional discrepancies in total penalties and the generally low level of the penalties imposed. New York had penalties of less than $50,000, while its neighbor New Jersey had fines of over one million dollars. Moreover, for 19 of the 50 States, total fines were less than $50,000 per State. Finally, given the number of cases, the tabulation reports that a surprising number were declined for prosecution.

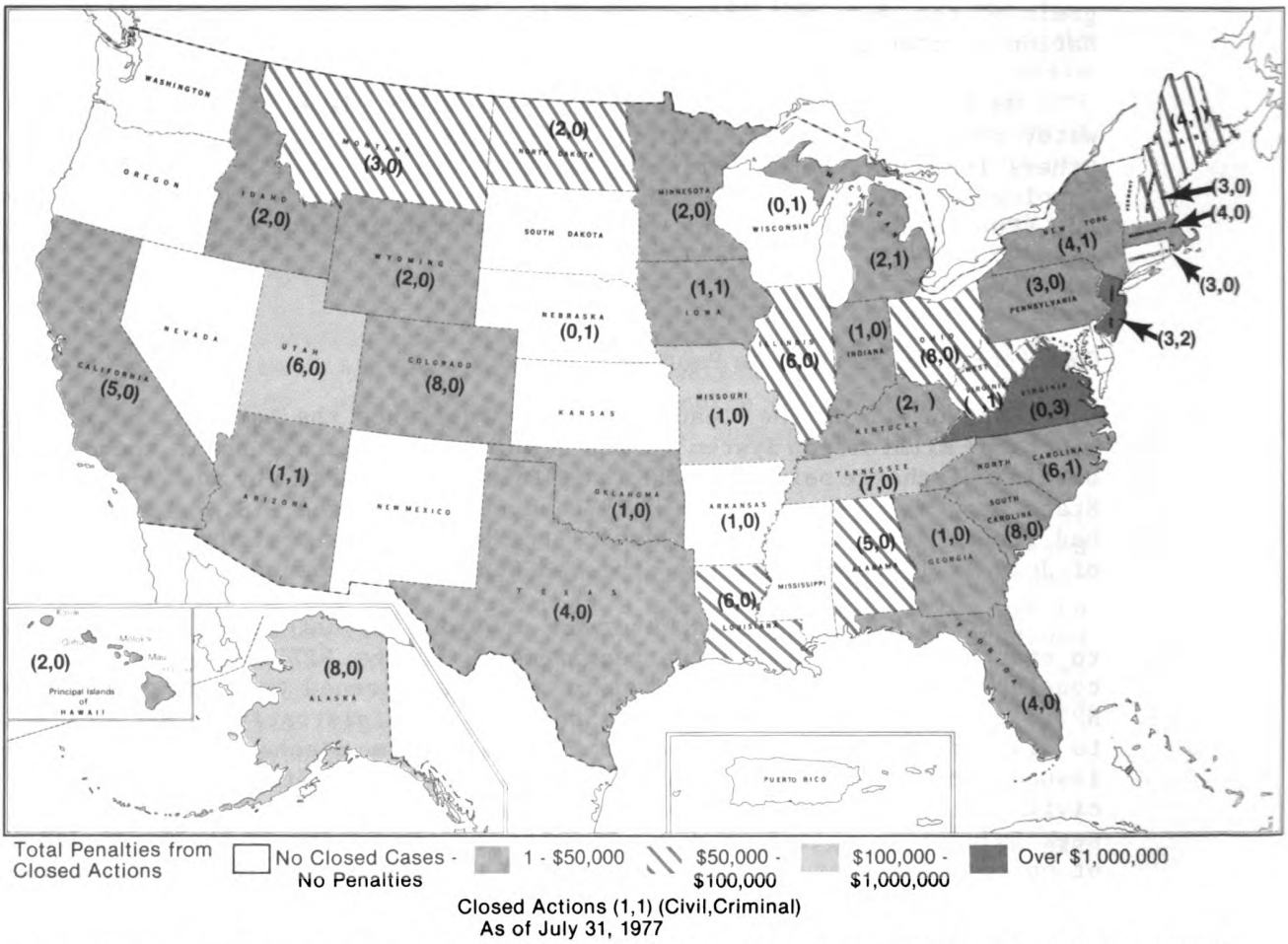

Figure IV-50: Enforcement actions brought under Sections 301 and 309 of Public Law 92-500 Penalties levied and cases prosecuted

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A recent aspect of the enforcement program is the "penalty policy" announced by the EPA Office of Water Enforcement in June 1977. This policy requires the imposition of penalties in amounts at least as great as the economic savings that accrued to the discharger through noncompliance with the July 1, 1977, deadline. During FY 1977, 1,128 administrative orders and 297 notices of violation were issued, and 115 cases were referred to the Department of Justice for civil or criminal relief. In FY 1977, $15,664,865 in EPA-enforced penalties and fines were collected from all sources.

Costs of Control

The costs of controlling of point sources have two elements: (1) industrial source costs and (2) municipal source costs. Because the Federal Government supports the planning and construction of municipal waste-water treatment facilities and not industrial treatment, the economic burden is quite different in each case.

What is industry now spending now on water pollution control? According to estimates of the Bureau of Economic Analysis in the Department of Commerce (Table IV-17), industry spent a total of 2.4 billion dollars on water pollution abatement in 1975, a sum which has increased to a planned 1977 expenditure of 3.2 billion dollars. In all, more is spent by industry on air pollution control than water pollution or solid waste control, but expenditures for water pollution abatement have risen faster than expenditures for either air pollution or solid waste control.

Industrial Costs

In their water quality reports to Congress, a total of 16 States provided estimates of statewide capital costs to meet the industrial effluent limitations required under Federal Water Pollution Control Act (Public Law 92-500) (see Table IV-18). The National Commission on Water Quality report estimates that the costs for meeting BPT requirements alone will be $37 billion. BAT requirements and New Source Performance Standards will cost an additional $23 billion and $20 billion, respectively, for a total cost of $80 billion to industry. The Council on Environmental Quality (CEQ) also estimated total projected industrial pollution control costs, which came to $40.3 billion, including BAT-level treatment for most industries. CEQ states that this figure should be the maximum amount spent to meet EPA guidelines.

Direct comparisons between the State estimates and the National Commission and CEQ estimates are difficult for several reasons. First, the 16 States that did provide estimates may not include a representative sample of the different industries that must spend substantial amounts on pollution control. Second, about half the States based their estimates on BPT requirements while the other half used BAT requirements. Third, some States did not include very small dischargers or thermal discharge in their estimates.

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Table IV-17.—New plant and equipment expenditures by U.S. business: total and for pollution abatement[a]
(millions of dollars)

Item	1975					1976					Planned 1977				
	Total[b]	Pollution abatement				Total[b]	Pollution abatement				Total[b]	Pollution abatement			
		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste		Total	Air	Water	Solid waste
All Industries	113,469	6,519	3,790	2,362	396	121,232	6,762	3,593	2,743	426	134,953	7,512	3,832	3,159	521
Manufacturing	48,314	4,475	2,494	1,736	245	52,979	4,382	2,105	1,993	284	59,582	4,730	2,177	2,276	283
Durable goods	22,046	1,775	1,161	529	85	23,595	1,560	952	537	72	26,474	1,847	998	765	84
Primary metals[c]	5,892	1,012	750	221	41	5,883	923	661	250	12	6,196	1,072	680	376	16
Blast furnaces, steel works	2,926	396	261	135	1	2,954	446	272	173	1	3,129	597	316	281	1
Nonferrous metals	2,267	546	425	82	39	2,139	405	323	71	11	2,216	380	287	80	14
Electrical machinery	2,327	136	34	93	9	2,640	148	44	86	19	2,927	120	47	57	16
Machinery, except electrical	4,736	83	40	37	6	5,026	80	40	30	10	5,585	135	50	71	15
Transportation equipment[c]	3,387	116	51	50	15	3,689	125	53	51	21	4,774	198	65	110	23
Motor vehicles	2,206	86	35	138	13	2,484	90	32	39	19	3,436	149	49	80	20
Aircraft[d]	915	26	14	11	1	983	32	20	11	2	1,097	31	15	14	2
Stone, clay & glass	1,389	198	164	31	3	1,675	103	74	25	5	1,751	118	79	32	6
Other durables[e]	4,315	229	122	97	10	4,682	181	81	95	5	5,241	206	76	120	9
Nondurable goods	26,268	2,700	1,333	1,208	160	29,384	2,821	1,153	1,456	212	33,108	2,889	1,180	1,511	199
Food including beverage	3,383	175	71	92	12	3,903	175	90	75	10	4,151	204	95	102	7
Textiles	680	31	15	15	1	841	37	11	24	2	936	36	11	24	1
Paper	2,908	489	273	189	27	3,473	511	182	304	25	4,028	567	212	329	26
Chemicals	6,300	684	250	394	40	6,723	765	287	433	45	7,343	740	298	403	48
Petroleum	10,497	1,239	684	483	72	11,744	1,275	554	594	126	13,317	1,262	527	626	109
Rubber	1,037	41	25	14	2	1,093	37	20	14	3	1,393	38	21	13	4
Other Nondurables[f]	1,463	41	14	22	6	1,607	23	9	11	2	1,040	34	17	14	4
Nonmanufacturing	65,175	2,074	1,296	626	152	68,253	2,381	1,488	750	142	75,371	2,775	1,655	883	238
Mining	3,823	73	32	31	10	3,972	86	47	29	10	4,407	130	40	41	49
Railroad	2,539	35	11	21	3	2,348	27	8	17	2	2,594	21	1	19	1
Air transportation	1,841	11	6	4	1	1,324	16	12	2	2	1,669	14	11	2	1
Other transportation	2,901	41	12	19	10	3,585	38	11	26	1	2,560	40	17	23	1
Public utilities	20,313	1,700	1,138	466	96	22,437	2,032	1,332	600	100	25,604	2,378	1,503	717	159
Electric	17,030	1,650	1,123	438	89	18,942	1,990	1,312	579	99	21,508	2,348	1,488	702	158
Gas and other	3,283	50	16	28	6	3,495	42	20	21	1	4,096	31	15	15	1
Communication, commercial, & other[g]	33,758	214	97	84	33	34,587	182	79	76	27	38,537	193	84	82	27

[a] Excludes agricultural business; real estate; medical, legal, educational, and cultural services; and nonprofit organizations. Pollution abatement operating costs are also excluded.

[b] Estimates of total new plant and equipment expenditures are based on the same surveys as the estimates of pollution abatement expenditures: for 1975, on the survey conducted in November 1975; for 1976 and planned 1977, on the survey conducted in November and December 1976.

[c] Includes industries not shown separately.

[d] Includes guided missiles and space vehicles.

[e] Consists of fabricated metal, lumber, furniture, instruments, and miscellaneous.

[f] Consists of apparel, tobacco, leather, and printing-publishing.

[g] Consists of communication, trade, service, construction, finance, and insurance.

Note: Estimates for 1973 and 1974 can be found in "Capital Expenditures by Business for Air, Water, and Solid Waste Pollution Abatement, 1974 and Planned 1975," SURVEY OF CURRENT BUSINESS, July 1975 pp. 15-19.

Source: U.S. Department of Commerce, Bureau of Economic Analysis.

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Table IV-18.—State cost estimates for industrial pollution control
(millions of dollars)

BAT Treatment Level:	
Delaware	100
Georgia	300
Kansas	158
Minnesota	700
Mississippi	422
New York	1,000
North Carolina	353
Tennessee	1,567
Texas	3,315
BPT Treatment Level:	
Illinois	1,200
Indiana	1,136
Michigan	1,200
Nebraska	243
Ohio	386
Virginia	100
Wisconsin	324

Source: Environmental Protection Agency.

Despite these difficulties, the State estimates do appear to be considerably lower than both the CEQ estimate and even the BPT-level treatment estimate of the National Commission. One possible explanation for this difference is that estimates of the type developed by the National Commission generally assume industrywide, end-of-pipe treatment as specified in the EPA effluent guideline development documents. In practice, many plants may be able to avoid installation of expensive treatment facilities by employing more efficient water usage, by instituting process changes, or by land application of wastes where land is available. Another possible explanation is that in many States a large part of the required facilities are already in place. The State estimates, which are generally based on surveys and other techniques that use local information, would detect these factors whereas national, industrywide estimates would not.

An integrated picture of the economic effect of water pollution control is difficult to draw. For example, the Council on Environmental Quality, the Department of Commerce, and the McGraw-Hill Publications Company prepare annual estimates of pollution abatement costs. These estimates differ because of the different cost definitions used. CEQ and EPA estimates

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relate primarily to Federal legislation and to State and local regulations enacted to comply with the Federal laws. Another difference is that while CEQ estimates do not include costs of meeting State and local standards when they are more stringent than the Federal standards, the estimates by the Department of Commerce and McGraw-Hill usually include these additional costs. A further discrepancy stems from the definition of what is or is not a pollution control expenditure. As mentioned above, CEQ and EPA estimates are based primarily on the costs of installing, maintaining, and operating an end-of-pipe device that has no function other than pollution abatement. The Department of Commerce and McGraw-Hill often include pollution abatement costs for controls that are integrated in the production process.

Municipal Control Costs

The 1976 Needs Survey of municipal construction costs, conducted by EPA and the States, provides the most recent estimate of needs for the categories of municipal facilities construction (Table IV-19). The total estimates from this survey are considerably lower than the estimates of the 1974 Needs Survey and estimates provided by the National Commission on Water Quality, particularly for the costs of correcting combined sewer overflow and the control of storm-water runoff (Table IV-19). This lower estimate results from the availability of more comprehensive facility planning information and the application of uniform design conditions and reporting criteria. It is also interesting to note that in the construction grants for treatment facilities that have been awarded to date there are lower estimates for the secondary treatment and interceptor sewer categories.

The Council on Environmental Quality did not estimate actual needs for municipal construction costs but instead projected future Federal obligations under the municipal grants program. By using this method, the Council estimated that the total capital investment would be $45.9 billion for all categories over the next 10 years.

As mentioned earlier, nonpoint sources are dealt with in areawide planning programs. The Federal role in water quality management planning consists of providing grant funds for development of plans and for reviewing the plans to ensure that they conform to the requirements of Section 208. A total of $216 million in grants had been awarded in fiscal year 1976 (Table IV-20).

Costs of controlling nonpoint sources are especially difficult to estimate. In their water quality reports to Congress, only a few States were able to provide statewide estimates for nonpoint source categories, mine drainage, and erosion control.

Pennsylvania, Kansas, and Illinois estimated costs for controlling mine drainage. These estimates ranged from $1 billion for Pennsylvania to $22 million for Kansas.

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Table IV-19.—Cost estimates for municipal facilities construction[a]
(billions of January 1976 dollars)

	Category	1976 needs survey EPA	1976 needs survey State	1974 needs survey EPA	1974 needs survey State	NCWQ[b]
I.	Secondary treatment	12.96	13.20	17.81	17.81	11.88
II.	More advanced treatment required by water quality standards	21.28	22.05	22.24	28.78	27.28
III A.	Correction of sewer infiltration/inflow	3.02	3.77	7.42	7.53	7.59
III B.	Major sewer rehabilitation	5.49	5.73	10.25	10.25	10.45
IV A.	Collector sewers	16.98	17.79	24.58	34.50	14.30
IV B.	Interceptor sewers	17.92	18.53	25.27	28.11	14.85
V.	Correction of combined sewer overflow	18.26	19.34	43.51	43.62	87.56
	Total (I-V)	95.90	100.42	151.08	170.57	173.91
VI.	Control of stormwater	54.13	57.25	329.00	329.00	174.47
	Total	150.04	157.67	480.08	499.57	348.38

[a]Totals may not sum due to rounding
[b]National Commission on Water Quality

Source: Environmental Protection Agency.

Table IV-20.—Total Section 208 grants awarded nationally

	Millions of dollars	No. of awards
Areawide:		
FY 74	$ 13	11
FY 75	150	138
FY 76	12	27
States:		
FY 76	41	49
Total	$ 216	225

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Summary

This section has presented a brief overview of water pollution and its control. Obtaining a national picture of water quality is difficult because it must be drawn from fragmentary data. At present, the Nation does not have a comprehensive national environmental monitoring program. Although there is much monitoring, the fragmentation, significant gaps, and data of varying quality impede the evaluation of pollution control. Incipient problems are difficult to indentify and the relationships between pollutants in the environment and health and welfare are hard to determine.

A comprehensive view of environmental quality requires three distinct but related types of monitoring. First, ambient monitoring measures the quality and characteristics of water. This kind of monitoring is particularly important because it can be used to set baselines and to indicate trends by which the success of regulations can be measured. It also permits the monitoring of environmental quality and the anticipation of emerging problems. Second, source monitoring measures the effluents entering the environment from both natural and manmade sources. This kind of monitoring seeks to determine the different sources of pollutants and to enforce compliance with discharge regulations. Third, monitoring the effects of pollution measures indicate how pollution affects human beings, animals, plants, and manufacturing materials. Effects monitoring is crucial in assessing the costs and benefits of controlling or not controlling pollutants at different levels.

Although monitoring is done on a large scale in this country, the choice of the different types of data to be collected and the handling of information at different stages is not coordinated. The present system consists of diverse programs conducted by many agencies at different levels of government.

This section has pieced together a national perspective on water quality. The first part (national patterns), focused on ambient monitoring data and the second dealt with sources of water pollution. Unfortunately, information is insufficient to understand these problems on a national basis. Because data on environmental effects is even more limited, no national assessment of effects has been made. Despite these shortcomings, many environmental problems are known. However, good monitoring information is a prerequisite for making good public policy choices, reducing controversy, and providing a basis for efficient evaluation of enforced standards.

The third part, which focused on the control of water pollution, suffers from a similar lack of information -- especially on the economic effects of regulation. These effects have become the source of debate, because the economy has had severe problems during much of the 1970's. Inflation, unemployment, and scarcities, especially energy shortages, have affected all. These problems have focused attention on the economic effects of environmental programs as they affect jobs, prices, and energy

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demands. However, present environmental law does not always demand that economics be taken into account. The issues at the core of environmental policy are those of determining acceptable risk, cost, and benefit associated with environmental regulations. To this end, accurate and reliable information forms the basis by which choice is made, and by which a national assessment is possible.

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Legal and Institutional Aspects of Water Management

Water Laws of the Nation

Availability of water has been the major influence determining where civilization developed. Early settlements occurred where water was available in its natural state. Today, however, control and conveyance of water has permitted development of areas that sometimes are hundreds of miles from where the water exists in its natural state. The conveyance of water over long distances for various beneficial purposes has been particularly important in arid regions. The arid Southwest has the most extensive water control and distribution facilities to be found anywhere in the Nation.

Water resource laws can originate from several sources, such as Federal and State constitutions and Acts of Congress and State legislatures interpreted by the courts and issued by various Federal and State agencies in the form of administrative laws. Conflicts between government agencies, particularly between Federal and State agencies, over water rights matters are serious. These conflicts have been well documented, so no purpose would be served by restating them here. However, there is a continuing need to better define the roles of all government agencies to provide procedures for resolving water rights conflicts that affect management decisions. Reconciling private, State, Federal-reserved, and Indian water rights with public use of water resources is a key consideration in many of the Nation's water problems.

In the United States, there are two general doctrines in water law -- the appropriation and the riparian (Figures IV-51 and IV-52). The law of appropriation, which is generally associated with the West, was intended to and did stimulate settlement by encouraging an economic use of water resources. The basic tenets of the appropriation system are: (1) a water right can be acquired by the party diverting the water from the water course and applying it to a "beneficial" use and (2) in accordance with the date of acquisition, an earlier acquired water right will have priority over other, later acquired water rights. Water in excess of that needed to satisfy existing rights is viewed as unappropriated water, available for appropriation by diversion and application to another beneficial use. The process of appropriation can continue until all water in a stream is subject to rights of use through withdrawals. However, competition for instream and offstream uses has lead to a careful review of whether the appropriation doctrine recognizes all water uses.

Generally, in the East, the law of riparian rights entitles adjacent (riparian) landowners to reasonable use of streamflow in competition with those who divert the stream for economic uses. As concerns over water quality and quantity increase, several eastern States are reviewing or have already adopted some parts of the appropriation law. In cases of unreasonable water diversions or uses, either the uses have been enjoined or the riparian owners have been compensated for the interference with their rights. The major thrust of the riparian law has been to protect private rather than public rights.

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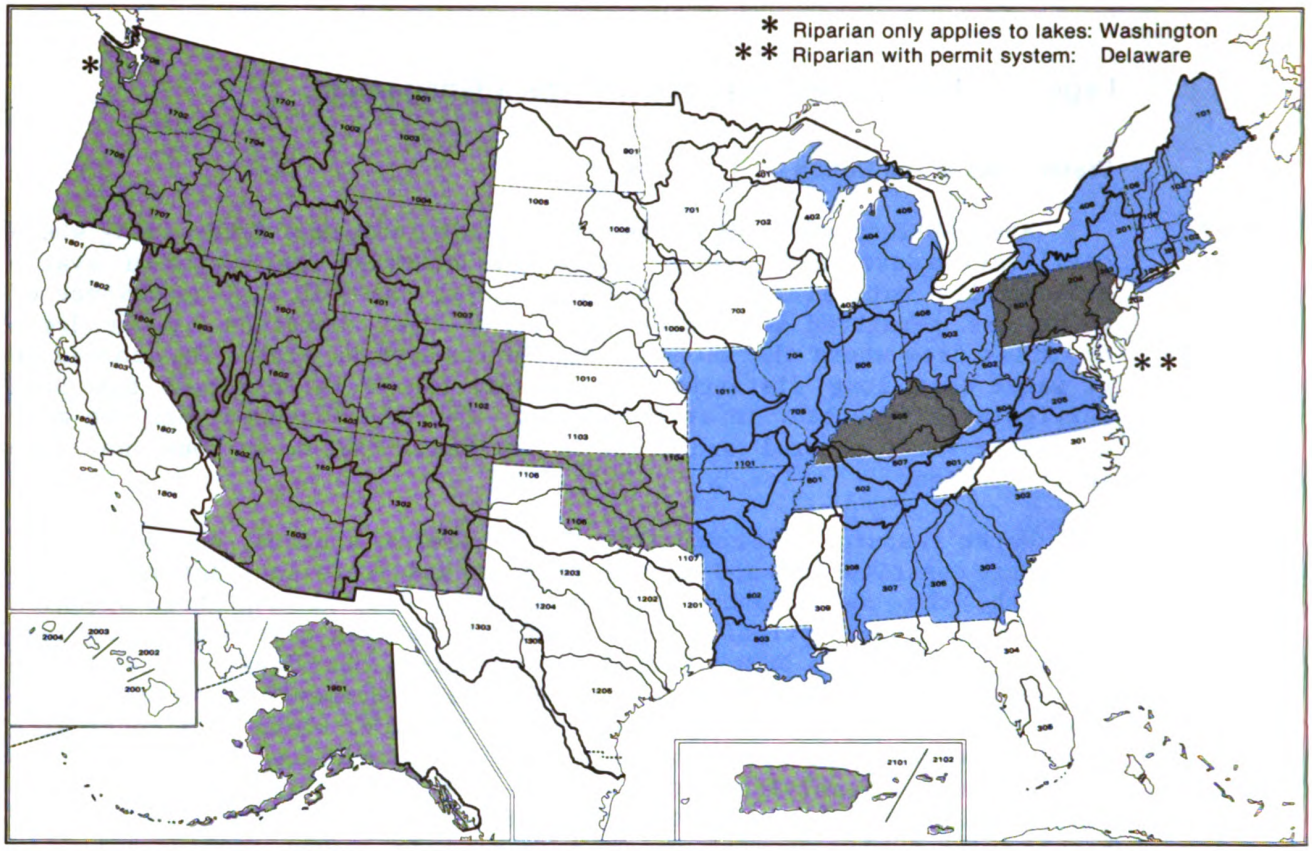

Figure IV-51: The Nation's surface water laws

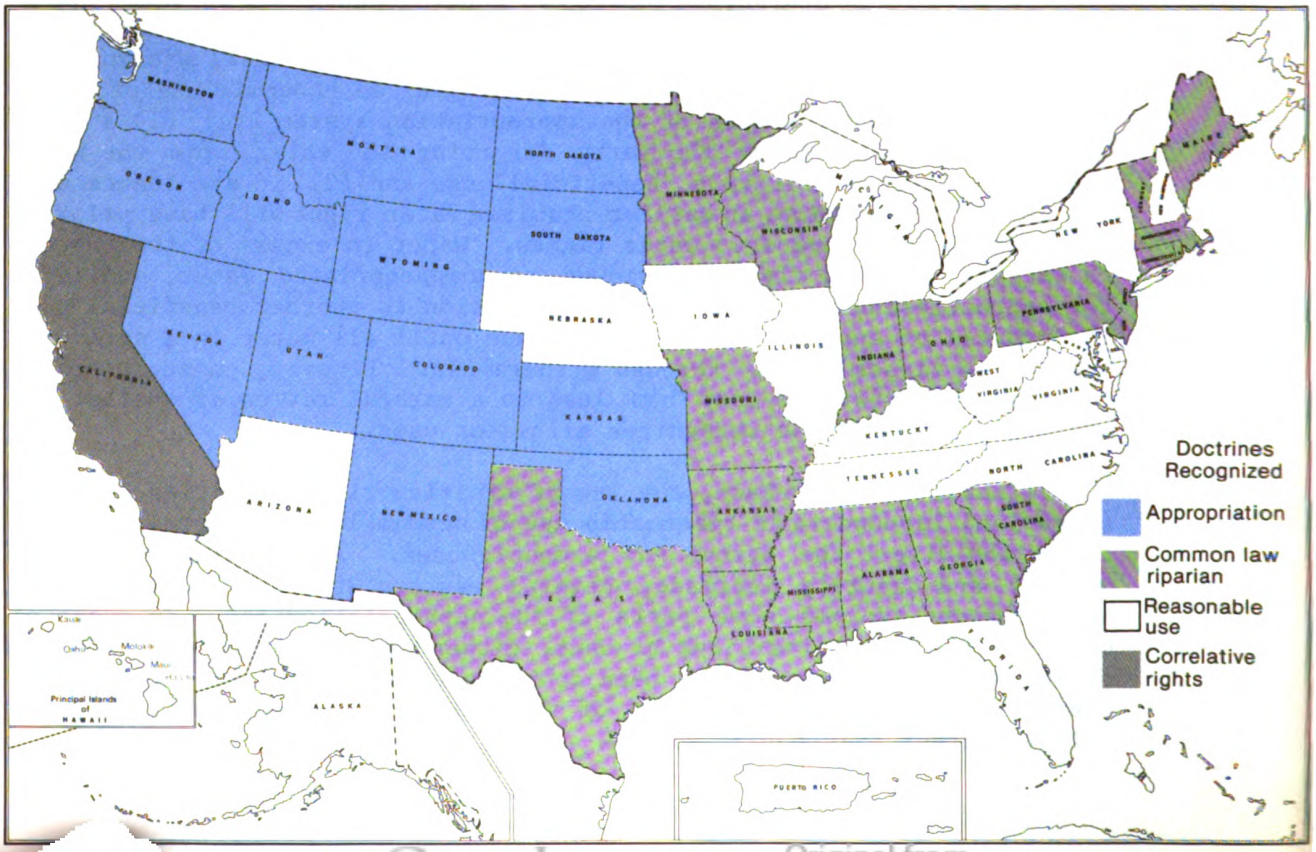

Figure IV-52: The Nation's ground water laws

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Treaties and Compacts

Water resource treaties and compacts provide direction for the use of water from some international and interstate streams. The geographic location of the major agreements and the amount of minimum flow requirements and allocations of the waters are presented in Figure IV-53. Most of these have been taken years of negotiation and compromise before agreement was reached.

As shown in Table IV-21, the United States has six treaties with Canada and three with Mexico that establish respective rights and responsibilities to waters flowing in streams crossing international boundaries. Similarly, as shown in Table IV-22, the States have negotiated 33 interstate compacts on flow of streams crossing State boundaries.

Water laws, interstate compacts, and international treaties have been established to provide a basis for settling conflicts in water management. These institutional arrangements must be updated from time to time to adjust to changing demands on the water resources.

Significant environmental and economic benefits could be realized from adopting improved institutional procedures for government agencies to cooperate in managing water resource systems that are competing for available water supplies. These should include procedures for resolving operational conflicts and for promoting a more unified operation. In some areas, this more efficient use of water resources would reduce the need for developing new facilities.

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Figure IV-53: Treaties and compacts

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Table IV-21.—International water treaties of the United States

	Treaty reference	Minimum flow requirements	Allocation
T1	Great Lakes and Missouri Regions (4 and 10) Canadian Boundary Waters Treaty, 1909, 36 Stat. 2448. United States and Canada; (4 and 1001).	No Minimum. No Minimum. No Minimum. Lake Ontario EL 248.0 and 3200 cfs out of Chicago 5100 cfs in at Albany	20,000 cfs N.Y. Niagara River 36,000 cfs Ontario above falls St. Mary River 500 cfs or 75% - Canada Milk River 500 cfs or 75% - U.S. Great Lakes--Level Control Lake St. Francis--Level Control, Water Quality. St. Lawrence--Level Control and Regulation of Discharge Lake Memphremagog - Level Control St. Croix River Basin Rainy River - Water Quality.
T2	Great Lakes Region (4) Niagara River Water Diversion Treaty, 1950, 1 U.S.T. 695 (TIAS 2130). United States and Canada.	Minimum 100,000 cfs over the falls 8AM-10PM April 1 to September 15; 100,000 cfs over the falls 8AM-8PM September 16 to October 31: 50,000 cfs over the falls at any time.	Niagara Falls and River All waters above the minimum flows over the falls may be diverted for power production 50% to each country.
T3	Souris-Red-Rainy Region (9) Lake of the Woods Convention 1925, 44 Stat. 2108. United States and Canada.	Regulates levels of Lake of the Woods between EL 1056 and 1061.25.	When level of the lake rises above EL 1061 or below EL 1056 discharge from lake becomes subject to board control. No interbasin transfers permitted without agreement.
T4	Souris-Red-Rainy Region (9) Rainy Lake Convention 1938, 54 Stat. 1800. United States and Canada.	By Commission - Kettle Fall Dam, International Falls Dam	By Commission.

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Table IV-21.—International water treaties of the United States (continued)

	Treaty reference	Minimum flow requirements	Allocation
(T5)	Rio Grande Region (13) Rio Grande Convention, 1906, 34 Stat. 2953. United States and Mexico.	Rio Grande at Juarez (From 1302 to 1303) 60,000 ac-ft/yr at Juarez Jan 0 Jul 8,180 Feb 1,090 Aug 4,370 Mar 5,460 Sep 3,270 Apr 12,000 Oct 1,090 May 12,000 Nov 540 Jun 12,000 Dec 0	Regardless of the amount delivered, U.S. may use all water between Juarez and Ft. Quitman.
(T6)	Rio Grande Convention, 1933, 48 Stat. 1621. United States and Mexico.	Flood control.	No specific allocation of flow.
(T7)	Rio Grande, Colorado, and Tijuana Treaty, 1944, T.S. 994, 59 Stat. 1219, (1303 and 1502).	Rio Grande below Ft. Quitman, Texas From Mex to 1303: Delivery from Mexico to U.S. minimum of 350,000 ac-ft/yr.	50% of the unallocated flow of the Rio Grande to each country. Other rivers in the basin are allocated by percentage of flow.
	Lower Colorado Region (15)	Colorado River at Border From 1502 to Mex: Delivery from U.S. to Mexico of minimum of 1,500,000 ac-ft/yr; maximum of 1,700,000 ac-ft/yr.	No allocation other than the deliveries as noted.

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Table IV-21.—International water treaties of the United States (continued)

	Treaty reference	Minimum flow requirements	Allocation
T8	Pacific Northwest Region (17) Columbia River Basin Cooperative Development Treaty, 1961, TIAS 5638 (15 U.S.T. 1555). United States and Canada.	Minimum of 2,500 cfs in the Kootenay River at the border (Montana) (after 2020 AD) Mica CK (Canada)--3,000 cfs Arrow Lake (Canada)--5,000 cfs Duncan Lake (Canada)--1,000 cfs.	Allocates storage and hydroelectric power development. Forbids diversions except for consumptive use, except from the Kootenay River.
T9	Alaska Region (19) Yukon River Agreement, 1871 United States and Canada.	From Canada to 19 Navigation - Exceptional because of restriction to other uses.	Provides Canada with a guarantee to the use of the Yukon River for access to the sea and prohibits construction or actions restricting traffic on the Yukon River (diversions).

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Table IV-22.—Interstate compacts on water resources of the United States

	Compact reference[a]	Minimum flow requirements	Allocation
C1	New England Region (1) Connecticut River Flood Control Compact, 1951, 64 Stat. 45. CT, MA, NH, VT.	Flood control.	Provides for flood control dams in Massachusetts, Vermont, and New Hampshire, provides for apportionment of tax losses due to Federal acquisition of lands for these dams among the States of Massachusetts, Vermont, New Hampshire, and Connecticut.
C2	Merrimack River Flood Control Compact, 1957, 71 Stat. 18. MA, NH.	Flood control.	Provides for construction of certain dams and reservoirs, for an apportionment if tax and other revenue losses result from U.S. acquisition of land for this purpose, and a procedure whereby other dams may be built by the United States or the States.
C3	New England Interstate Water Pollution Control Compact, 1947, 61 Stat. 682. CT, ME, MA, NH, RI, VT.	Water quality.	Provides for the study and control of pollution of interstate and tidal waters in the States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
C4	New York Harbor (Tri-State) Interstate Sanitation Compact, 1935, 49 Stat. 932. NJ, NY, CT.	Water quality.	Provides for the regulation and control of water pollution and sewage treatment and discharge in designated areas of Connecticut, New Jersey, and New York.
C5	Thames River Flood Control Compact, 1957, 72 Stat. 364. MA, CT.	Flood control.	Agrees to the construction by the United States of certain dams and reservoirs for flood control in Connecticut and Massachusetts.

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

	Compact reference[a]	Minimum flow requirements	Allocation
C6	Mid-Atlantic Region (2) Potomac River Basin Compact, 1939, 54 Stat. 748, as amended, 84 Stat. 856.	Water quality.	Provides for the formation of the Potomac Valley Conservancy District in the mentioned States and for the study of and the making and recommending of standards for water pollution and sewage disposal within that District.
C7	Delaware River Basin Compact, 1961, 75 Stat. 688. Release required determined by adjudication: 283 U.S. 805 (1931) superseded by 347 U.S. 995 (1954). DE, NJ, NY, US; (0203 to estuary).	1,750 cfs required at Montague based on adjudication and a basin yield of 0.45 cfs per sq. mi. (from earlier attempts at a compact).	Allocations made by the Commission.
C8	Susquehanna River Basin Compact, 1970, 84 Stat. 1509. NY, PA, MD; (0204)	Releases: by Commission's decision No Required Releases Correlative Rights Possible low flow min. in Oct. of 2,800 cfs to be agreed upon.	By permit or by Commission's decision.
C9	Great Lakes Region (4) Great Lakes Basin Compact, 1968, 82 Stat. 414. PA, IL, IN, MI, MN, OH, PA, WI.	Flood control.	In compliance with State release criteria to protect downstream damages and reduce economic losses.
C10	Ohio Region (5) Ohio River Valley Water Sanitation Compact, 1939, 54 Stat. 752. IL, IN, KY, NY, OH, PA, TN, WV.	Water quality.	Provides for the study, control, and regulation of water pollution, sewage treatment, and discharge of industrial waste into the waters of the Ohio River Valley.

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

	Compact reference[a]	Minimum flow requirements	Allocation
(C11)	Wheeling Creek Watershed Protection and Flood Prevention District Compact, 1967, 81 Stat. 553. PA, WV.	Flood control.	Creates a watershed protection and flood control district and provides for the construction and maintenance of dams and reservoirs.
(C12)	Tennessee Region (6) Tennessee River Basin Water Pollution Control Compact, 1955, 72 Stat. 823. TN, MS, KY.	Water quality.	Provides for the study of water pollution problems in the river basin, for the establishment of water quality standards, and for the enforcement of those standards.
(C13)	Souris-Red-Rainy Region (9) Red River of the North Compact, 1937, 52 Stat. 150. ND, SD, MN.	Flood control and water quality.	Creates the Tri-State Waters Area and provides for the administration and coordination of all public works on boundary waters in the area.
(C14)	Missouri Region (10) Yellowstone River Compact, 1950, 65 Stat. 663. MT, ND, WY; (1004).	No minimum.	Allocates percentages of flow: Above Rock Lake-Clarks Fork — Wyoming 60% Above Yellowstone-Bighorn Rivers — 80% Above Yellowstone-Tongue Rivers — 40% Above Yellowstone-Powder Rivers — 42%
(C15)	Upper Niobara Basin Compact, 1969, 83 Stat. 86. WY, NB; (1005).	No minimum.	Allocates storage and ground-water development at Anchor Dam.
(C16)	Belle Fourche River Compact, 1943, 58 Stat. 94. SD, WY; (1005).	No minimum.	90% to South Dakota, 10% to Wyoming.
(C17)	South Platte River Compact, 1923, 44 Stat. 195. CO, NE; (1007). South Platte River Lodgepole Creek.	120 cfs at State line, April 1 to October 15.	Colorado 100% October 15 to April 1.

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

Table IV-21

Interstate compacts on water resources of the United States (continued)

	Compact reference[a]	Minimum flow requirements	Allocation
C18	Big Blue River Compact, 1971, 86 Stat. 193. KS, NE; (1010). Big Blue River Little Blue River.	Minimum at the State-line gaging station: May: Little Blue 45 cfs; Big Blue 45 cfs Jun: Little Blue 45 cfs; Big Blue 45 cfs Jul: Little Blue 75 cfs; Big Blue 80 cfs Aug: Little Blue 80 cfs; Big Blue 90 cfs Sep: Little Blue 60 cfs; Big Blue 65 cfs	Same as releases.
C19	Republican River Compact, 1942, 57 Stat. 86. CO, KS, NE; (1010).	No minimum. Guide check station 132,000 cfs near State line.	Detailed allocation by total ac-ft/yr. State totals are: Colorado 54,100 ac-ft/yr. Kansas 190,300 ac-ft/yr. Nebraska 234,500 ac-ft/yr.
C20	Arkansas-White-Red Region (11) Arkansas River Compact, 1948, 63 Stat. 145. CO, KS; (1102). Arkansas and Purgatoire Rivers.	At junction of Arkansas and Purgatoire Rivers below John Martin Dam. Summer - April 1 to October 1: To Colorado: 750 cfs (600 when total storage is below 20,000 ac-ft) To Kansas: 500 cfs (400 when total storage is below 20,000 ac-ft) TOTAL: 1,250 cfs (1,000 when total storage is below 20,000 ac-ft) Winter - November 1 to March 31: To Colorado: 100 cfs.	Same as releases; when water stored is near exhaustion, Colorado is allotted 100%.

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

	Compact reference [a]	Minimum flow requirements	Allocation
(C21)	Arkansas River Basin Compact, 1965, 80 Stat. 1409. KS, OK; (1103). Arkansas River, Grand River, Neosho River, Salt Fork River, Verdigris River, Cimarron River.	No specified releases - unrestricted use.	Allocates reservoir construction. Kansas gets 100% of average natural flow plus portion of the new reservoir storage.
(C22)	Arkansas River Basin Compact, 1970, 87 Stat. 569. AR, OK.	No minimum.	Arkansas: No more than 50% flow from Spavinaw basin. No more than 60% flow from Illinois basin. No more than 100% flow from Lee Creek No more than 60% flow from Poteau basin. Oklahoma: No more than 60% flow from Arkansas basin.
(C23)	Canadian River Compact, 1950, 66 Stat. 74. NM, OK, TX; (1105).	No minimum.	Allocates reservoir storage. Flow decided by Commission.
(C24)	Texas-Gulf Region (12) Sabine River Compact, 1953, 68 Stat. 690, as amended, 76 Stat. 34. LA, TX; (1201).	36 cfs at State line.	50% to each State.
(C25)	Rio Grande Region (13) Costilla Creek Compact, 1963, 77 Stat. 350. CO, NM; (1301).	No minimum.	Colorado: Diversions 50.62 cfs; Release 36.5% New Mexico: Diversions 89.08 cfs; Release 63.5% New Mexico: Diversions 13.42 cfs; Release Above Cost

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

Compact reference[a]	Minimum flow requirements	Allocation
(C26) Rio Grande Compact, 1938, 53 Stat. 785. CO, NM, TX; (1301).	No minimum? 790,000 ac-ft/yr. is given as the "normal release" but seldom has been attained.	Allocation by proportion of an upstream index flow.
(C27) Pecos River Compact, 1948, 63 Stat. 159. NM, TX; (1304).	Minimum is the "1947 condition" --Use inflow-outflow method to determine delivery to Texas. The method and amounts are presently in dispute. Flow of the Pecos averaged 136,900 ac-ft per year, for 36 years through 1973; but was 43,200 ac-ft in 1972 calendar year. This shows great variability.	50% of flood waters to each State, 43% of salvaged water from New Mexico to Texas.
(C28) Upper Colorado Region (14) Upper Colorado River Basin Compact, 1948, 63 Stat. 31. AZ, CO, NM, UT, WY; (1402).		Arizona 50,000 ac-ft, and Colorado 51.75%; New Mexico 11.25%; Utah 23.00%; Wyoming 14.00% (after Arizona's allocation and the delivery of the required flow to the lower basin).
(C29) Colorado River Compact, 1922, 45 Stat. 1057, 1064. AZ, CA, CO, NV, NM, UT, WY; (1403).	75,000,000 ac-ft at Lee Ferry, Arizona, in any 10-year period.	Nevada, 300,000 ac-ft/yr. Arizona 2,800,000 ac-ft/yr. Upper basin to lower basin, 7,500,000 ac-ft/yr, delivered at Lee Ferry, Arizona. 4,400,000 ac-ft/yr. to California after Central Arizona Project is in use.

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Table IV-22.—Interstate compacts on water resources of the United States (continued)

	Compact reference[a]	Minimum flow requirements	Allocation
C30	La Plata River Compact, 1922, 43 Stat. 796. CO, NM; (1403).	No minimum; releases by index schedule.	Unrestricted use when flow is 100 cfs or more at the State line; otherwise, 50% each.
C31	Great Basin Region (16) Bear River Compact, 1955, 72 Stat. 38. ID, UT, WY; (1601).	Over 350 cfs at the Wyoming-Idaho border or a water emergency is declared.	Allocation by schedule of percentage of flow when a water emergency has been declared. Storage capacity is allocated.
C32	Pacific Northwest Region (17) Snake River Compact, 1949, 64 Stat. 29. ID, WY; (1703).	No minimum.	Idaho 96%; Wyoming 4%.
C33	California Region (18) Klamath River Basin Compact, 1957, 71 Stat. 497. OR, CA; (1801).	No release or diversion requirement.	Acreage Limitation: California 100,000 acres Oregon 200,000 acres

[a]Compact reference: Water resource region
Compact name, date, and statute reference
States involved; (subregion)
0 Map reference
River--Often omitted because of inclusion in compact name

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PART V
SYNOPSES OF THE WATER RESOURCES REGIONS

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CONTENTS

Introduction ——— 1
New England Region (1) ——— 3
Mid-Atlantic Region (2) ——— 9
South Atlantic-Gulf Region (3) ——— 15
Great Lakes Region (4) ——— 21
Ohio Region (5) ——— 27
Tennessee Region (6) ——— 33
Upper Mississippi Region (7) ——— 39
Lower Mississippi Region (8) ——— 45
Souris-Red-Rainy Region (9) ——— 51
Missouri Region (10) ——— 57
Arkansas-White-Red Region (11) ——— 63
Texas-Gulf Region (12) ——— 69
Rio Grande Region (13) ——— 77
Upper Colorado Region (14) ——— 83
Lower Colorado Region (15) ——— 91
Great Basin Region (16) ——— 99
Pacific Northwest Region (17) ——— 105
California Region (18) ——— 111
Alaska Region (19) ——— 117
Hawaii Region (20) ——— 123
Caribbean Region (21) ——— 129

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Introduction

This last part of Volume 2 summarizes the 21 regional assessment reports that were developed by the regional sponsors (listed in Volume I - Summary). These regional reports were developed during the Specific Problem Analysis phase of the assessment process. In Volume 4, the full-length regional reports present socioeconomic, environmental, and water information, discuss functional and location-specific water problems, and provide State-regional recommendations on planning, research, data collection, and institutional needs.

The first sections of each summary contain brief statements about the total area,[1] major river systems, and overall water supply in the region. Next follows a synopsis of the major water-related problems and issues and the general conclusions and recommendations. These topics are discussed in detail in Volume 4.

The section of each summary entitled National and State-Regional Futures compares the State-Regional Future (SRF) and National Future (NF), developed by State-regional and Federal entities, respectively. Despite several attempts to arrive at reconciled figures, wide differences still separate NF and SRF information because of discrepancies in assumptions, goals, and objectives. The State-regional alternative information should be considered in any evaluation of the water resources situation in the 21 water resources regions.

Geographic problem areas identified by each regional sponsor are shown on the corresponding region map and problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each geographic problem area and by Federal representatives for entire subregions. The nature and magnitude of problems perceived from the regional viewpoint are often at variance with those of the Federal perspective.

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[1] Estimates of total area are based on acreages listed in Volume 3, Appendix I. These represent the total area of subarea approximations of the hydrologic subregions comprising each Water Resources region. Because the boundaries of subareas follow political delineations, there will be slight discrepancies between the "subarea" acreages listed in this part and "subregion" drainage areas in Volume 3, Appendix II.

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The regional reports in Volume 4 were developed from technical memoranda prepared by State and regional study participants under contractual arrangement with the Water Resources Council. The four technical memoranda developed during the Specific Problem Analysis phase include: Technical Memorandum 1, problem identification made by regional, State, local, and Federal agencies; Technical Memorandum 2, State-regional resource goals and policies, related future needs, and the identification of severe water and related land resource problems; Technical Memorandum 3, the effects of not resolving resource problems, and the programs available to help resolve selected resource problems; and Technical Memorandum 4, recommendations to resolve the region's resource problems and a summary of the three previous technical memoranda.

Since the regional study groups did not generalize their information for the national-level use, the technical memoranda more accurately depict the current and projected water problems and developments.

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New England Region (1)

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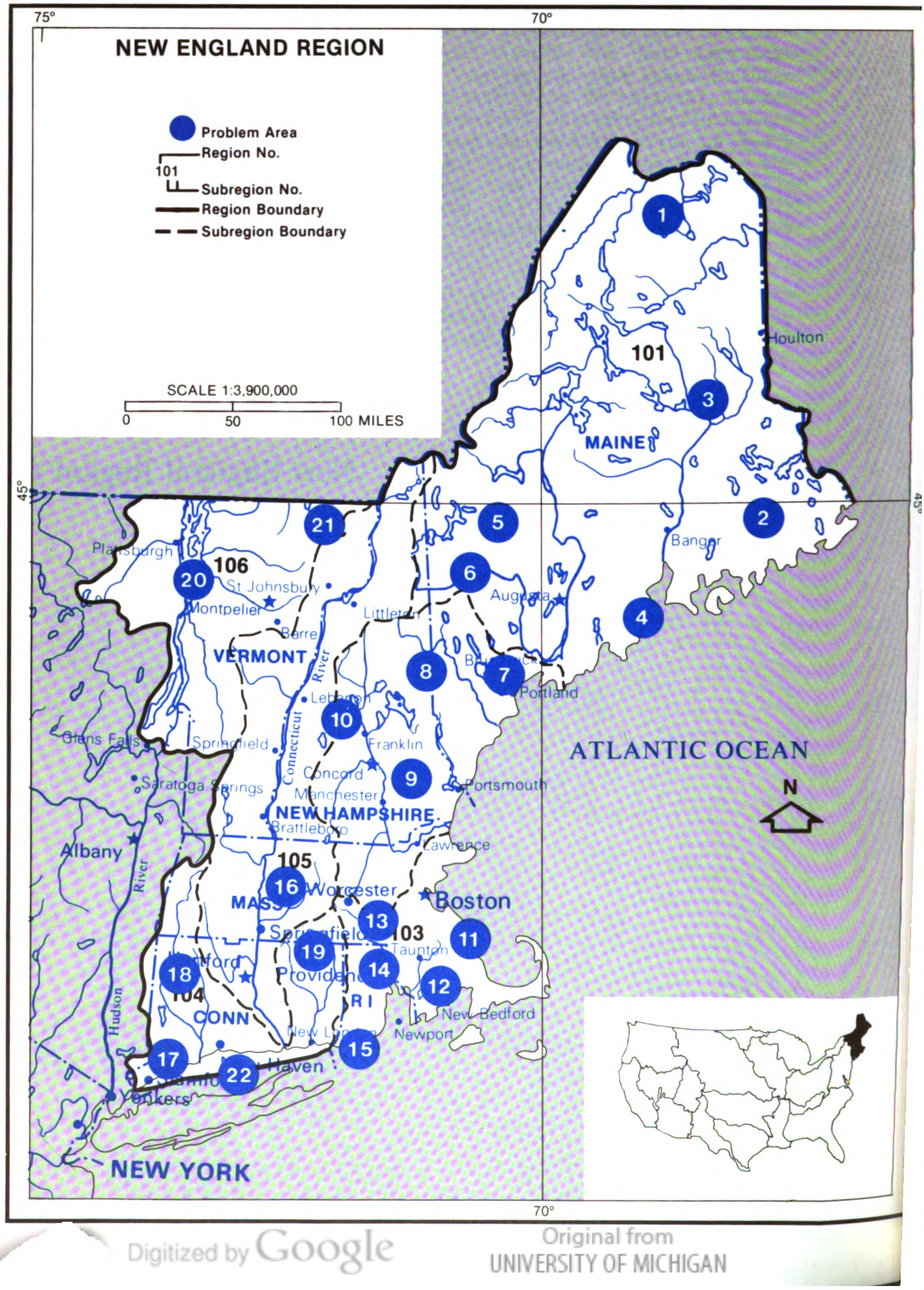

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NEW ENGLAND REGION (1)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 101	Northern Maine					O		O				O		O	
Area 1	St. John River Basin	X				X	X			X		X		X	
2	St. Croix and Maine Eastern Coastal					X	X	X		X			X	X	
3	Penobscot River Basin		X			X	X			X			X	X	
4	Maine Central Coastal					X	X	X		X		X	X	X	
5	Kennebec River Basin					X	X			X		X	X	X	
6	Androscoggin River Basin					X	X			X			X	X	
Subregion 102	Saco-Merrimack					O							O	O	
Area 7	Presumpscot River and Casco Bay					X	X	X		X		X	X	X	
8	Saco and Maine Southern Coastal	X	X			X	X	X		X		X	X	X	
9	New Hampshire Coastal	X	X			X	X	X		X		X		X	
10	Merrimack River Basin	X	X			X	X	X		X		X	X	X	
Subregion 103	Massachusetts-Rhode Island Coastal	O				O	O			O		O	O	O	
Area 11	Massachusetts Coastal	X	X			X	X	X		X		X	X	X	
12	Narragansett Bay	X	X			X	X	X		X		X	X	X	
13	Blackstone River Basin	X	X			X	X			X		X		X	
14	Pawtuxet River Basin	X	X			X	X			X		X	X	X	
15	Pawcatuck River Basin	X	X			X	X			X		X		X	
Subregion 105	Connecticut River	O		O		O				O			O	O	
Area 16	Connecticut River Basin and Conn. Central Coastal	X	X			X	X	X		X		X	X	X	
Subregion 104	Housatonic-Thames	O		O		O		O		O			O	O	
Area 17	Connecticut Western Coastal	X	X			X	X	X		X		X	X	X	
18	Housatonic River Basin	X	X			X	X	X		X		X	X	X	
19	Thames River Basin and Conn. Eastern Coastal	X	X			X	X	X		X		X	X	X	
22	Long Island Sound		X			X	X	X						X	
Subregion 106	Richelieu				O							O		O	
Area 20	Lake Champlain Basin		X			X	X			X		X		X	
21	Lake Memphremagog-St. Francis River Basin													X	

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New England Region (1)

Total Area and Major River Systems

The New England Region has over 44 million acres, slightly over 2 percent of the total area of the conterminous United States. The region's abundant water resources, 30,000 miles of streams, more than 5,000 lakes, and 6,000 miles of coastline, include New England's largest single basin, that of the Connecticut River. Most of the New England Region rivers flow in a generally southerly or southeasterly direction toward Long Island Sound or the Atlantic Ocean. Exceptions are the Saint John River and the Lake Champlain and Lake Memphremagog drainages.

Water Supply Situation

Overall, the region appears to have adequate water and related land resources to provide for future generations. However, because continuous settlement in urbanized areas has placed quantitative and qualitative stress on local resources, scarcity due to maldistribution of water and poor water quality does occur at the local level. The potential for severe water supply shortages is substantial, especially if water sources are not protected and managed wisely.

Industry is the largest consumptive water user.

Water-related Problems

New England faces problems of water pollution, local flooding, insufficient water supplies, energy facility siting, dredging effects, inadequate water-based recreation opportunities, and conflicts over use of water and related lands. The severity of most problems intensifies near metropolitan areas, especially since many urban areas are located at points where surface-water flows cannot assimilate accumulated waste products from upstream. Discrepant distribution of water within the region arises from specific major issues including proposed interbasin diversions from the Connecticut River Basin to Boston, land-use controls, and oil and gas reserves development on George's Bank. The primary challenges facing the New England Region in the near future are distribution of enough high quality water to provide for domestic, industrial, and agricultural needs, and the proper allocation of land for economic growth and maintenance of the environment.

The 22 geographic problem areas identified by the New England River Basins Commission are shown on the New England Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

The New England regional sponsor proposes a set of objectives designed to achieve an overall strategy to resolve resource issues and suggests ways to implement them. In Volume 4, detailed recommendations are given for problems of water quality, water supplies, flooding and wetlands destruction, erosion and sedimentation, low streamflows and fluctuating lake levels, inadequate water-oriented recreation, energy facility siting, and coastal petroleum development and transportation. These recommendations incorporate three approaches: data collection and research; planning studies; and legal, institutional, and policy changes.

National and State-Regional Futures

Table V-1 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the New England Region. For withdrawal and consumption estimates it was necessary to adopt the National Future information as New England's State-Regional Future. This use should not imply full review and acceptance of National Future information; instead, it reflects the lack of State information on a subregional basis. State data collection programs are addressing the "information gap" revealed in some of the resource categories. As it becomes available, more precise information will be incorporated into the continuing water assessment and basin planning programs. However, the subregions are not now appropriate geographic units for most State resource programs.

Values for streamflow at the outflow point in Table V-1 represent the estimated streamflow of the region in an average year under present and future conditions of consumptive use, imports, exports, and reservoir evaporation. The slight difference between SRF and NF is attributed to differing population estimates.

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Table V-1.—Socioeconomic and volumetric data summary: the New England Region

Category	"1975"		1985		2000	
	NF	SRF[a]	NF	SRF[a]	NF	SRF[a]
SOCIOECONOMIC DATA (1000)						
Total population	12,492	12,380	13,613	13,442	15,313	14,965
Total employment	5,460	5,460	6,204	6,204	7,209	7,209
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	78,661	NE	78,661	NE	78,661	NE
Streamflow at outflow point(s)	78,180	77,870	78,014	NE	77,598	NE
Fresh-water withdrawals	5,098	5,098	3,939	3,939	3,230	3,230
Agriculture	53	53	60	60	65	65
Steam electric	1,263	1,263	1,069	1,069	375	375
Manufacturing	2,170	2,170	1,022	1,022	781	781
Domestic	1,122	1,122	1,223	1,223	1,356	1,356
Commercial	361	361	393	393	442	442
Minerals	90	90	115	115	153	153
Public lands	2	2	2	2	3	3
Fish hatcheries	37	37	55	55	55	55
Other	0	0	0	0	0	0
Fresh-water consumption	481	481	647	647	1,063	1,063
Agriculture	43	43	48	48	52	52
Steam electric	21	21	18	18	167	167
Manufacturing	192	192	332	332	567	567
Domestic	164	164	179	179	196	196
Commercial	48	48	52	52	58	58
Minerals	11	11	16	16	20	20
Public lands	2	2	2	2	3	3
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	635	664	NE	NE	NE	NE
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	69,001	69,001	69,001	69,001	69,001	69,001

NE - Not estimated.

[a] The New England River Basins Commission adopted the National Future as New England's State-Regional Future for withdrawals and consumption because of the lack of State information on a subregion basis.

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Mid-Atlantic Region (2)

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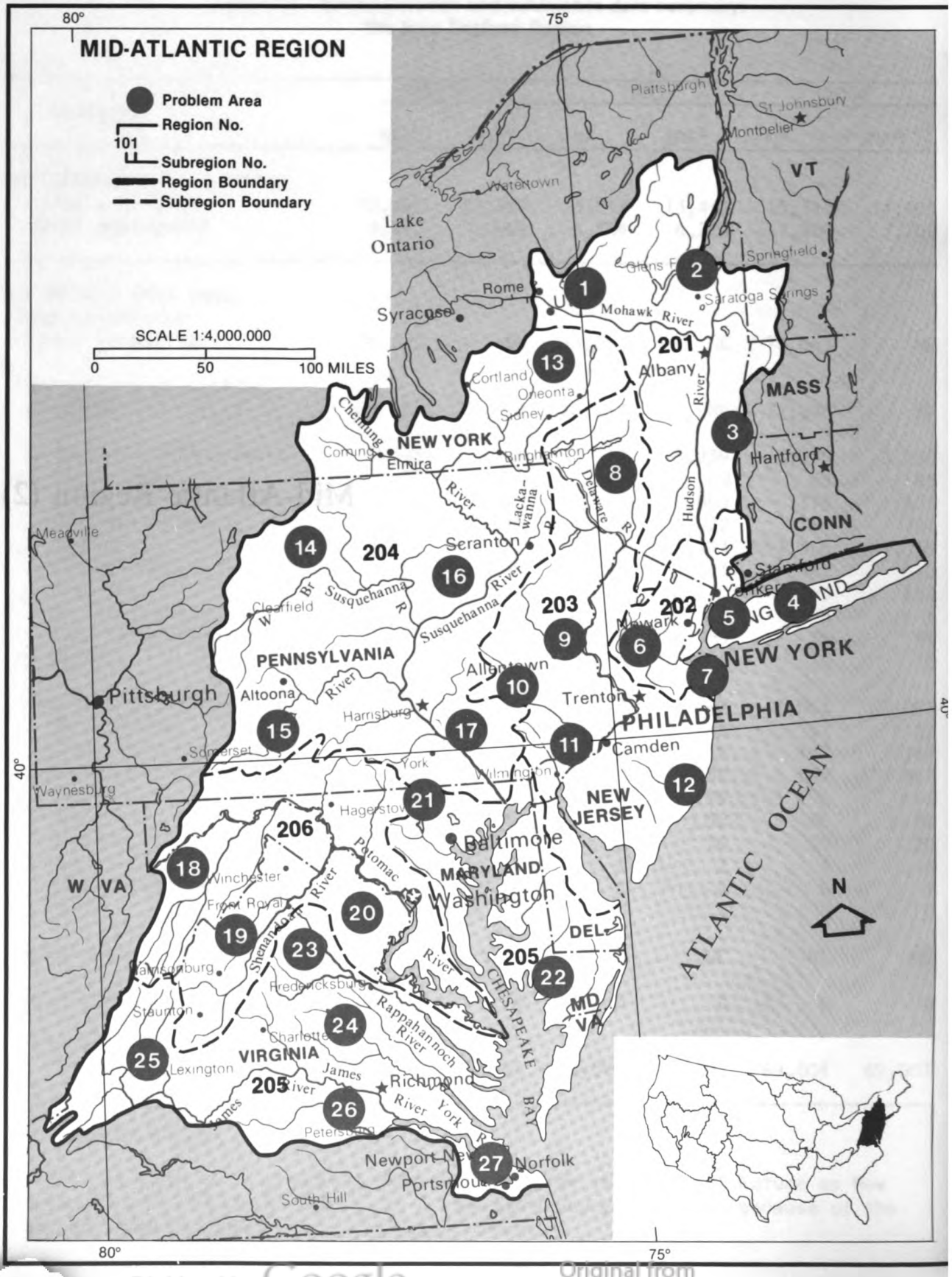

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MID-ATLANTIC REGION (2)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 201	Upper Hudson	O	O			O						O	O	O	O
Area 1	Mohawk River above Little Falls, N.Y.	X				X				X				X	X
2	Hudson River above Albany, N.Y.	X				X									
3	Hudson River Basin — Remainder	X				X		X				X	X	X	X
Subregion 202	Lower Hudson-Long Island-North New Jersey	O	O			O	O	O	O	O		O	O	O	O
Area 4	Nassau and Suffolk Counties, N.Y.	X	X			X	X	X		X		X		X	
5	New York City and Westchester Co.	X		X		X	X	X		X		X	X	X	
6	Passaic & Raritan Rivers & No. New Jersey Streams	X	X			X	X	X		X	X			X	
7	Atlantic Ocean Drainage, Monmouth Co., N.J.	X		X			X	X		X		X	X	X	
Subregion 203	Delaware	O	O			O	O	O	O	O	O	O	O	O	O
Area 8	Delaware River above Montague, N.J.	X	X			X	X			X		X		X	
9	Delaware River above Trenton, N.J.	X	X			X	X			X			X	X	X
10	Schuylkill River above Pottstown, Pa.	X	X			X	X			X				X	
11	Lower Schuylkill River & Delaware Estuary	X	X			X	X	X		X	X		X	X	
12	Atlantic Ocean Drainage, Remainder of N.J.	X	X	X		X	X	X		X		X	X	X	
Subregion 204	Susquehanna	O		O	O	O		O		O	O	O	O	O	O
Area 13	Susquehanna River above Towanda, Pa.	X	X			X	X			X		X		X	
14	W. Branch, Susquehanna Riv. above Williamsport, Pa.	X	X			X				X		X			
15	Juniata River above Newport, Pa.	X	X			X				X		X			
16	Susquehanna River above Harrisburg, Pa.	X	X			X				X	X	X	X		
17	Susquehanna River Basin — Remainder	X	X			X	X			X		X			
Subregion 206	Potomac	O	O	O		O	O	O		O		O	O	O	O
Area 18	Potomac River above Hancock, Md.		X			X	X					X		X	
19	Shenandoah River above Millville, W.Va.		X			X	X					X			
20	Potomac River Basin — Remainder	X	X			X	X	X		X		X		X	
Subregion 205	Upper and Lower Chesapeake	O	O		O	O	O	O	O	O	O	O	O	O	
Area 21	Patuxent River & Western Shore of Chesapeake Bay					X	X	X	X	X	X	X	X	X	
22	Delmarva Peninsula & Eastern Shore of Chesapeake Bay					X	X	X		X	X	X	X	X	
23	Rappahannock River Basin, Va.		X			X		X						X	
24	York River Basin, Va.		X			X		X		X			X	X	
25	James River above Scottsville, Va.					X				X				X	
26	James River above Hopewell, Va.					X	X			X		X	X	X	
27	James River Basin — Remainder	X	X				X	X		X		X	X	X	

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Mid-Atlantic Region (2)

Total Area and Major River Systems

The Mid-Atlantic Region covers over 66 million acres. Rivers in the northern half of the region flow generally southward to the ocean; the southern rivers flow in an easterly direction. The Hudson and the Delaware Rivers flow to the Atlantic Ocean directly; the Susquehanna, Potomac, Rappahannock, York, and James Rivers empty into the Chesapeake Bay. The harbors and waterways of the region are an integral part of the Nation's transportation system.

Water Supply Situation

The natural supply of water exceeds both present and anticipated demands, but distribution and quality are problems. Water supply shortages are becoming severe in certain areas throughout the region, especially in headwater sub-basins, bays, estuaries, and lower tidal reaches of rivers. These supply problems will worsen as the population increases and as saline intrusion limits the use of ground water.

Manufacturing and steam electric plants now withdraw the greatest amounts of water from streams and ground water.

Water-related Problems

The Mid-Atlantic Region is the oldest, the most developed, and the most densely populated region in the Nation. Therefore, its water problems have probably the most diverse, complex, and unique conflict of demands, institutional arrangements, and feasibility of solutions.

The most severe and widespread problems involve local water supply; salt-water intrusion; flooding of urban and developed lands and encroachments on flood plains; erosion and the effects of sedimentation on water courses, reservoirs, navigation channels, and wetlands; disposal of excavated and dredged materials and sewage sludge; and conflicts in water use among urban, industrial, conservation, and recreation uses.

The 27 geographic problem areas identified by the North Atlantic Division Corps of Engineers are shown on the Mid-Atlantic Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

The Mid-Atlantic regional assessment indicates that the Federal Government should act as a unifying force and should provide cost-sharing programs. No new Level B studies are recommended. Data collection and research should expand to include flow requirements and instream needs. Analyses of existing institutional arrangements are recommended.

National and State-Regional Futures

Table V-2 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Mid-Atlantic Region.

The differences in information are relevant to future planning since they affect estimates of water supplies, withdrawals, consumption, and instream uses. The NF makes no projections for current downstream water rights; the SRF assumes no changes in these matters. Differences in NF and SRF withdrawal projections result from the different population estimates adopted by the States of New York, New Jersey, Virginia, and Pennsylvania and from varying rates of per capita needs. Estimates of water needs for various manufacturing industries and for steam electric generation also differ. The larger SRF projections for irrigation withdrawals stem from the Pennsylvania projections for its portions of subregions 203, 204, and 206.

Whether the NF or SRF projections materialize depends on: the resolution of national policy, which will affect the economy, technological development, and public desires in energy development; implementation of environmental programs; and related matters. During the projected period, all views of the future must be considered and adapted as policy is resolved and as decisions and future plans are made concerning water and related problems. The gross amount of water available on a regionwide level is much greater than either the NF or the SRF projections of withdrawal would require. In some cases, decisions on use will be made locally, e.g., in the category of irrigation. In other cases such as needs of energy production, decisions on use will depend on national and international events, on production and use of fossil and nuclear fuels, and on the alternative and still experimental means of fuel and energy production that presented problems of uncertainty in the early projections for the assessment.

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Table V-2.—Socioeconomic and volumetric data summary: the Mid-Atlantic Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	39,612	38,933	43,873	42,265	49,939	46,709
Total employment	17,097	17,108	19,730	19,730	23,307	23,307
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	81,001	NE	81,001	NE	81,001	NE
Streamflow at outflow point(s)	79,190	78,984	78,529	NE	77,453	NE
Fresh-water withdrawals	18,300	18,909	15,857	17,032	13,873	16,122
Agriculture	333	529	435	779	552	1,025
Steam electric	7,463	7,872	7,130	7,734	4,657	5,947
Manufacturing	5,416	5,918	2,526	3,245	1,942	2,869
Domestic	3,954	4,155	4,467	4,740	5,168	5,598
Commercial	650	[a]	726	[a]	826	[a]
Minerals	459	421	548	516	700	663
Public lands	4	14	4	18	7	20
Fish hatcheries	21	NE	21	NE	21	NE
Other	0	0	0	0	0	0
Fresh-water consumption	1,843	1,994	2,472	2,791	3,548	4,164
Agriculture	264	439	338	658	425	864
Steam electric	103	78	224	162	644	489
Manufacturing	607	678	934	1,073	1,361	1,773
Domestic	705	742	790	826	896	947
Commercial	91	[a]	101	[a]	114	[a]
Minerals	70	52	82	65	102	82
Public lands	3	5	3	7	6	9
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	0	0	0	0	0
Ground-water withdrawals	2,661	2,811	NE	2,891	NE	3,011
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	68,840	68,840	68,840	68,840	68,840	68,840

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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South Atlantic-Gulf Region (3)

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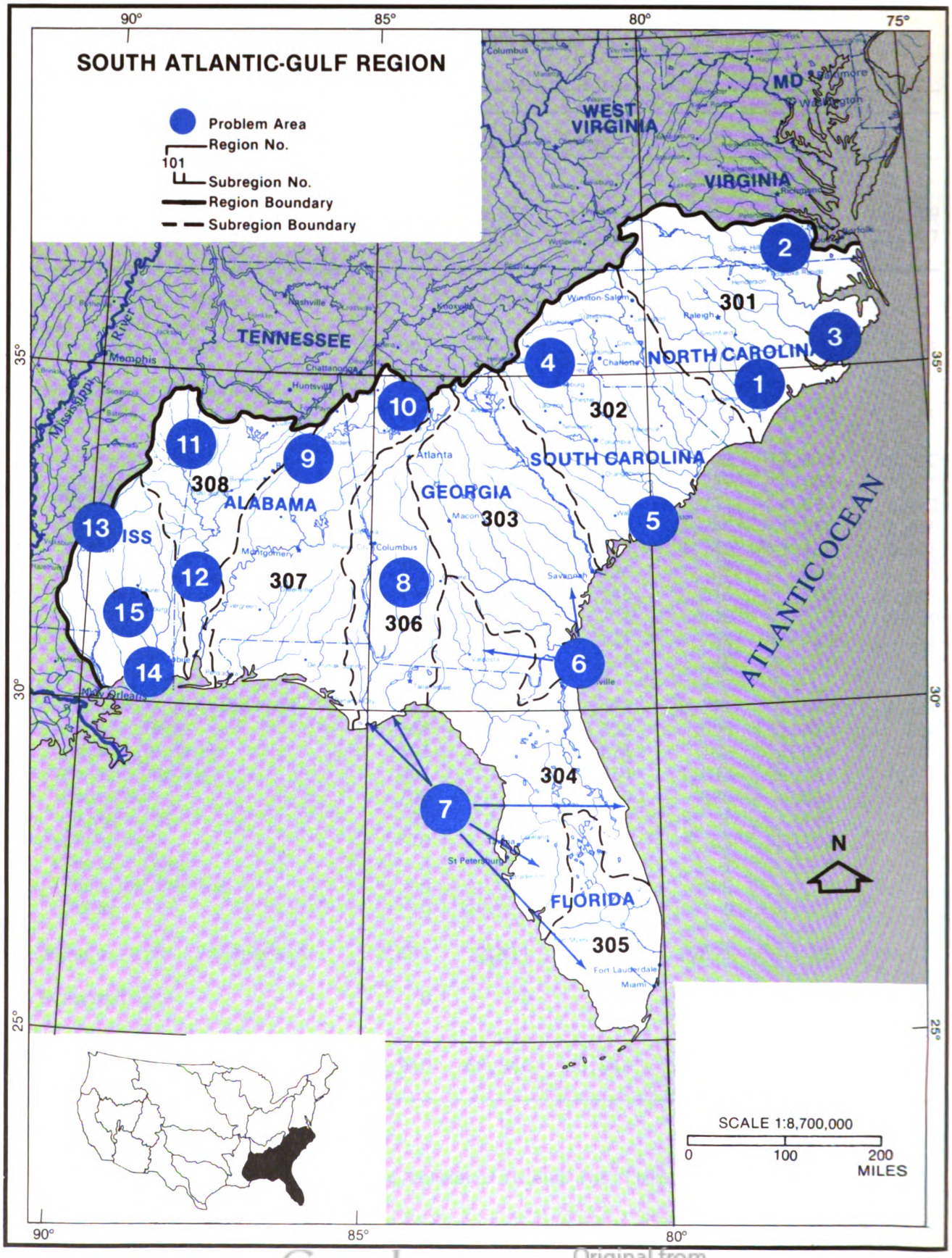

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SOUTH ATLANTIC-GULF REGION (3)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representativ												
		Water quantity				Water quality				Related lands				
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts
Subregion 301	Roanoke-Cape Fear	O				O	O				O			
Area 1	Cape Fear – North Central, North Carolina	X				X		X		X	X	X		X
2	Chowan-Lower Roanoke-Pasquotank	X	X					X		X				X
3	Central North Carolina Coast		X					X		X				X
Subregion 302	Pee Dee-Edisto					O								
Area 4	Catawba-Broad-Saluda	X	X			X	X					X		X
5	Southeast South Carolina Coast							X						
Subregion 303	Savannah-St. Marys	O					O	O			O			
and 304	St. Johns-Suwannee													
Area 6	Southeast S.C. Coast, Ga. Coastal Plain & No. Fla.		X				X							
Subregion 304	St. Johns-Suwanee/Southern Florida/Apalachicola/													
305, 306, 307	Alabama-Choctawatchee	O				O	O					O		
Area 7	Florida Coast											X		
Subregion 306	Apalachicola	O										O		
Area 8	Apalachicola-Chattahoochie-Flint		X	X		X	X			X		X		X
Subregion 307	Alabama-Choctawatchee	O								O		O		
and 308	Mobil-Tombigbee													
Area 9	Black Warrior-Cahaba	X												
Subregion 307	Alabama-Choctawatchee	O								O		O		
Area 10	Coosa in Georgia					X								
Subregion 308	Mobil-Tombigbee					O								
Area 11	Tombigbee		X				X							
12	Mobile-Lower Tombigbee	X					X				X			X
Subregion 309	Pascagoula-Pearl					O					O			
Area 13	Upper Pearl					X								
14	Mississippi Coast							X						
15	Pascagoula	X					X							X

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South Atlantic-Gulf Region (3)

Total Area and Major River Systems

The South Atlantic-Gulf Region encompasses a total area of over 173 million acres. The region contains 24 major river basins including the Roanoke, the Cape Fear, the Savannah, the Suwannee, the Tombigbee, and the Pearl and many minor coastal river systems.

Water Supply Situation

The South Atlantic-Gulf Region has ample surface and ground water to provide for an expanding economy. Generally good quality ground water that can be developed in coastal plain areas is abundant. Water resources, however, are not always well located for the needs, and local water shortages already occur in highly developed upstream areas.

Steam electric plants currently make the largest water withdrawals; the paper and pulp industry also makes large water demands.

Water-related Problems

Major problems with water and related land resources result from growth and related water demands in areas where water is limited. Stream headwaters and industrialized areas are particularly affected. In other areas, overpumping of ground water has led to salt-water intrusion, another threat to usable water supply. In addition to water quantity limitations, excessive pollutants are reaching the streams and coastal waters, and, in some areas, threatening ground-water resources. Floodplain management and flood control structures are needed in many areas of the region. Protection of beach areas and associated waters from erosion and water quality degradation is a major concern, especially in Florida. There are conflicts over the dredging and filling of wetlands, along with other water and related land-use issues. Along interstate streams numerous management problems occur regarding interbasin and interstate transfers of water. The region contains many environmentally sensitive areas that deserve consideration.

The 15 geographic problem areas identified by the Southeast Basins Inter-Agency Committee are shown on the South Atlantic-Gulf Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

In the South Atlantic-Gulf Region, the Federal Government should assist in the resolution of problems of regional or national significance by supplying technical and financial support for programs such as construction of navigation systems, USDA Type IV Cooperative Studies, and data and research supplements. Five geographic areas are listed as potential Level B study areas; additional planning studies are recommended for 10 areas. An expansion of data collection and research is needed in 21 separate subject areas including streamflows, ground-water aquifiers, and water withdrawals and consumptive use. Fourteen institutional problems and the levels of government responsible for their resolution are given in Volume 4.

National and State-Regional Futures

Table V-3 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the South Atlantic-Gulf Region. The totals for flows reflect total outflows from the nine subregions of the region.

The difference between SRF and NF information reflects discrepancies in assumptions, goals, and objectives at the regional and State level versus those at the national level. An assumption at the regional level is that water withdrawals will tend to increase at a fairly high rate because water will be abundant as a result of proper planning and management. NF values, on the contrary, assume a large reuse of water by 2000. Differences in manufacturing water use estimates reflect the SRF assumption that no major changes will take place in the reuse of water. NF values show manufacturing plants reusing significant amounts of water by 2000, thus reducing the total manufacturing withdrawals. Some SRF information on manufacturing water use from central systems could not be separated for tabular analysis. SRF values indicate a significant expansion of central public water systems to serve outlying areas and a larger percentage being served by these systems in the future than the NF values show.

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Table V-3.—Socioeconomic and volumetric data summary: the South Atlantic-Gulf Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	25,423	26,164	29,334	30,736	34,680	36,761
Total employment	10,345	10,518	12,282	12,682	14,727	15,542
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	232,538	NE	232,538	NE	232,538	NE
Streamflow at outflow point(s)	228,010	228,036	225,766	227,960	222,485	227,443
Fresh-water withdrawals	24,510	26,461	25,457	29,256	28,340	34,777
Agriculture	3,598	5,262	4,174	6,123	4,711	6,955
Steam electric	12,768	13,262	12,912	12,930	13,952	13,937
Manufacturing	4,103	3,824	3,377	5,061	3,318	7,194
Domestic	2,288	3,016[a]	2,801	3,701[a]	3,486	4,714[a]
Commercial	553		632		769	
Minerals	1,178	1,069	1,538	1,409	2,077	1,939
Public lands	5	28[b]	6	32[b]	10	38[b]
Fish hatcheries	17		17		17	
Other	0	NE	0	NE	0	NE
Fresh-water consumption	4,867	6,062	6,772	7,760	10,053	10,272
Agriculture	2,886	4,210	3,350	4,904	3,799	5,586
Steam electric	153	156	722	721	1,857	1,856
Manufacturing	611	735	1,203	972	2,532	1,381
Domestic	880	786[a]	1,079	934[a]	1,345	1,139[a]
Commercial	118		138		161	
Minerals	214	165	274	215	349	291
Public lands	5	10[b]	6	14[b]	10	19[b]
Fish hatcheries	0		0		0	
Other	0	NE	0	NE	0	NE
Ground-water withdrawals	5,449	7,037	NE	8,711	NE	10,688
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	188,655	577[c]	188,655	648[c]	188,655	648[c]

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.
[b] SRF public lands water use includes fish hatcheries requirements.
[c] SRF lists legal requirements only; data were developed by specific river basins.

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Great Lakes Region (4)

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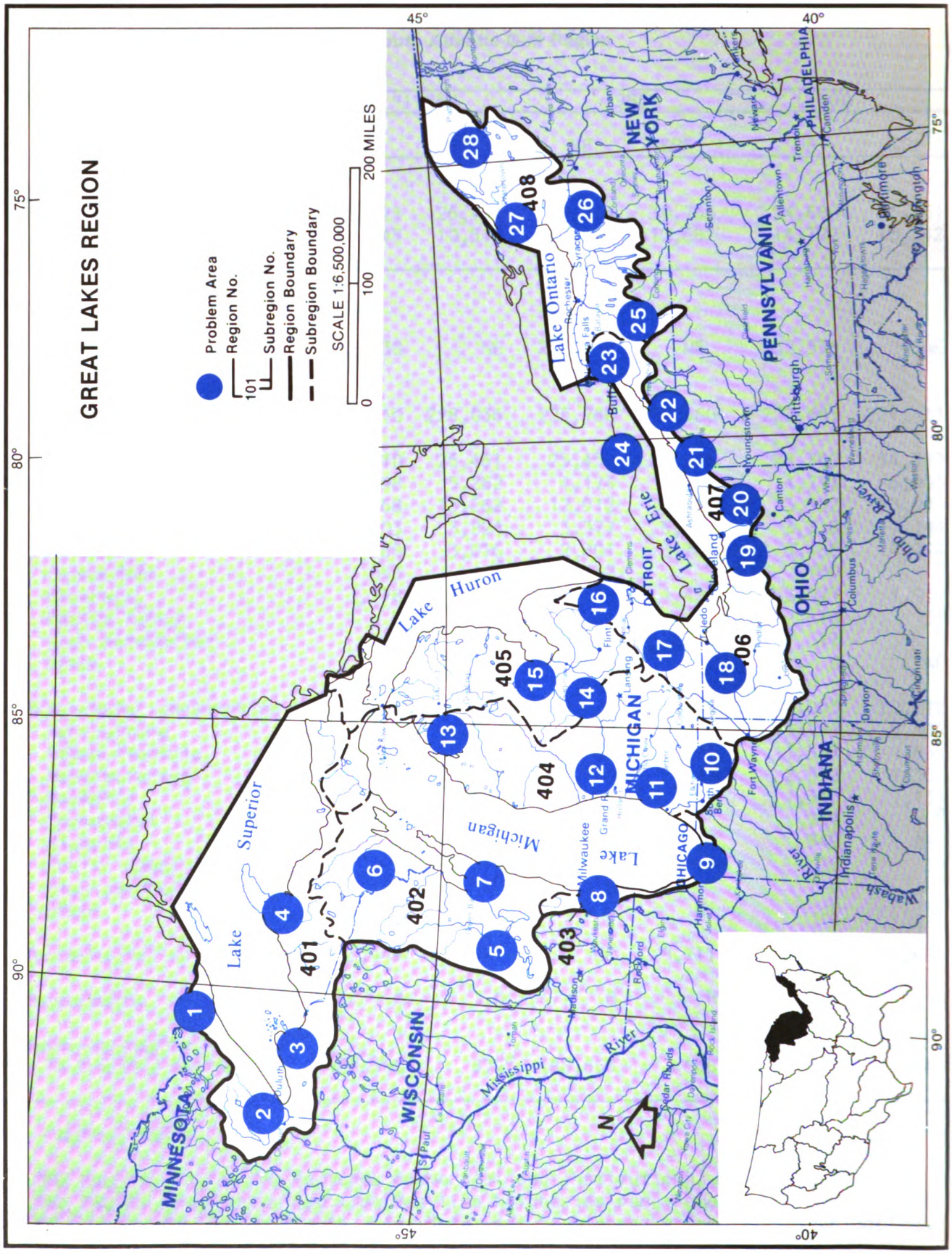

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GREAT LAKES REGION (4)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 401	Lake Superior					O						O			O
Area 1	Superior Slope Complex			X				X				X	X	X	X
2	St. Louis River Basin/Duluth Superior Area	X		X		X		X		X	X	X	X	X	
3	Apostle Islands, Bad River, Montreal River Complex			X		X		X		X		X	X	X	
4	Mich.'s Upper Pen.-Lake Superior & Lake Huron Drain.	X	X	X		X	X	X		X	X	X	X	X	X
Subregion 402	NW Lake Michigan					O							O		O
Area 5	Fox-Wolf River Basin	X	X	X		X	X			X		X	X	X	
6	Northwest Shore of Lake Michigan		X	X		X	X	X		X	X	X	X	X	
7	Sheboygan-Green Bay Complex			X		X	X	X		X	X	X	X	X	
Subregion 403	SW Lake Michigan		O			O	O			O		O	O		O
Area 8	Southeast Wisconsin Complex		X	X		X	X	X		X	X	X	X	X	
9	Chicago-Indiana Complex	X	X			X	X	X		X	X	X	X	X	X
Subregion 404	Eastern Lake Michigan					O						O			O
Area 10	St. Joseph River Basin	X		X		X		X		X	X	X	X	X	X
11	Kalamazoo-Black-Macatawa-Paw River Basins		X			X	X	X		X	X	X	X	X	
12	Grand River Basin	X		X		X	X	X		X	X	X	X	X	
13	Northern Lower Peninsula		X	X		X	X					X	O	X	X
Subregion 405	Lake Huron					O						O			O
Area 14	Saginaw River Basin					X	X			X	X	X	X	X	X
15	Saginaw Bay-Thumb Complex		X	X			X	X	X	X	X	X	X	X	X
Subregion 406	St. Clair-Western Lake Erie					O				O		O	O		O
Area 16	Detroit Metropolitan Area	X		X		X		X		X	X	X	X	X	X
17	Huron-Raisin Complex	X	X	X		X	X	X		X	X	X	X	X	X
18	Maumee River Basin	X		X		X	X	X		X	X	X	X	X	
19	Ohio Lake Plains	X	X	X		X	X	X		X	X	X	X	X	
Subregion 407	Eastern Lake Erie					O					O	O			O
Area 20	Cleveland-Akron Metro Area		X	X		X		X		X	X	X	X	X	
21	Grand-Ashtabula-Conneaut River Basins	X		X		X		X		X	X	X	X	X	
22	Erie-Chautauqua Complex		X	X		X	X	X		X	X	X	X	X	X
23	Erie-Niagra Region	X		X		X		X		X		X	X	X	
24	Lake Erie Basin			X		X	X	X				X	X	X	X
Subregion 408	Lake Ontario					O						O			O
Area 25	Genesee River Basin					X		X		X		X	X	X	X
26	Great Finger Lakes-Oswego River Basin	X		X		X				X	X	X	X	X	X
27	Lake Ontario Lake Plains	X				X		X				X	X	X	X
28	Black River-St. Lawrence Complex	X		X		X		X		X	X	X	X	X	X

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Great Lakes Region (4)

Total Area and Major River Systems

The Great Lakes Region, about 4 percent of the total area of the 48 contiguous United States, contains over 85 million acres. Waters from Lake Superior, Lake Michigan, and the Georgian Bay all drain into Lake Huron, which discharges water to Lake Erie through the St. Clair River, Lake St. Clair, and the Detroit River. Lake Erie, in turn, drains through the Niagara River to Lake Ontario, whose outlet is the head of the St. Lawrence River. Most of the water withdrawn from the Great Lakes hydrologic system comes directly from the lakes, which all together are the world's largest surface body of fresh water. An important navigation system is formed by the lakes and their connecting waterways and channels.

Water Supply Situation

While the overall water supply in the region is abundant, there are shortterm problems with ground-water depletion in localized areas, especially in Illinois, and with severe droughts in inland portions of Michigan, Minnesota, and Wisconsin. Additionally, competition for use of the available supply for drinking water and waste discharges results in misallocation and increased costs for treatment of the resource.

The largest amount of water withdrawn goes to cool steam electric generating plants; manufacturing sectors consume the largest percentage of water.

Water-related Problems

The major water resource difficulties include water quality, erosion and sedimentation, flooding and land-use conflicts, and localized water supply and instream flow problems. Water quality concerns, which are especially prevalent in and near highly urbanized areas, include toxic materials, eutrophication, and esthetic problems. Lake Erie has the most critical pollution problem. Flooding and erosion have resulted in significant economic damages and have caused concern about flood-plain and coastal land use. Erosion and sedimentation have lowered the potential for agricultural production, have impaired water quality, and have reduced the esthetic and environmental attributes of streams and rivers throughout the basin. Power production, navigation, and environmental disruptions occur periodically during times of low lake levels.

The 28 geographic problem areas identified by the Great Lakes Basin Commission are shown on the Great Lakes Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

The Great Lakes Region recommends that the Federal Government coordinate and fund resource programs to ensure a unified approach to water resource problems. Special studies are prescribed for three areas of investigation: (1) the cumulative effects of human and natural activities on the Great Lakes; (2) the effects of national and regional energy demands on the lakes; and (3) the relationships between the Great Lakes Region and outside influences. The research and data needs identified include tracing bioactive pollutants of the Great Lakes, soils and land-use surveys, and toxic substances and waste management research. Recommendations for institutional arrangements regarding such issues as flood-plain management, mineral resources, recreation and natural areas, agriculture, forestry, water quality, and land resources are discussed.

National and State-Regional Futures

Table V-4 presents the National Future (NF) estimates of streamflows and water needs in the Great Lakes Region.

The Great Lakes Basin Commission adopted the position that the nationally generated National Future values describing socioeconomic changes, volumetric data for withdrawal and consumptive use, and water supply information would be acceptable as the State-Regional Future values for the Great Lakes Region. For those categories where NF values were not available, information was taken from the Great Lakes Basin Framework Study. The use of the National Future information does not imply full review and acceptance; rather it reflects the lack of State information on a subregion basis.

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Table V-4.—Socioeconomic and volumetric data summary: the Great Lakes Region

Category	"1975"		1985		2000	
	NF	SRF[a]	NF	SRF[a]	NF	SRF[a]
SOCIOECONOMIC DATA (1000)						
Total population	30,391	30,391	32,855	32,855	36,351	36,351
Total employment	12,796	12,796	14,446	14,446	16,583	16,583
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	75,281	NE	75,281	NE	75,281	NE
Streamflow at outflow point(s)	72,710	72,710	71,981	NE	70,588	NE
Fresh-water withdrawals	42,813	42,813	32,666	32,666	25,623	25,623
Agriculture	230	230	296	296	369	369
Steam electric	24,362	24,362	22,689	22,689	16,061	16,061
Manufacturing	13,220	13,220	4,106	4,106	2,821	2,821
Domestic	3,267	3,267	3,614	3,614	4,077	4,077
Commercial	1,010	1,010	1,091	1,091	1,206	1,206
Minerals	696	696	831	831	1,044	1,044
Public lands	6	6	13	13	17	17
Fish hatcheries	22	22	26	26	28	28
Other	0	0	0	0	0	0
Fresh-water consumption	2,598	2,598	3,300	3,300	4,693	4,693
Agriculture	199	199	254	254	319	319
Steam electric	175	175	497	497	1,384	1,384
Manufacturing	1,474	1,474	1,719	1,719	2,059	2,059
Domestic	476	476	519	519	563	563
Commercial	113	113	123	123	140	140
Minerals	155	155	175	175	211	211
Public lands	6	6	13	13	17	17
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	1,215	1,215	NE	NE	NE	NE
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	63,951	63,951	63,951	63,951	63,951	63,951

NE - Not estimated.

[a] The Great Lakes Basin Commission accepted the National Future as the State-Regional Future for use in the national assessment because of the lack of State data on a subregion basis.

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Ohio Region (5)

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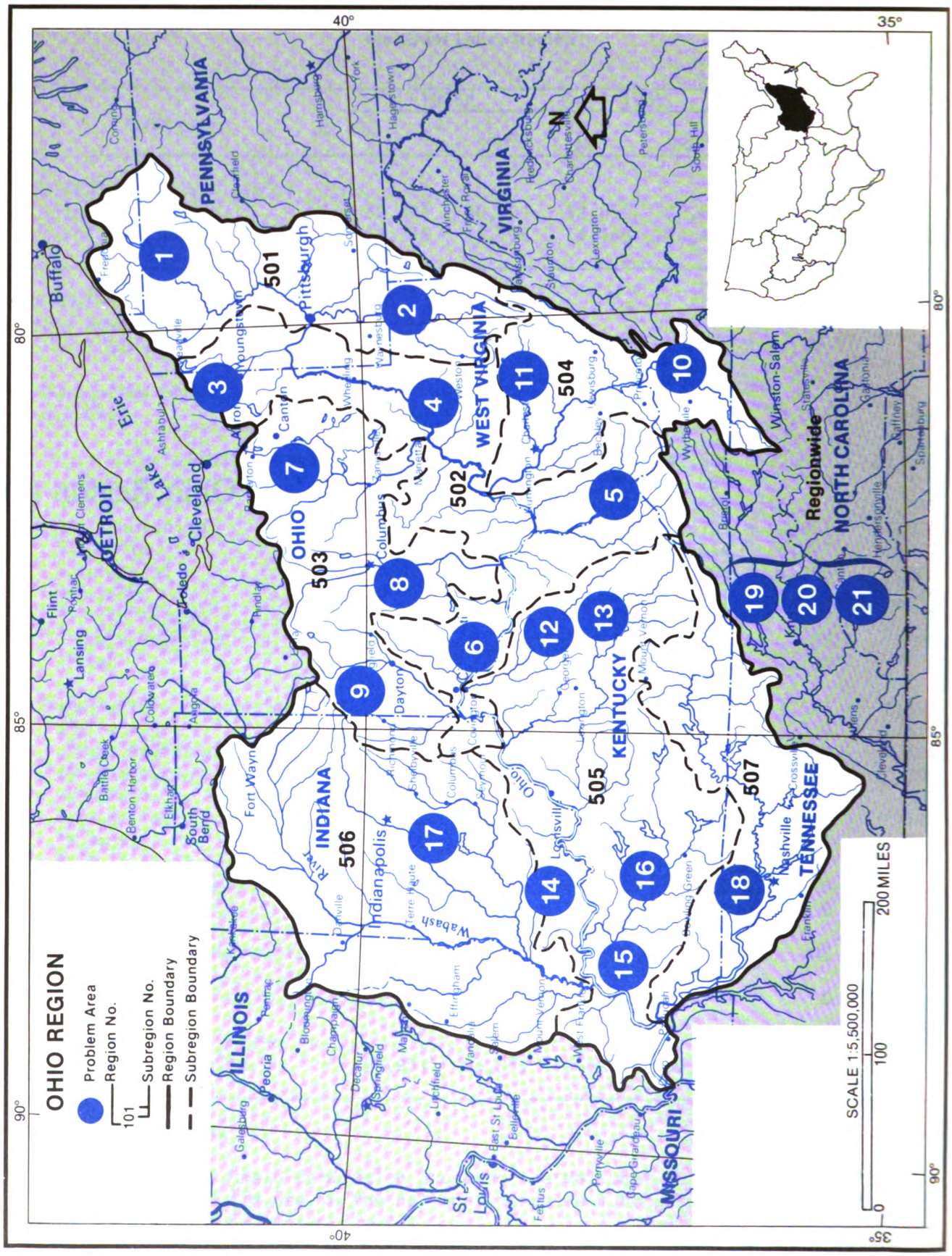

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OHIO REGION (5)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 501	Ohio Headwaters					O						O			O
Area 1	Allegheny River Basin	X				X				X				X	
2	Monongahela River Basin	X			X	X				X				X	
Subregion 502	Upper Ohio-Big Sandy					O				O		O			O
Area 3	Mahoning River Basin	X				X				X	X				
4	Upper Ohio River Main Stem					X	X			X		X			
5	Big Sandy-Guyandotte River Basins					X						X			
6	Middle Ohio River Main Stem		X			X				X		X			
Subregion 503	Muskingum-Scioto-Maimi					O				O		O			O
Area 7	Muskingum River Basin	X			X	X	X			X	X				
8	Scioto River Basin	X	X		X	X									
9	Great Miami River Basin				X	X	X			X	X				
Subregion 504	Kanawha					O				O		O			O
Area 10	New River Basin	X				X				X	X	X			
11	Kanawha River Main Stem	X				X				X	X	X		X	
Subregion 505	Kentucky-Licking-Green-Ohio					O				O		O			O
Area 12	Licking River Basin	X			X	X				X					
13	Kentucky River Basin	X	X		X	X				X			X		
14	Lower Ohio River Main Stem	X			X	X				X	X	X			
15	Tradewater River Basin	X				X					X			X	
16	Green River Basin	X				X	X			X	X	X			
Subregion 506	Wabash					O						O			O
Area 17	Wabash River Basin	X			X	X				X	X	X		X	
Subregion 507	Cumberland					O						O			O
Area 18	Cumberland River Basin	X	X			X	X			X					
19	Ohio River Basin: Regionwide Mine Drainage	X				X	X					X			
20	Ohio Region: Non-Point Source Pollution	X			X	X						X			
21	Ohio Region: Energy														

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Ohio Region (5)

Total Area and Major River Systems

The Ohio Region embraces a total area of over 102 million acres. The Ohio River, the region's primary river, is formed by the confluence of the Allegheny and the Monongahela Rivers at Pittsburgh and is joined by major downstream tributaries. It flows in a southwesterly direction and joins the Mississippi River at Cairo, Illinois. The Ohio River is a key element of the Nation's inland waterways system.

Water Supply Situation

Overall, the basin has an excellent potential for water supply that should enable its residents to overcome any supply problems. Ground water is a valuable regional resource, but in many areas it has not been developed to its water supply potential. The Ohio Region contains vast amounts of bituminous coal, about 70 percent of the national reserves. The relatively abundant water supplies provide a great potential for increased energy-related development within the region. Water withdrawals for mining of fuels are projected to increase from less than one percent of the total withdrawals in "1975" to about 2 percent in 2000.

Surface- and ground-water withdrawals have many uses, principally for steam electric generation, followed by manufacturing.

Water-related Problems

The major concern facing the region is the water quality, which is severely affected in metropolitan areas and downstream from these areas. Problems from acid mine drainage are the most significant, but industrial wastes, domestic sewage, and agricultural runoff are serious concerns as well. Improved management practices must correct erosion and sedimentation, flooding, land-use conflicts, instream flow inadequacies, and local supply problems. Floods throughout the basin, particularly in urban areas, cause much industrial, residential, and transportational damages annually. Agricultural flood damage is also substantial in the basin. Institutional and physical management decisions must resolve conflicts among various interests such as navigation, recreation, and industries.

The 21 geographic problem areas identified by the Ohio River Basin Commission are shown on the Ohio Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

A major role of the Federal Government in water-resources management within the Ohio Region is to help resolve problems of water pollution, especially those resulting from acid mine drainage, and to resolve problems of flooding through cost-sharing programs and coordination efforts. A regional plan for the basin has already been developed, but specific areas should be investigated. Data and research are needed for: freshwater management in the Allegheny Basin; the effects of hydrogen sulfide on fish; recreation; and inventory and classification of fisheries.

The region's most severe water resources problem has been pollution of streams and lakes by high-acid drainage waters from abandoned mines and heavy sediment loads from active mines or recently mined areas. The Ohio River Basin Commission recommended a Federal program to abate pollution from these abandoned mines, and the State members of the commission worked closely with the Congress in developing legislation to meet this need. Their efforts successfully culminated in the passage of the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87). This Act strengthened the requirements for pollution abatement from active mines that empty directly into surface waters. Today, assuming successful implementation of the Act of 1977, the significant remaining problem to be addressed at the Commission level is ground-water pollution from mines. Analysis of this problem is currently underway.

National and State-Regional Futures

Table V-5 presents the National Future (NF) estimates of streamflows and water use in the Ohio Region. The Ohio Region has adopted the National Future as its State-Regional Future for these water data categories. Therefore, the NF and SRF values for withdrawals, consumption, and streamflow estimates are in agreement for the Ohio Region. The Ohio River Basin Commission decided to accept the National Future values for use in the national assessment, not because there was agreement with the numbers themselves, but because they could not be separated into any meaningful disaggregation for use at the regional level.

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Table V-5.—Socioeconomic and volumetric data summary: the Ohio Region

Category	"1975"		1985		2000	
	NF	SRF[a]	NF	SRF[a]	NF	SRF[a]
SOCIOECONOMIC DATA (1000)						
Total population	21,158	21,158	22,722	22,722	24,791	24,791
Total employment	8,313	8,313	9,429	9,429	10,838	10,838
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	180,111	NE	180,111	NE	180,111	NE
Streamflow at outflow point(s)	178,000	178,000	176,937	NE	174,674	NE
Fresh-water withdrawals	34,934	34,934	27,838	27,838	16,925	16,925
Agriculture	160	160	195	195	230	230
Steam electric	21,022	21,022	21,008	21,008	10,574	10,574
Manufacturing	10,881	10,881	3,323	3,323	2,341	2,341
Domestic	1,842	1,842	2,068	2,068	2,343	2,343
Commercial	495	495	529	529	571	571
Minerals	493	493	662	662	808	808
Public lands	5	5	8	8	12	12
Fish hatcheries	36	36	45	45	46	46
Other	0	0	0	0	0	0
Fresh-water consumption	1,798	1,798	2,527	2,527	4,332	4,332
Agriculture	150	150	180	180	213	213
Steam electric	324	324	656	656	1,692	1,692
Manufacturing	817	817	1,095	1,095	1,757	1,757
Domestic	349	349	389	389	424	424
Commercial	62	62	67	67	74	74
Minerals	91	91	132	132	160	160
Public lands	5	5	8	8	12	12
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	1,843	1,843	NE	NE	NE	NE
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	160,520	160,520	160,520	160,520	160,520	160,520

NE - Not estimated.

[a] The Ohio River Basin Commission accepted the National Future as the State-Regional Future for use in the national assessment because of the lack of regional data on a subregion basis.

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Tennessee Region (6)

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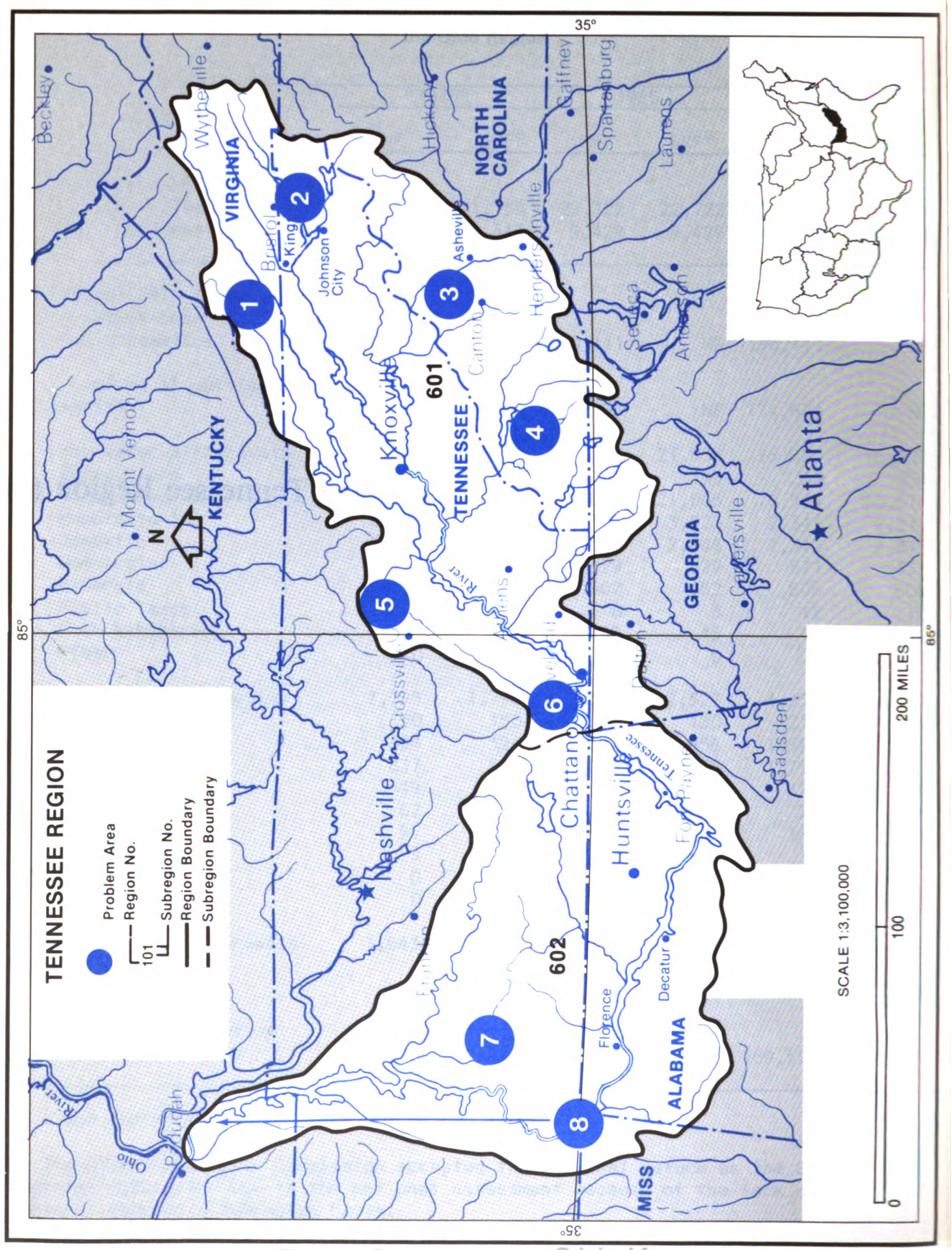

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TENNESSEE REGION (6)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 601	Upper Tennessee					O				O		O			
Area 1	Clinch-Powell	X				X				X		X			
2	Holston	X				X				X				X	
3	Grench Broad					X				X				X	
4	Little Tennessee-Hiwassee					X				X		X		X	
5	Emory	X				X				X		X		X	X
6	Chattanooga	X			X	X				X			X		
Subregion 602	Lower Tennessee					O				O		O			
Area 7	Buffalo	X								X		X			X
8	Locks at Pickwick and Kentucky Dams				X										

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Tennessee Region (6)

Total Area and Major River Systems

The Tennessee Region covers an area of over 27 million acres. Seven large and numerous small rivers feed the Tennessee River as it makes its U-shaped course through the region. Parts of seven States are drained--more than half of Tennessee and smaller portions of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia.

Water Supply Situation

The Tennessee Region has ample land and water resources to provide for an expanding economy with a quality environment; the overall water supply situation is excellent. Problems with streamflows in the region are due generally to conflicts in use rather than to quantity of streamflows.

The major portion of water withdrawals is used by steam electric plants.

Water-related Problems

The most severe problems are with water quality, flooding, erosion and sedimentation, land and water use conflicts, local water supply, and navigational lock capacity. Water and land problems are generally more severe in the eastern upstream areas and near Chattanooga at the center of the region. Water pollution is acute at the manufacturing centers and in upstream areas where paper and pulp plants are located. Flooding is a problem throughout the region, but is most severe in the East where the rugged terrain limits the amount of developable land and encourages building in the flood plain. Water supply shortages are very localized and generally limited to areas near the basin rim. Occasional shortages occur farther downstream because of conflicts in water use among recreation, hydropower generation, and industrial water supply users.

The eight geographic problem areas identified by the Tennessee Valley Authority are shown on the Tennessee Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

Several Level B studies are proposed for various portions of the Tennessee Region. Planning studies and programs are also necessary to prevent increases in flood damages, to change selected stretches of rivers to wild and scenic status, and to reclaim lands degraded by mining activities. Endangered species, point sources of pollution, and navigation are currently under study and may need further attention. Research is needed to determine the effects of reservoir releases on fish and aquatic life and to develop means of aquatic weed control.

National and State-Regional Futures

Table V-6 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Tennessee Region.

Both views of the future need to be considered in decisions and future plans for water-related problems. The amount of water required to meet the SRF projected manufacturing demands is much greater than that required in the NF projections. The NF assumed future high rates of recirculation as a conservation and cost-minimization measure. The SRF assumed that there would be little pressure to conserve because of the region's abundance of water, except in those headwater areas where the recirculation rates are already very high. Differences in irrigation water are high, but irrigation uses an insignificant portion of the region's water, and any effect on the region's resource will be very localized.

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Table V-6.—Socioeconomic and volumetric data summary: the Tennessee Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	3,565	3,565	4,034	4,034	4,615	4,615
Total employment	1,359	1,359	1,617	1,617	1,943	1,943
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	41,113	NE	41,113	NE	41,113	NE
Streamflow at outflow point(s)	40,800	40,800	40,466	NE	40,008	NE
Fresh-water withdrawals	7,412	7,292	7,131	8,858	6,013	8,893
Agriculture	41	41	50	55	58	72
Steam electric	4,799	4,799	5,738	5,738	4,581	4,581
Manufacturing	2,093	1,973	765	2,487	671	3,537
Domestic	263	263	319	319	383	383
Commercial	90	90	102	102	116	116
Minerals	110	110	140	140	186	186
Public lands	1	1	2	2	3	3
Fish hatcheries	15	15	15	15	15	15
Other	0	0	0	0	0	0
Fresh-water consumption	313	304	647	555	1,105	818
Agriculture	38	41	46	54	54	71
Steam electric	42	42	231	231	417	417
Manufacturing	147	135	266	166	514	210
Domestic	59	59	69	69	76	76
Commercial	11	11	12	12	14	14
Minerals	15	15	21	21	27	27
Public lands	1	1	2	2	3	3
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	271	271	NE	277	NE	277
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	38,480	38,480	38,480	38,480	38,480	38,480
Navigation	16,100	16,720	16,100	17,754	16,100	18,102

NE - Not estimated.

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Upper Mississippi Region (7)

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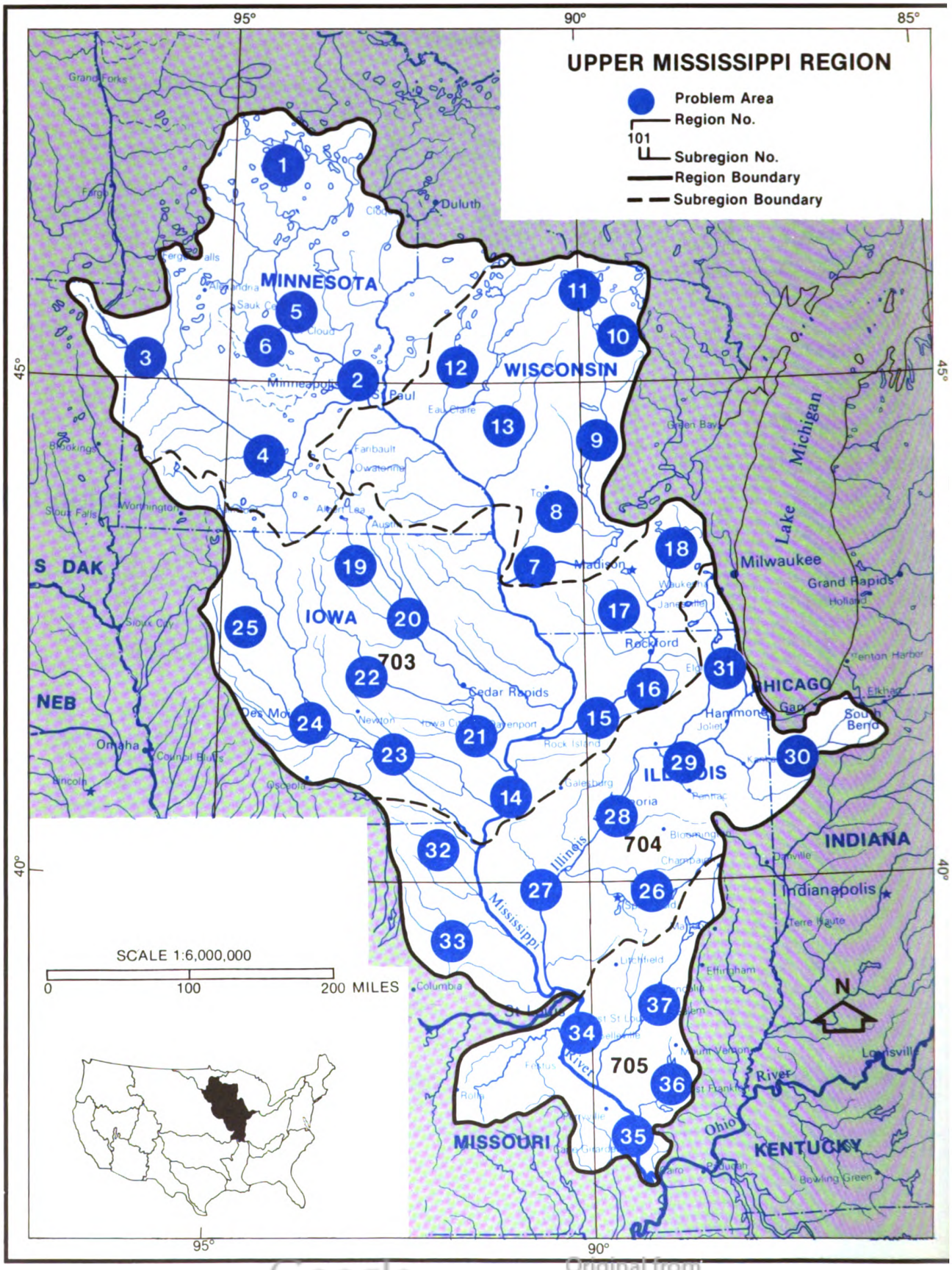

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UPPER MISSISSIPPI REGION (7)

PROBLEM MATRIX

Problem area		Problem issues														
		O= Identified by Federal Agency Representative; X= Identified by State-Regional Representative														
		Water quantity				Water quality				Related lands						
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Subsidence	Water related use conflicts	Other
Subregion 701	Mississippi Headquarters	O			O	O					O	O	O		O	
Area 1	Mississippi River Headwaters, Minnesota	X								X		X			X	
2	Minneapolis – St. Paul S.M.S.A., Minnesota	X	X		X	X	X			X	X	X	X		X	
3	Upper Minnesota River Basin, Minn. and S. Dak.	X	X			X	X			X	X	X			X	
4	Lower Minnesota River Basin, Minnesota	X	X			X				X	X	X	X		X	
5	Clearwater River Basin, Minnesota					X						X				
6	Crow River Basin, Minnesota									X		X				
Subregion 702	Black-Root-Chippewa-Wisconsin					O				O		O	O		O	
Area 7	Upper Miss. River Mainstem, Ill., Iowa, Minn. & Wisc.					X				X		X	X		X	
8	Lower Wisconsin – LaCross River Basin, Wisconsin				X	X	X			X		X			X	
9	Central Wisconsin River Basin, Wisconsin	X	X			X	X			X		X			X	
10	Upper Wisconsin River Basin, Wisconsin					X	X			X		X			X	
11	Upper Chippewa River Basin, Wisconsin					X						X			X	
12	Lower Chippewa River Basin, Wisconsin					X				X		X			X	
13	Black, Buffalo, and Trempealeau River Basins, Wis.		X				X			X		X				
Subregion 703	Rock-Mississippi-Des Moines				O	O				O		O	O		O	
Area 14	Middle Mississippi River Mainstem, Ill., Iowa & Mo.					X				X	X	X	X		X	
15	Lower Rock River Basin, Illinois				X	X				X	X	X	X			
16	Kishwaukee River Basin, Illinois		X			X				X	X	X	X		X	
17	Pecatonica River Basin, Illinois & Wisconsin				X	X				X	X	X	X		X	
18	Upper Rock River Basin, Illinois & Wisconsin		X		X	X	X			X		X			X	
19	Upper Cedar River Basin, Iowa and Minnesota	X	X			X	X			X		X				
20	Middle Cedar River Basin, Iowa	X	X			X				X		X			X	
21	Lower Iowa – Cedar Rivers, Iowa					X	X			X		X				
22	Middle Iowa River, Iowa					X	X			X		X				
23	Skunk River Basin, Iowa	X	X		X	X				X		X				
24	Middle Des Moines River, Iowa		X		X	X	X			X		X			X	
25	Upper Des Moines River Basin, Iowa & Minnesota	X	X		X						X	X			X	
Subregion 704	Salt-Sny-Illinois	O	O		O	O	O			O	O	O	O		O	
Area 26	Sangamon River Basin, Illinois	X	X		X	X	X			X		X				
27	Lower Illinois River & Tributaries, Illinois	X	X			X	X			X		X	X			
28	Middle Illinois River & Tributaries, Illinois	X	X			X	X			X		X	X	X		
29	Upper Illinois River & Tributaries, Illinois		X			X	X			X		X	X			
30	Kankakee River Basin, Illinois & Indiana					X	X			X		X	X		X	
31	Fox River Basin, Illinois & Wisconsin	X	X			X	X			X		X			X	
32	Fabius River Basin, Missouri	X	X		X	X	X			X		X			X	
33	Salt River Basin, Missouri	X	X		X	X	X			X		X			X	
Subregion 705	Lower Upper Mississippi	O	O		O	O	O			O		O	O		O	
Area 34	St. Louis S.M.S.A., Illinois & Missouri	X	X		X	X	X			X		X	X		X	
35	Lower Mississippi River Basin, Illinois & Missouri					X	X			X		X	X		X	
36	Big Muddy River and Tributaries, Illinois		X			X	X			X		X				
37	Kaskaskia River Basin, Illinois		X			X	X			X		X	X		X	

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Upper Mississippi Region (7)

Total Area and Major River Systems

The Upper Mississippi Region includes the drainage area of the Mississippi River above its confluence with the Ohio River and encompasses over 115 million acres. Many rivers flow through the region in a general north-south direction, and the Mississippi River bisects the area. Tributaries of the Mississippi drain most of Minnesota, Wisconsin, Illinois, and Iowa; a significant portion of Missouri; and small areas in Indiana, Michigan, and South Dakota. The Upper Mississippi River is a key element in the Nation's inland waterway system. Large amounts of ground water are stored within much of the region.

Water Supply Situation

The regional gross water supply situation is excellent, and land and water resources are ample to provide for an expanding economy with a quality environment.

Water is withdrawn from the streams and ground for many uses; the largest amount is used as cooling water for steam electric plants.

Water-related Problems

The most severe concerns are water quality, erosion and sedimentation, flooding, land-use conflicts, local water supply, instream flow inadequacies, drainage, and navigation and dredging. Water quality problems and erosion and sedimentation tend to be more severe in the downstream portions of the region. Water quality is often a major concern in metropolitan areas, while serious water supply shortages occur in some rural places. During drought periods, locally high withdrawal and consumptive use create supply and instream flow problems.

The 37 geographic problem areas identified by the Upper Mississippi River Basin Commission are shown on the Upper Mississippi Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

Conclusions and recommendations include needs for: planning studies; modified and/or further research and data collection; and changes in institutional arrangements, water policies, and water-oriented programs. These approaches are to be applied to water quality, water supply, fish and wildlife, recreation, preservation of environmental quality, flood damage reduction and watershed protection, and other multifaceted needs. In the Upper Mississippi Region, the Federal Government role should be to emphasize coordination and funding of water resources efforts.

National and State-Regional Futures

Table V-7 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Upper Mississippi Region.

NF and SRF estimates of total withdrawals show close similarity. Two internal discrepancies exist, however, in the agriculture and domestic categories. The SRF projections for irrigation water requirements are consistently larger than those of the NF, while SRF projections for domestic use are smaller than the corresponding NF figures. SRF and NF have excellent agreement on consumptive use values for "1975." The total estimates become more discrepant in future years. SRF irrigation and domestic use projections again vary quite markedly from the NF values.

Both views of the future must be considered for decisions and future plans concerning water-related problems. The amount of water required to meet the SRF projected irrigation needs is much greater than that required by the NF projections. Local decisions will be made on irrigation development; its impact on the water supplies will be local. On a regionwide basis, the amounts of water involved in irrigation in either case are only a small percentage of available water.

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Table V-7.—Socioeconomic and volumetric data summary: the Upper Mississippi Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	13,387	13,228	14,408	14,096	15,822	15,716
Total employment	5,615	5,615	6,325	6,325	7,202	7,202
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	135,057	NE	135,057	NE	135,057	NE
Streamflow at outflow point(s)	121,000	117,279	113,867	NE	111,234	NE
Fresh-water withdrawals	12,401	12,352	10,386	10,380	7,910	7,905
Agriculture	422	497	566	899	691	1,027
Steam electric	7,644	7,644	6,347	6,347	3,537	3,537
Manufacturing	2,030	2,283	886	974	728	795
Domestic	1,450	1,073	1,609	1,182	1,808	1,400
Commercial	515	515	552	552	603	603
Minerals	333	333	417	417	533	533
Public lands	2	2	3	3	4	4
Fish hatcheries	5	5	6	6	6	6
Other	0	0	0	0	0	0
Fresh-water consumption	1,145	1,153	1,604	1,821	2,688	2,908
Agriculture	383	441	513	779	627	888
Steam electric	129	129	352	352	1,079	1,079
Manufacturing	240	259	309	338	506	552
Domestic	282	213	302	224	324	237
Commercial	63	63	67	67	74	74
Minerals	46	46	58	58	74	74
Public lands	2	2	3	3	4	4
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	2,366	2,127	NE	1,698	NE	1,718
Evaporation	43	2,468	45	2,468	46	2,468
Instream approximation						
Fish and wildlife	110,750	110,750	110,750	110,750	110,750	110,750

NE - Not estimated.

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Lower Mississippi Region (

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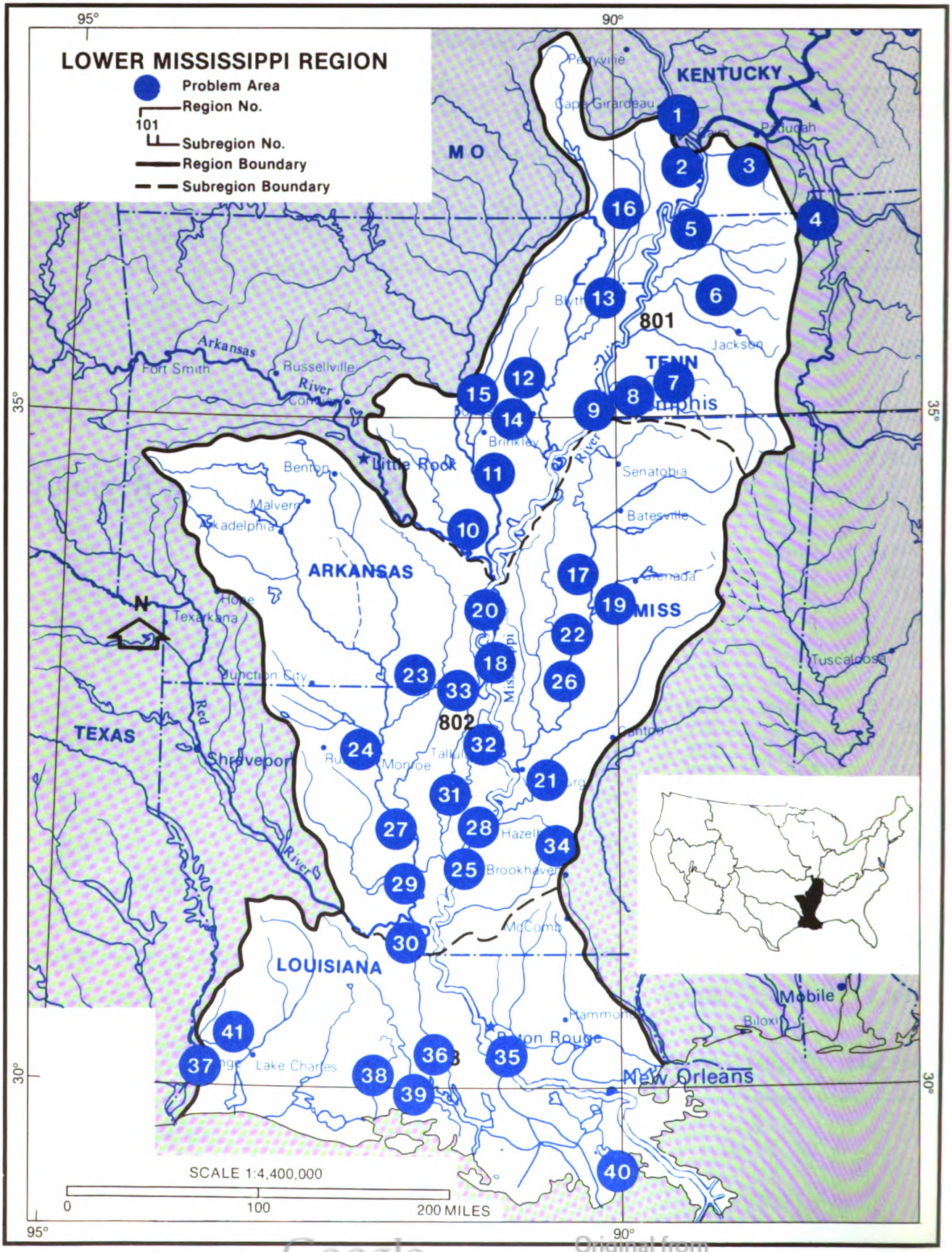

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LOWER MISSISSIPPI REGION (8)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative														
		Water quantity				Water quality				Related lands						
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Subsidence	Water related use conflicts	Other
Subregion 801	Hatchie-Mississippi-St. Francis									O	O	O			O	
Area 1	Above St. John's Bayou									X	X			X		
2	St. John's Bayou & New Madrid Floodway	X								X	X				X	
3	Mayfield Creek Basin					X				X		X				
4	Bayou du Chien					X				X		X				
5	Mud Lake									X	X					
6	Obion and Forked Deer Rivers	X			X					X		X				
7	Wolf-Losahatchie Basin	X				X				X		X				
8	Nonconnah Creek	X			X	X				X	X	X			X	
9	Horn Lake Creek	X								X		X				
10	Lower White River		X	X					X	X	X					
11	Big Creek, Arkansas	X								X	X	X				
12	St. Francis Basin									X		X				
13	Mississippi River Main Stem				X						X	X	X			
14	L'Anguille River	X								X		X				
15	Cache River Basin	X								X		X				
16	Little River Basin									X		X				
Subregion 802	Yazoo-Mississippi-Ouachita					O				O	O	O				O
Area 17	Upper Yazoo				X	X			X	X	X	X			X	
18	Steele Bayou				X	X				X	X	X			X	
19	Yazoo River	X			X	X				X	X	X	X		X	
20	Greenville, Mississippi				X	X				X	X				X	
21	Vicksburg, Mississippi				X	X				X	X	X			X	
22	Greenwooo, Mississippi	X								X	X	X			X	
23	Crossett, Arkansas				X								X		X	
24	Monroe-West Monroe, Louisiana				X	X				X	X				X	
25	Tensas-Cocodrie	X								X	X	X			X	
26	Yazoo Blackwater				X	X				X	X	X			X	
27	Bushley Bayou	X								X	X	X			X	
28	Sicily Island	X								X	X	X			X	
29	Losto Lake to Jonesville	X								X	X	X			X	
30	Below Red River	X								X	X	X			X	
31	Franklin Parish, Louisiana	X								X	X	X			X	
32	Tensas River				X	X				X	X	X			X	
33	Mississippi River Main Stem				X					X		X	X			
34	Homechitto River – Bayou Pierre	X								X		X				
Subregion 803	Mississippi-Delta					O	O	O		O	O	O			O	
Area 35	New Orleans-Baton Rouge	X			X	X		X		X		X	X		X	
36	Atchafalaya Basin Floodway									X		X			X	
37	Gulf Intracoastal Waterway				X	X						X	X			
38	Mermentau River Basin	X								X	X					
39	Bayou Teche-Vermillion River Basin	X	X	X						X	X					
40	Grand Isle and Vicinity	X								X		X				
41	Lake Charles and Vicinity	X				X	X									

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Lower Mississippi Region (8)

Total Area and Major River Systems

The total area of the Lower Mississippi Region is over 67 million acres which include portions of Missouri, Tennessee, Kentucky, Arkansas, Mississippi, and Louisiana. The Mississippi River and the Gulf Intracoastal Waterway are nationally important navigation systems.

Water Supply Situation

In general, water supplies are adequate and most water supply problems stem more from resource distribution than from availability. The region has vast ground-water reserves and it benefits from the tremendous inflow from the Upper Mississippi and its tributaries. Localized shortages occur because of lack of access to drainage arteries and/or poor or insufficient ground-water sources.

The largest portion of water withdrawals is for irrigation.

Water-related Problems

The major needs and problems are concerned with water supplies for municipal, industrial, thermoelectric power generation, energy production, and irrigation uses and with developments for navigation, flood control, land treatment and management, fish and wildlife habitat, and water-oriented outdoor recreation. The maintenance and improvement of the existing navigation system in the Lower Mississippi Region is important on both regional and national levels. As far as the region itself is concerned, however, flood control on the Mississippi River and tributaries is the most severe and urgent problem. Approximately half of the entire area within the Lower Mississippi Region is subject to flooding. Most of the flood-prone lands are used for crop production and pasture. Meeting the increased future need for food will require continued and accelerated planning for flood control and other resource development measures to ameliorate the major agricultural losses from flooding.

The 41 geographic problem areas identified by the Mississippi River Commission Corps of Engineers are shown on the Lower Mississippi Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

It is recommended that the State of Mississippi statewide Level B study be funded. Other studies needed are listed under Level C-type general investigations and special studies. Data collection and research are needed to correct deficiencies in several important subject areas. Specific needs for institutional and policy changes are outlined, and the Federal role is described. Included in the Lower Mississippi Regional Report is a tabulation of preauthorization, postauthorization, and special authority studies that must be finished so that projects can be approved and constructed.

National and State-Regional Futures

Table V-8 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Lower Mississippi Region.

In a few functional use categories such as steam electric and agriculture, there is excellent agreement between NF and SRF withdrawal and consumptive use figures. The category showing the largest discrepancy is manufacturing. Since manufacturing is one of the largest water users in the region, the discrepancy is quite significant. NF values for manufacturing water use were developed by the U.S. Bureau of Domestic Commerce (BDC) based on surveys of major manufacturing concerns throughout the Nation. The survey data were checked against aggregated totals published by the Bureau of the Census of the U.S. Department of Commerce. SRF values were taken from the Lower Mississippi Region Comprehensive Study, a recently completed interagency study which based its water use estimates on water use surveys, personal interviews, and published data. The methodology used by the NF and SRF to develop current manufacturing water use was very similar. On the other hand, the BDC assumed extremely high recirculation rates for future years, which accounts for the large differences between SRF and NF manufacturing use in 1985 and 2000.

Other categories of water use in which significant discrepancies exist include minerals, domestic, and other functional uses. Differences in data sources and methodology generally account for the differences in minerals and domestic water use. With manufacturing water use, it was not possible to resolve these discrepancies. In the other functional uses, the SRF values include a large water usage for fish and wildlife and commercial fishing. There is a significant documented use of water in these categories which the NF information does not recognize.

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Table V-8.—Socioeconomic and volumetric data summary: the Lower Mississippi Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	6,417	6,536	6,767	7,094	7,142	8,156
Total employment	2,285	2,330	2,553	2,572	2,863	3,043
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	455,390	NE	455,390	NE	455,390	NE
Streamflow at outflow point(s)	433,000	433,000	417,457	NE	411,308	NE
Fresh-water withdrawals	14,567	19,330	17,453	28,530	24,841	44,387
Agriculture	4,624	4,889	4,613	5,011	4,507	5,316
Steam electric	4,175	4,175	9,313	9,313	16,687	16,687
Manufacturing	4,163	5,498	1,634	8,888	1,365	16,102
Domestic	655	800	721	900	790	1,185
Commercial	150	[a]	159	[a]	170	[a]
Minerals	799	189[b]	1,010	249[b]	1,318	332[b]
Public Lands	1	NE	3	NE	4	NE
Fish hatcheries	<1	NE	<1	NE	<1	NE
Other	0	3,779[c]	0	4,169[c]	0	4,765[c]
Fresh-water consumption	4,027	8,304	4,554	9,476	5,511	11,820
Agriculture	3,109	3,531	3,258	3,632	3,335	3,877
Steam electric	54	54	118	118	291	291
Manufacturing	314	997	552	1,672	1,067	3,047
Domestic	294	366	319	416	344	499
Commercial	49	[a]	51	[a]	54	[a]
Minerals	206	48[b]	253	56[b]	416	131[b]
Public lands	1	NE	3	NE	4	NE
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	3,308[c]	0	3,582[c]	0	3,957[c]
Ground-water withdrawals	4,838	6,413	NE	7,616	NE	9,123
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	359,033	NE	359,033	NE	359,033	NE

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.
[b] A portion of SRF minerals water use includes saline water.
[c] SRF other water use includes fish and wildlife and commercial fishing requirements.

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Souris-Red-Rainy Region (9)

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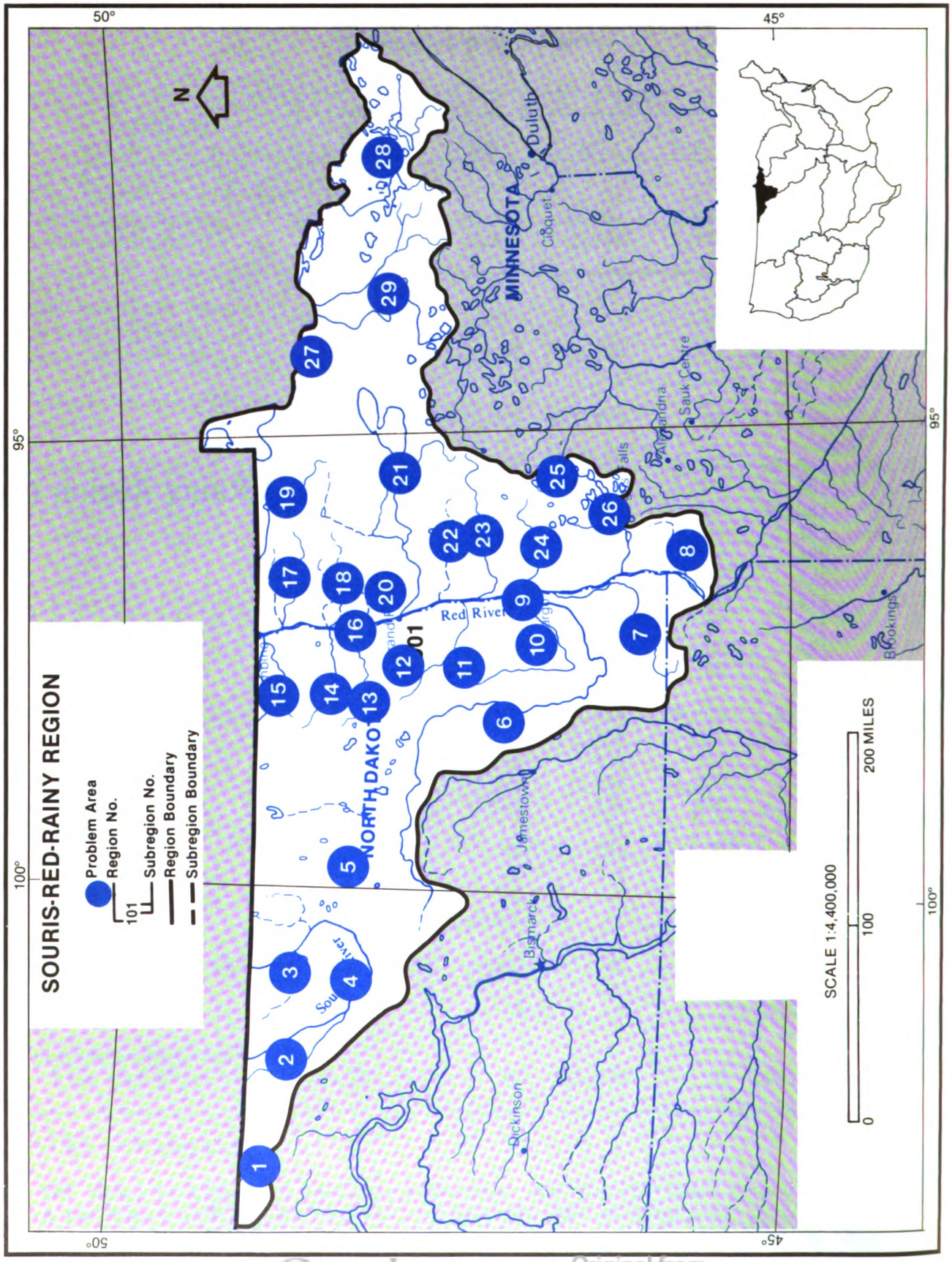

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SOURIS-RED-RAINY REGION (9)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 901	Souris-Red-Rainy		O			O	O			O	O			O	
Area 1	Long Creek, North Dakota	X				X	X								X
2	Glacial Lake Souris, North Dakota	X	X		X	X	X			X		X		X	
3	Lake Metigoshe, North Dakota	X	X			X	X			X	X	X		X	
4	Souris River Main Stem, North Dakota	X	X			X	X			X				X	
5	Devils Lake Basin, North Dakota	X			X	X	X			X	X	X		X	
6	Sheyenne River Basin, North Dakota	X	X			X	X			X	X			X	
7	Wild Rice River Basin, N. Dak. and S. Dak.	X			X	X	X			X					X
8	Bois de Sioux – Mustinka River Basin	X			X	X	X			X		X		X	
9	Red River Main Stem, Minnesota and North Dakota	X	X		X	X	X			X		X		X	
10	Lower Sheyenne, Maple and Rush River Basins, N. Dak.	X	X		X	X	X			X	X	X		X	
11	Goose River Basin, North Dakota	X	X			X	X			X	X	X		X	
12	Turtle River Basin, North Dakota				X	X	X			X				X	
13	Forest River Basin, North Dakota				X	X	X			X	X				X
14	Park River Basin, North Dakota	X	X		X	X	X			X	X			X	X
15	Pembina River Basin, North Dakota	X	X		X	X	X			X	X	X		X	
16	Red Lake River Basin and Red River Main Stem	X	X		X	X	X			X	X	X		X	
17	Two Rivers Basin, Minnesota	X	X		X	X	X			X	X	X		X	
18	Tamarac River Basin, Minnesota	X	X		X	X	X			X	X				
19	Roseau River Basin, Minnesota				X	X	X			X					
20	Middle and Snake River				X	X	X			X	X	X		X	
21	Upper Red Lake River Basin		X			X					X	X			X
22	Sand Hill River Basin, Minnesota				X	X	X			X	X	X		X	
23	North Branch of the Wild Rice-Marsh River, Minn.				X	X	X			X	X	X		X	
24	South Branch of the Buffalo River, Minnesota				X	X	X			X	X	X		X	
25	Detroit Lakes, Minnesota		X			X						X			
26	Otter Tail River Basin, Minnesota					X	X			X		X			
27	Rainy River Main Stem, Minnesota					X	X			X	X	X			
28	B.W.C.A. – Voyageur Nat'l Park & Perimeter, Minn.				X	X	X			X		X		X	
29	Little Fork – Big Fork River Basins, Minnesota									X		X		X	

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Souris-Red-Rainy Region (9)

Total Area and Major River Systems

The Souris-Red-Rainy Region encompasses about 35 million acres in the drainage areas of the three rivers. Flowing northward, the Souris-Red-Rainy Rivers eventually empty into Canada's Hudson Bay.

Water Supply Situation

In most of the Minnesota portion of the region, the abundant water resources are generally more than sufficient to meet needs. In the more western portions of the region, however, water resources can be quite limited during drought periods.

Manufacturing and irrigation account for the largest amounts of water withdrawals.

Water-related Problems

The Souris-Red-Rainy Region contains an array of water and related land resources problems and issues. Some of these, such as flooding, drought, wetness, wind and water erosion, and loss of waterfowl habitat, are long-standing problems. Others, including a shortage of water-based recreation opportunities, pollution of streams and ground water, lake eutrophication, and inadequate municipal and industrial water supplies, have been recognized only recently as being serious. Conflicts occur among competing users of water and related land resources.

The 29 geographic problem areas identified by the Upper Mississippi River Basin Commission are shown on the Souris-Red-Rainy Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

Conclusions and recommendations regarding the need for planning studies are presented in the Souris-Red-Rainy Regional Report along with an indication of the governmental level with primary responsibility to implement these projects. Data collection and research deficiencies in numerous areas should be corrected. Specific suggestions for institutional and policy changes are discussed. In the Souris-Red-Rainy Region, the Federal Government should provide coordination and funding for water resources efforts.

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National and State-Regional Futures

Table V-9 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Souris-Red-Rainy Region.

NF and SRF total withdrawals and consumption for "1975" and 1985 agree closely. In the year 2000, SRF total estimates are significantly larger than those of the NF because of larger SRF projections for irrigation water requirements.

The National Future and the State-Regional Future should both be considered in making decisions and future plans concerning water-related problems. Decisions on irrigation development will be made locally; its impact on the water supplies will be local. Over the region as a whole, the amounts of water involved in irrigation in either case are only a small percentage of available water.

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Table V-9.—Socioeconomic and volumetric data summary: the Souris-Red-Rainy Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	649	649	625	625	595	595
Total employment	241	241	244	244	246	246
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	6,122	NE	6,122	NE	6,122	NE
Streamflow at outflow point(s)	6,010	6,010	5,974	NE	6,314	NE
Fresh-water withdrawals	336	330	329	364	587	980
Agriculture	72	66	177	212	471	865
Steam electric	82	82	23	23	0	0
Manufacturing	102	102	44	44	31	30
Domestic	53	53	56	56	56	56
Commercial	15	15	15	15	14	14
Minerals	8	8	9	9	10	10
Public lands	1	1	2	2	2	2
Fish hatcheries	3	3	3	3	3	3
Other	0	0	0	0	0	0
Fresh-water consumption	112	108	204	231	446	753
Agriculture	63	58	149	176	387	694
Steam electric	1	1	0	0	0	0
Manufacturing	13	14	19	19	23	23
Domestic	25	25	25	25	25	25
Commercial	6	6	6	6	6	6
Minerals	3	3	3	3	3	3
Public lands	1	1	2	2	2	2
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	86	374	NE	142	NE	374
Evaporation	16	40	18	55	19	97
Instream approximation						
Fish and wildlife	3,673	3,673	3,673	3,673	3,673	3,673

NE - Not estimated.

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Missouri Region (10)

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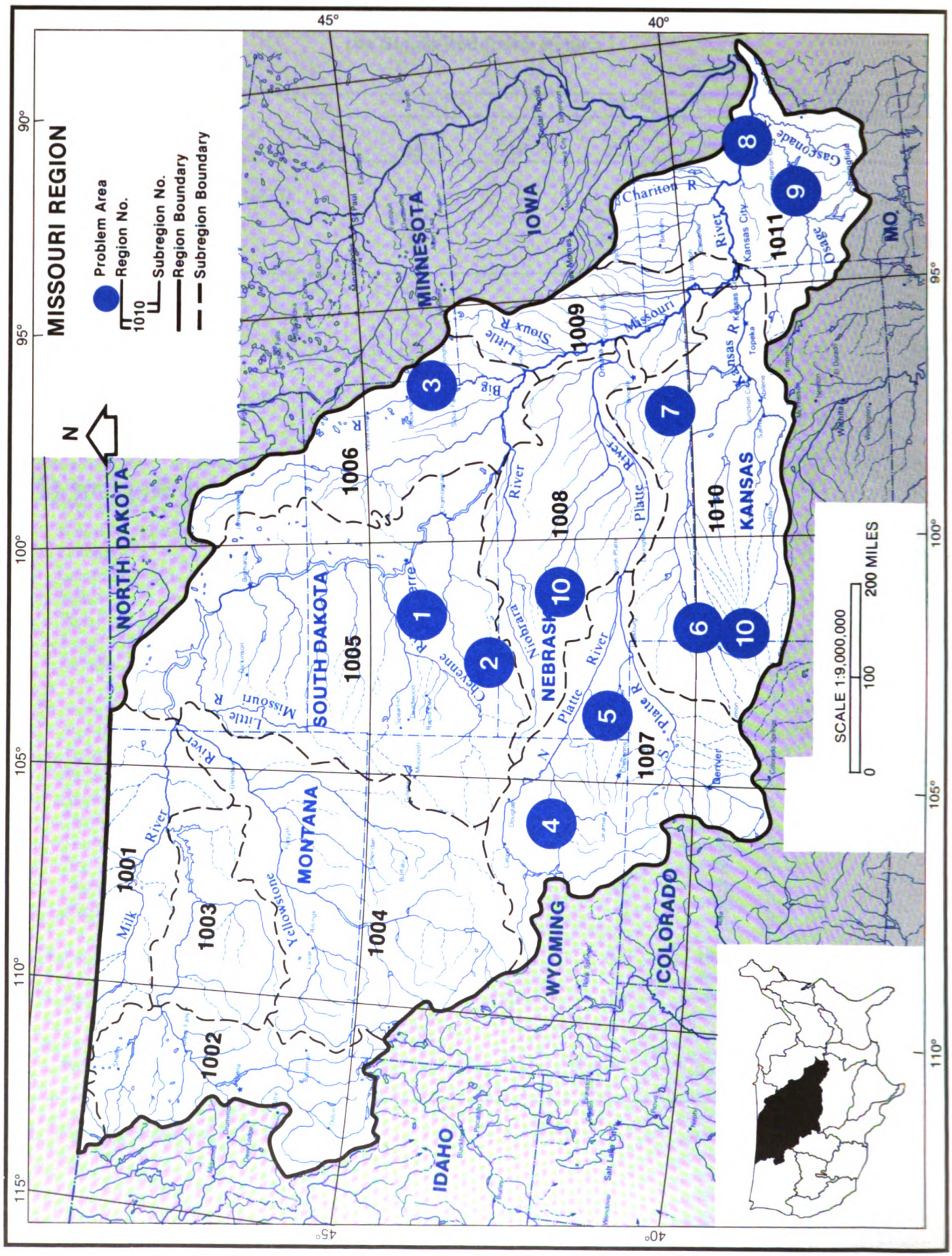

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MISSOURI REGION (10)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1001	Missouri-Milk-Saskatchewan	O				O					O			O	O
Subregion 1002	Missouri–Marias	O				O								O	O
Subregion 1003	Missouri-Musselshell	O				O					O			O	O
Subregion 1004	Yellowstone	O				O	O				O			O	O
Subregion 1005	Western Dakotas	O				O	O				O	O		O	O
Area 1	Bad River Basin	X	X			X	X			X		X			X
2	White River – Medicine Creek Basins	X	X			X	X			X				X	X
Subregion 1006	Eastern Dakotas	O	O			O	O					O		O	O
Area 3	Big Sioux River Basin	X	X			X	X			X	X			X	X
Subregion 1007	North and South Platte	O	O			O				O	O			O	O
Area 4	Middle North Platte River Basin	X			X	X	X			X		X		X	X
5	Nebraska Panhandle	X	X			X	X								
Subregion 1008	Niobrara-Platte-Loup	O	O			O					O			O	O
Subregion 1009	Middle Missouri	O	O			O	O			O	O		O	O	O
Subregion 1010	Kansas	O	O				O			O	O	O	O	O	O
Area 6	Upper Republican River Basin	X	X			X	X			X				X	X
7	Big and Little Blue River Basins	X	X			X	X			X	X	X		X	X
Subregion 1011	Lower Missouri	O					O			O		O	O	O	O
Area 8	Tri-Cities Area, Missouri					X	X			X					X
9	Lake of the Ozarks, Missouri					X	X		X					X	X
10	Ogallala Ground Water Area		X				X							X	

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Missouri Region (10)

Total Area and Major River Systems

The Missouri Region contains one-sixth of the total area of the 48 contiguous States, over 327 million acres. There are few natural lakes; most of the region's available water areas are found at manmade reservoirs. Six large reservoirs on the Missouri River mainstem generate most of the region's hydropower, provide flood protection and recreation water, maintain adequate flows for an 8-month navigation season and for water quality and water supply needs. They are also intended to divert water northeastward and eastward for irrigation as well as for municipal and industrial needs. Other tributary manmade reservoirs provide additional storage capacity and most of the water surface for water-oriented recreation as well as for fish and wildlife propagation and preservation.

Water Supply Situation

Increased competition for available water supplies indicates the need to examine current and projected water uses to ensure efficiencies and an equitable distribution of available supplies. Many locations throughout the region have water shortages during periods of low streamflow. Seven States in the region are considered to have water-short areas.

A great portion of the water consumed in the region is used for irrigation. This situation will probably continue since the number of acres of land under irrigation has been increasing steadily and is expected to continue to grow.

The Northern Great Plains of the Missouri Region contain large reserves of low-sulphur coal which probably will supply a significant portion of the country's energy in the future. Withdrawals for mining of fuels will increase from 144 mgd in "1975" to 236 mgd in 2000.

Water-related Problems

There are numerous water and related land area problems throughout the region. Because Indian and Federal reserved water rights have not been quantified, the uncertainty makes it difficult and sometimes impossible to plan for using and managing the available water supplies in large areas of the region. The projected estimates of future water use indicate that, during extended drought periods, sufficient water to maintain navigation flows may not be available. The western streams are particularly susceptible to fluctuating streamflows since they are fed only by spring snowmelt and runoff from erratic rainfall. At times the only streamflow comes from reservoir releases or irrigation return flows. Sheet, gully, and streambank erosion cause the loss of valuable soils and lands at many locations, making silt the worst pollutant throughout the region. Some communities

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suffer periodic flooding, and many suffer periodic water shortages. Non-point source pollution will continue to impair water quality.

The 10 geographic problem areas identified by the Missouri River Basin Commission are shown on the Missouri Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire sub-regions.

Conclusions and Recommendations

Conclusions and recommendations regarding the Federal role are discussed in the Missouri Regional Report. The Federal Government should continue to provide funding and should initiate and coordinate studies on several specific questions relating to problems in the Missouri Region.

National and State-Regional Futures

Table V-10 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Missouri Region.

The SRF values were developed by the 10 States and the 10 Federal agencies represented on the Missouri River Basin Commission (MRBC) to reflect the needs and objectives of management, conservation, and development of the water and related land resources in the region.

The amounts of water needed to meet the SRF projected irrigation and manufacturing requirements for the year 2000 are greater than those required by the NF projections. The amounts of water included in offstream developments are significant throughout the region. These amounts could seriously affect the instream flows needed for power generation at the Federal hydroelectric projects, the Missouri River navigation project, riverine recreation, fish and wildlife, and water quality.

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Table V-10.—Socioeconomic and volumetric data summary: the Missouri Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	8,832	9,066	9,298	10,046	10,044	11,762
Total employment	3,695	3,936	4,084	5,061	4,573	5,759
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	57,012	NE	57,012	NE	57,012	NE
Streamflow at outflow point(s)	44,100	44,193	37,428	41,341	35,880	37,956
Fresh-water withdrawals	38,016	34,434	48,037	43,227	44,359	48,216
Agriculture	32,086	28,461	39,935	34,231	36,894	39,325
Steam electric	3,540	3,540	5,834	5,834	4,938	4,938
Manufacturing	669	650	315	910	292	1,166
Domestic	961	1,264	1,045	1,666	1,161	2,055
Commercial	285	[a]	306	[a]	336	[a]
Minerals	269	313	356	340	424	418
Public lands	159	159	198	198	266	266
Fish hatcheries	47	47	48	48	48	48
Other	0	0	0	0	0	0
Fresh-water consumption	15,469	15,832	19,206	20,327	19,913	25,740
Agriculture	14,664	14,750	18,156	18,741	18,265	23,342
Steam electric	68	68	239	239	637	637
Manufacturing	136	205	122	337	202	527
Domestic	262	537	280	695	302	831
Commercial	69	[a]	72	[a]	78	[a]
Minerals	111	113	139	117	163	137
Public lands	159	159	198	198	266	266
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	10,407	4,196	NE	5,941	NE	8,371
Evaporation	4,924	2,621	5,324	2,621	5,595	2,621
Instream approximation						
Fish and wildlife	33,958	NE	33,958	NE	33,958	NE

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Arkansas-White-Red Region (11)

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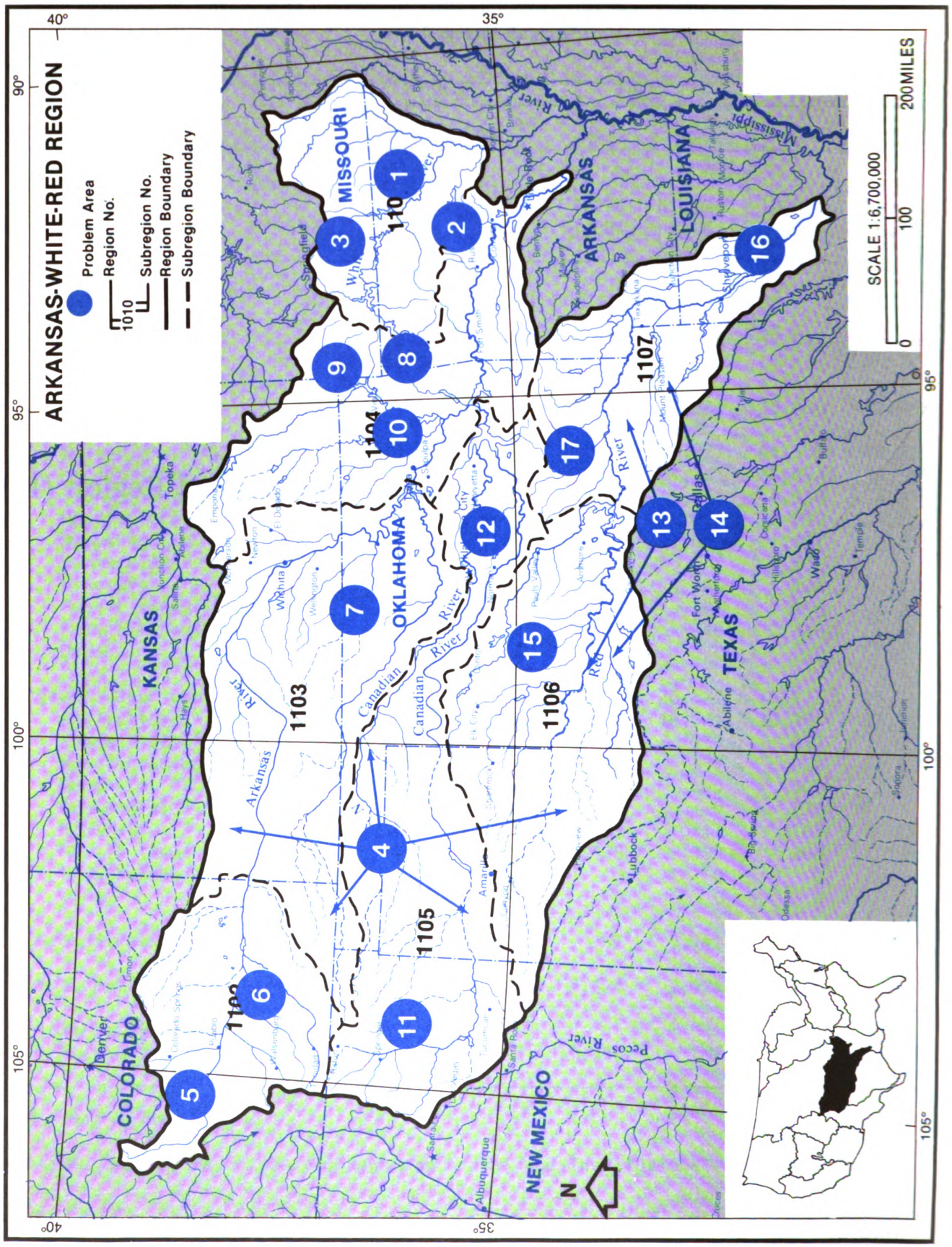

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ARKANSAS-WHITE-RED REGION (11)

PROBLEM MATRIX

Problem area		Problem issues: O= Identified by Federal Agency Representative; X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1101	Upper White									O					
Area 1	Ozarks Area, Arkansas	X	X				X			X	X				
2	Arkansas Statewide	X					X			X					
3	Springfield Area, Missouri	X	X			X	X			X	X			X	
Subregion 1102	Upper Arkansas		O				O								O
Area 4	High Plains Ogallala Formation		X												
5	Arkansas Drainage above Pueblo, Colorado	X			X	X				X			X	X	
6	Arkansas Drainage Pueblo to Kansas Border	X			X	X				X		X			X
Subregion 1103	Arkansas-Cimarron	O	O			O				O		O			O
Area 4	High Plains Ogallala Formation		X												
7	Oklahoma	X	X			X	X			X	X				
Subregion 1104	Lower Arkansas	O				O				O		O			O
Area 8	Ozarks Areas, Benton & Washington Counties, Arkansas	X	X			X	X			X	X	X			
2	Arkansas Statewide	X					X			X					
9	Joplin Area, Missouri	X	X			X	X								
10	Oklahoma	X			X	X				X		X	X	X	X
Subregion 1105	Canadian	O	O			O									O
Area 4	High Plains Ogallala Formation		X												X
11	New Mexico	X	X			X	X			X		X		X	
12	Oklahoma	X	X			X	X			X	X	X			X
13	Texas Statewide: Flooding									X		X		X	X
14	Small Cities & Rural Communities, Texas	X	X			X	X								
Subregion 1106	Red-Washita		O			O									
Area 4	High Plains Ogallala Formation		X												
15	Oklahoma	X	X			X	X			X					
13	Texas Statewide: Flooding									X		X		X	X
14	Small Cities and Rural Communities, Texas	X	X			X	X								
Subregion 1107	Red-Sulphur									O		O			
Area 2	Arkansas Statewide	X				X				X					
16	Red River Area, Louisiana	X				X	X			X	X	X			X
17	Oklahoma	X	X		X	X				X	X	X			X
13	Texas Statewide: Flooding									X		X		X	X
14	Small Cities and Rural Communities, Texas	X	X			X	X								

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Arkansas-White-Red Region (11)

Total Area and Major River Systems

The Arkansas-White-Red Region has over 156 million acres. The three rivers drain all of Oklahoma and parts of Colorado, Kansas, Missouri, Arkansas, New Mexico, Texas, and Louisiana. The Arkansas and White Rivers discharge waters into the Mississippi River, and the Red River flows into the Atchafalaya River.

Water Supply Situation

The overall water supply outlook is one of cautious optimism, although much water-resource development will be needed to keep pace with growing needs under the prevailing rigorous conditions of water supply and under the criteria for maintaining wholesome environmental conditions. The quantity of water available in the western and central portions is inadequate for many requirements.

Irrigation accounts for the largest portion of water withdrawals and consumptive use.

Water-related Problems

The High Plains and central portion have water supply problems that will require cities and industries to change their patterns of water use to meet pollution discharge restrictions and to satisfy supply needs economically. In addition to water quantity limitations, water quality, erosion and sedimentation, flooding, and Indian water rights also are of concern. The large irrigation water requirement often accentuates these problems by creating low streamflows and ground-water depletions.

The 17 geographic problem areas identified by the Arkansas-White-Red Basins Inter-Agency Committee are shown on the Arkansas-White-Red Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

In the Arkansas-White-Red Region, the role of the Federal Government should be to provide assistance only if local and State authorities determine that they have no other solutions. Further Level B studies are not recommended at this time. Additional data collection and research are needed to supply information on ground- and surface-water considerations. To permit better use of water, various compacts between States are proposed. The States make separate conclusions and recommendations.

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National and State-Regional Futures

Table V-11 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Arkansas-White-Red Region.

The State-Regional Future values have been developed to reflect records and estimates of the eight States of the region. The records from the States of Colorado, Kansas, Oklahoma, New Mexico, and Texas are pertinent to the administration of water rights under the Doctrine of Prior Appropriation.

Accordingly, the SRF values on withdrawals and consumptive use in these five States must be considered. In a number of cases, SRF values for irrigation consumptive use and withdrawals differ substantially from NF values. Although the region's problems are, for the most part, identified in both futures, the severity of some problems appears greater in the SRF estimates.

SRF estimates of manufacturing and steam electric water withdrawals and consumption are consistently larger than the corresponding NF figures. The NF values show a greater proportion of water use in the minerals category than do those of regional sources.

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Table V-11.—Socioeconomic and volumetric data summary: the Arkansas-White-Red Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	6,846	7,350	7,268	8,321	7,815	9,819
Total employment	2,670	1,565[a]	2,987	1,966[a]	3,369	2,530[a]
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	65,207	NE	65,207	NE	65,207	NE
Streamflow at outflow point(s)	62,600	62,605	56,192	NE	55,896	NE
Fresh-water withdrawals	12,868	13,551	13,799	16,434	13,337	22,622
Agriculture	10,195	9,827	10,721	11,737	10,055	16,056
Steam electric	498	1,297	1,026	2,032	1,012	3,233
Manufacturing	713	956	476	989	480	1,268
Domestic	735	1,060[b]	807	1,321[b]	894	1,645[b]
Commercial	210		221		238	
Minerals	448	200	469	142	571	206
Public lands	26	30	33	32	39	36
Fish hatcheries	43	NE	46	NE	48	NE
Other	0	180	0	177	0	178
Fresh-water consumption	8,064	9,433	8,769	11,611	8,887	16,405
Agriculture	7,263	8,379	7,706	10,221	7,404	14,422
Steam electric	89	126	237	285	457	577
Manufacturing	165	347	232	407	360	562
Domestic	279	466[b]	305	591[b]	331	710[b]
Commercial	69		72		78	
Minerals	173	70	184	67	218	90
Public lands	26	27	33	30	39	34
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	17	0	10	0	10
Ground-water withdrawals	8,846	6,968	NE	NE	NE	NE
Evaporation	2,615	10,179[c]	2,910	11,330[c]	3,111	12,388[c]
Instream approximation						
Fish and wildlife	46,169	NE	46,169	NE	46,169	NE

NE- Not estimated.

[a] Total includes only subregions 1101, 1102, 1105, 1106, and 1107. Data were not available for subregions 1103 and 1104.
[b] SRF domestic water use includes commercial and institutional requirements.
[c] Total does not include subregion 1102 for which data were not available.

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Texas-Gulf Region (12)

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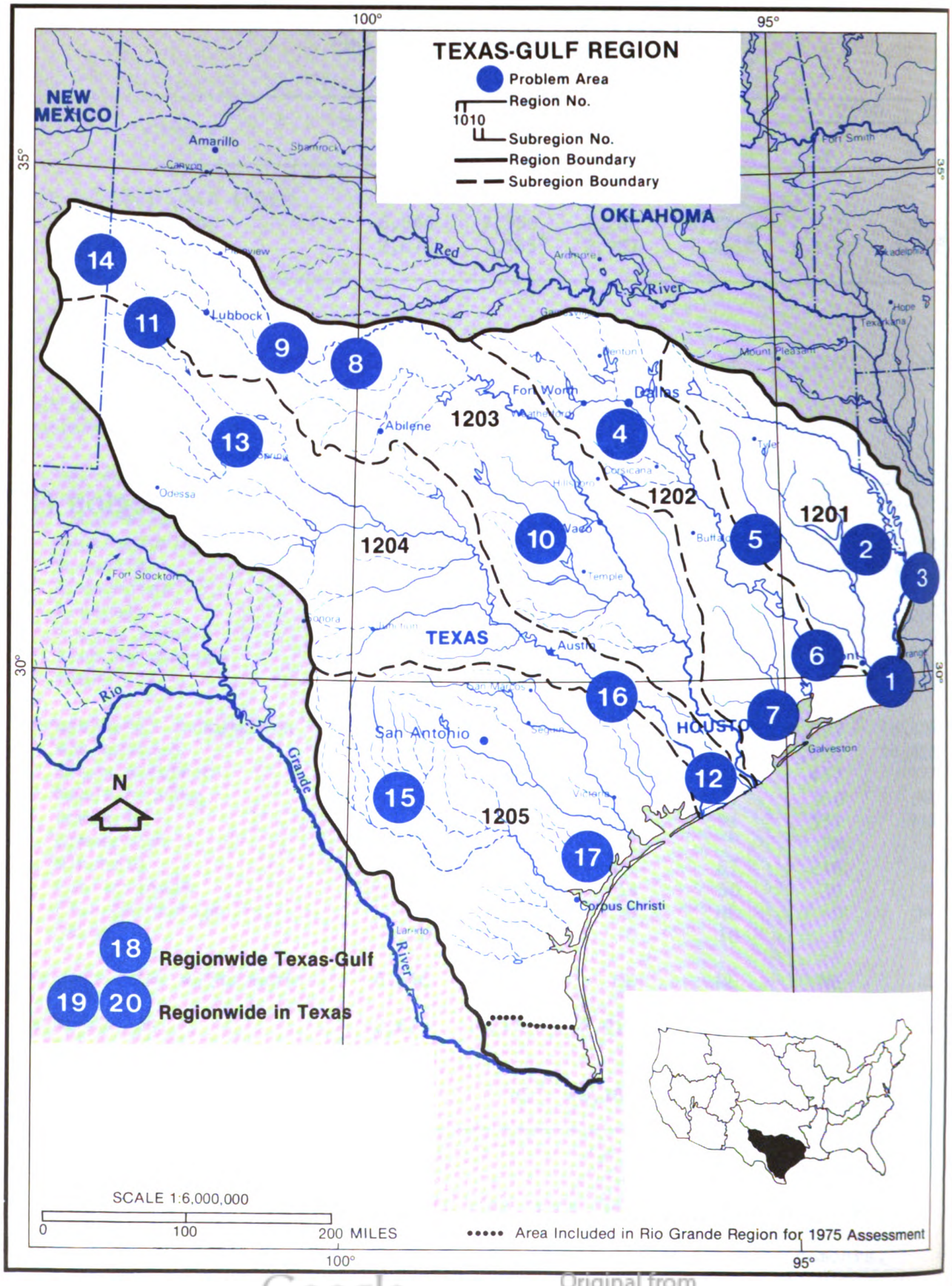

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TEXAS-GULF REGION (12)

PROBLEM MATRIX

Problem area		Problem issues														
		O= Identified by Federal Agency Representative X= Identified by State-Regional Representative														
		Water quantity				Water quality				Related lands						
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Subsidence	Water related use conflicts	Other
Subregion 1201	Sabine-Neches			O				O		O		O				
Area 1	Beaumont-Port Arthur Metropolitan Area, Texas					X	X	X				X	X			
2	Sabine River, Louisiana	X								X		X				
3	Sabine River, Louisiana	X								X		X				X
Subregion 1202	Trinity-Galveston Bay	O	O	O			O	O		O		O				O
Area 4	Upper Trinity River Basin, Texas	X	X													
5	Dallas-Fort Worth (Trinity River & Tributaries), Tex.					X										X
6	Houston-Galveston Metropolitan Area, Texas	X	X	X		X	X			X	X	X		X		X
7	Houston Metropolitan Area, Texas					X	X	X				X	X			
Subregion 1203	Brazos		O			O				O						
Area 8	Haskell and Jones Counties, Texas						X									X
9	Brazos Basin above Possum Kingdom Reservoir, Tex.					X					X					X
10	Mid-Brazos River Basin, Texas		X				X									
11	Texas High Plains, Texas		X													
Subregion 1204	Colorado (Texas)		O			O									O	
Area 12	Jackson County and Vicinity, Texas						X		X	X				X		
13	Upper Colorado River, Texas	X	X			X	X									
14	Curry, Roosevelt, & Lea Counties, New Mexico	X	X				X			X		X				
Subregion 1205	Nueces-Texas Coastal		O			O						O				
Area 15	Carrizo Aquifer (Winter Garden Area), Texas		X				X									X
16	Edwards (Balcones Fault Zone) Aquifer, Texas	X	X			X	X									X
17	Corpus Christi Metropolitan Area, Texas	X	X			X	X			X		X				X
Regionwide in Texas-Gulf Area	18 Texas Bays and Estuaries, Texas	X		X		X		X		X		X	X		X	
Regionwide in Texas Area	19 Small Cities & Rural Communities, Texas	X	X			X	X			X						
	20 Texas, Statewide: Flood Problems & Hurricanes									X		X			X	X

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Texas-Gulf Region (12)

Total Area and Major River Systems

The Texas-Gulf Region includes a total of almost 114 million acres. Virtually all of the region lies within Texas, although small portions of Louisiana and New Mexico are included. Much of the region consists of the drainage areas of the Sabine, Neches, Trinity, San Jacinto, Brazos, Colorado, Lavaca, Guadalupe, San Antonio, and Nueces Rivers and their associated coastal basins. These rivers drain in a general northwest-southeast course to the Gulf of Mexico. The ports in the Texas-Gulf Region are among the busiest in the Nation.

Water Supply Situation

Historically, ground water has supplied an appreciable percentage of total water. Because pumpage exceeds natural recharge in most aquifers, however, the region will increasingly depend on surface-water supplies. In many areas, especially in the western portion of the region, water supply will become critical.

The largest amount of water withdrawals is for irrigated agriculture.

Water-related Problems

In much of the Texas-Gulf Region there is little excess storage capacity in surface-water reservoirs to meet water demands during drought. Coupled with declining ground-water resources, this could result in serious supply shortages. In addition to supply limitations, there are problems of water quality, flooding, drainage, erosion and sedimentation, inadequate water-oriented recreation opportunities, and land subsidence and fault activation. Estuarine management is needed to ensure sufficient fresh-water inflows at appropriate geographic locations. Similarly, water-resources management must ensure proper distribution of supply.

The 20 geographic problem areas identified by the Texas Department of Water Resources are shown on the Texas-Gulf Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

In the Texas-Gulf Region, the Federal Government should assist in the resolution of problems having regional or national significance and should formulate a national water policy that preserves the sovereignity of States with regard to water laws. The Texas Water Plan, currently being updated, remains the official guide to State policy. It seeks to reach a mutually responsible relationship between Federal and State water agencies. Funding is deemed necessary for water resource projects and research and technology development programs.

National and State-Regional Futures

Table V-12 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Texas-Gulf Region.

In "1975," total NF withdrawals exceed total SRF withdrawals by 6,415 mgd, primarily because of differences in water withdrawals for irrigation, manufacturing, and mining. Total NF consumption exceeds total SRF consumption by 3,098 mgd for "1975." The differences in irrigation seem to account for most of the total consumption discrepancy between the SRF and the NF.

Significant differences also appear in the percentages of withdrawals consumed for domestic, steam electric power generation, and irrigation uses. For each of these uses, the percentage of withdrawals consumed is significantly lower for the NF information. On the whole, the SRF values indicate about 78 percent of the withdrawals are consumed, while the NF values indicate about 67 percent.

Total SRF withdrawals projected for the year 2000 exceed total NF withdrawals by 2,000 mgd, due primarily to differences in domestic, manufacturing, mining, and irrigation withdrawal projections. Total SRF consumption exceeds total NF consumption by 1,961 mgd, primarily because of differences in domestic, manufacturing, mining, and irrigation uses.

On the whole, SRF values for consumptive use as a share of withdrawal for 2000 is about 74 percent, while the NF figures indicate approximately 70 percent. Consumptive use as a percentage share of withdrawal for major users are as follows:

1. NF domestic consumptive use remains at about 34 percent during the period "1975" to 2000, while SRF consumptive use remains about 56 percent during the same period.

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2. NF consumptive use for manufacturing increases from 30 percent in "1975" to 78 percent by the year 2000, while SRF data increase from 33 percent to 47 percent during the same period.

3. NF consumptive use for agriculture remains at about 82 percent from "1975" to 2000, while SRF consumptive use for agriculture remains at about 90 percent.

Consequently, although both SRF and NF values indicate an increase in water use efficiency among manufacturing industries, the NF figures indicate a much greater increase. There does not appear to be much change in the SRF and NF ratios for domestic and agricultural uses.

The SRF streamflow is 26,368 mgd. The NF streamflow is comparable at 28,270 mgd. Basically, SRF and NF used the same methodology to analyze the flow characteristics at the farthest downstream gaging station(s) in each subregion and to compute the ungaged runoff below the farthest downstream gaging station(s) in order to derive the streamflow. However, the SRF and NF analyses were performed independently of each other. Consequently, the difference between the SRF and NF streamflow figures is most probably due to inconsistency in the selection of the periods of record for the streamflow information.

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Table V-12.—Socioeconomic and volumetric data summary: the Texas-Gulf Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	9,911	10,233	11,162	12,470	12,907	15,990
Total employment	4,109	4,022	4,827	5,180	5,767	6,769
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	33,951	NE	33,951	NE	33,951	NE
Streamflow at outflow point(s)	28,270	26,368	23,554	22,097	23,135	18,152
Fresh-water withdrawals	16,925	10,510	15,932	13,212	14,991	16,991
Agriculture	11,718	7,397	9,530	8,230	7,655	9,499
Steam electric	724	296	1,000	712	1,713	1,508
Manufacturing	1,932	1,177	2,559	1,466	2,444	2,273
Domestic	1,207	1,427	1,380	2,556	1,621	3,379
Commercial	283	[a]	317	[a]	300	[a]
Minerals	1,044	194	1,133	234	1,245	284
Public lands	<1	19	2	14	2	15
Fish hatcheries	17	NE	11	NE	11	NE
Other	0	<1	0	<1	0	33
Fresh-water consumption	11,259	8,161	10,227	10,005	10,529	12,490
Agriculture	9,527	6,726	7,794	7,487	6,328	8,558
Steam electric	99	149	270	357	991	752
Manufacturing	571	387	1,003	551	1,917	1,073
Domestic	413	794	467	1,485	541	1,936
Commercial	94	[a]	103	[a]	118	[a]
Minerals	555	100	588	119	632	146
Public lands	<1	NE	2	NE	2	NE
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	5	0	6	0	24
Ground-water withdrawals	7,222	7,172	NE	4,961	NE	3,398
Evaporation	1,705	1,743	1,875	1,964	1,992	1,972
Instream approximation						
Fish and wildlife	22,917	NE	22,917	NE	22,917	NE

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Rio Grande Region (13)

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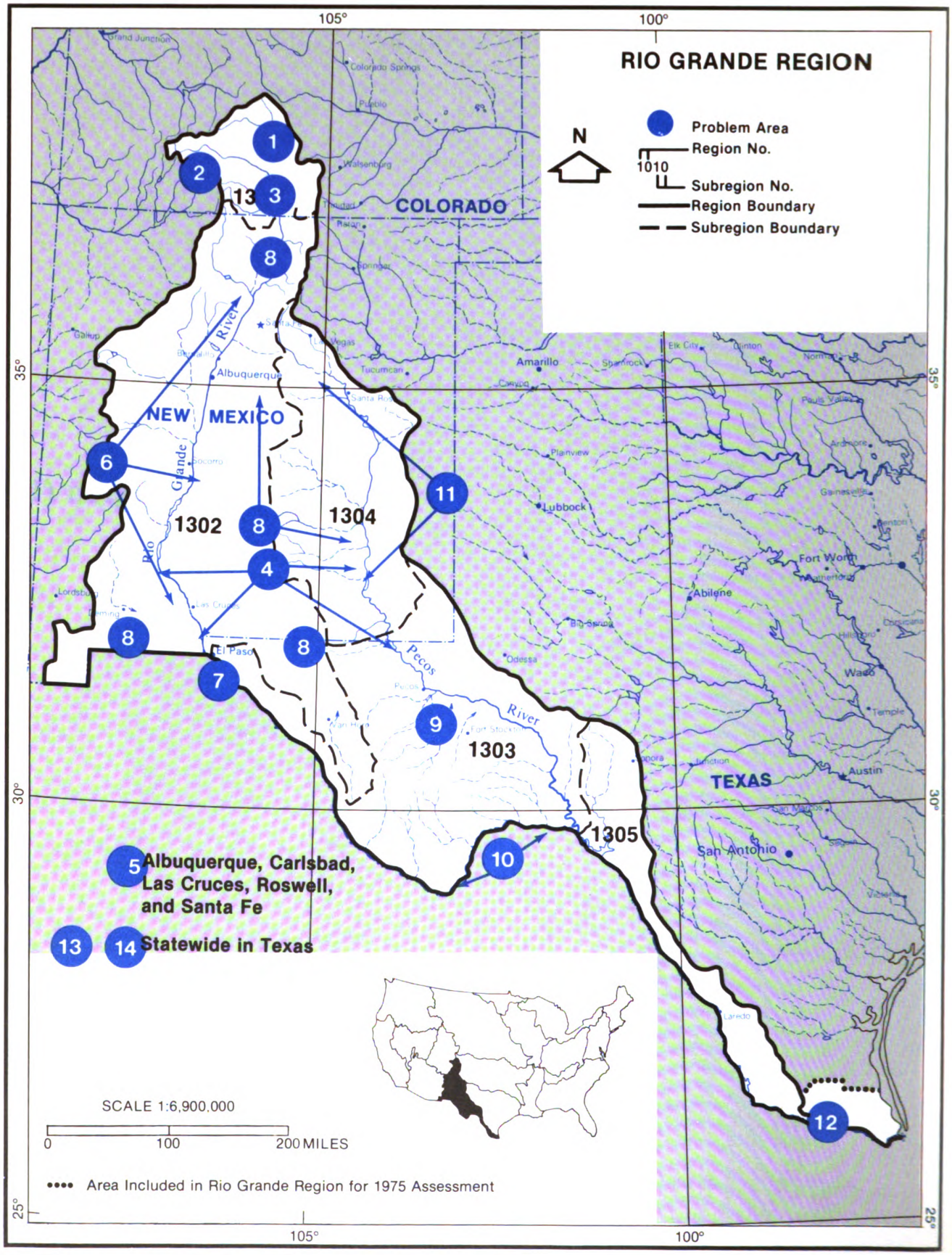

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RIO GRANDE REGION (13)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1301	Rio Grande Headwaters	O	O							O					O
Area 1	San Luis Valley Closed Basin	X												X	X
2	Hinsdale, Rio Grande, & Mineral Counties					X								X	
3	Del Norte, Colorado, to Colo.-N. Mex. State Line	X				X				X				X	
Subregion 1302	Middle Rio Grande	O	O			O	O			O					O
Area 4	Rio Grande Basin, New Mexico	X	X		X					X		X		X	
5	Albuquerque, Carlsbad, Las Cruces, Roswell and Santa Fe, New Mexico	X	X												X
6	Espanola Valley & Rio Grande West Side Tributaries									X		X			X
7	El Paso Area		X				X								
8	Roswell Artesian Basin, Sunshine Valley, Estancia Basin, Carrizozo, Nutt-Hockett Area, and Mimbres Underground Basin		X				X								
Subregion 1303	Rio Grande-Pecos	O	O			O	O								O
Area 9	Trans-Pecos Region, Texas	X	X			X	X								
10	Rio Grande Canyon, Texas														X
Subregion 1304	Upper Pecos	O	O			O	O								O
Area 4	Rio Grande Basin, New Mexico	X	X		X					X		X		X	
5	Albuquerque, Carlsbad, Las Cruces, Roswell and Santa Fe, New Mexico	X	X												X
8	Roswell Artesian Basin, Sunshine Valley, Estancia Basin, Corrizozo, Nutt-Hockett Area, and Mimbres Underground Basin		X				X								
11	Pecos River downstream from Santa Rosa, N. Mex.					X							X		X
Subregion 1305	Lower Rio Grande	O	O			O	O	O		O					O
Area 12	Lower Rio Grande Valley	X				X									
Regionwide in Texas															
Area 13	Small Cities & Rural Communities, Texas	X	X			X	X								
14	Texas Statewide: Flood Problems & Hurricanes									X					

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Rio Grande Region (13)

Total Area and Major River Systems

The Rio Grande Region, in the southwest corner of the United States, totals almost 88 million acres. The Rio Grande River flows south-southeasterly to the Gulf of Mexico; its waters are regulated by various treaties and compacts between the United States and Mexico and among Colorado, New Mexico, and Texas. Closed basins are important in the region's hydrology.

Water Supply Situation

Ground water, an important segment of the water supply, will be under additional stress from increasing population. There is no surplus water for new or expanding current uses. The existing supply is completely appropriated by current demands.

Irrigation is the major water consumer. There will be shifts from irrigation to other uses in the future, but irrigation is still projected to remain the largest consumptive use.

Water-related Problems

Shortages in meeting current needs make conservation a necessity. Ground water depletions and salinity problems caused from reuse of water in the basin are anticipated. Dissolved and suspended solids are major pollutants degrading water quality. Other problems involve erosion and sedimentation, flooding, unsatisfactory domestic water supplies (under the 1974 Safe Drinking Water Act), and needs for more water-based recreation opportunities.

The 14 geographic problem areas identified by the Rio Grande Coordinating Committee are shown on the Rio Grande Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

General conclusions and recommendations are made regarding the need for storage and regulating works to amend water supply shortages and the need for a comprehensive water quality program to relieve salinity problems. No Level B studies are recommended. The Rio Grande supports a land-development program emphasizing environmental concerns. Specific conclusions and recommendations are made by Colorado, New Mexico, and Texas.

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National and State-Regional Futures

Table V-13 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Rio Grande Region.

Comparisons of the State-Regional Future (SRF) with the National Future (NF) illustrate that some functional use categories differ significantly because sources of data, as well as assumptions and criteria used in compiling the data, were different. In some cases the trends or magnitudes of the data reveal that there are potential problems relating to growth, recession, or magnitude of water requirements, even though there are differences in the basic estimates from the two sources.

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Table V-13.—Socioeconomic and volumetric data summary: the Rio Grande Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	1,695	1,868	1,780	2,678	1,875	3,630
Total employment	599	620	659	792	732	1,017
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	4,813	NE	4,813	NE	4,813	NE
Streamflow at outflow point(s)	1,230	1,228	424	NE	707	NE
Fresh-water withdrawals	6,321	6,031	6,204	6,794	5,633	7,198
Agriculture	5,722	5,540	5,537	5,999	4,917	6,049
Steam electric	34	24	16	30	10	76
Manufacturing	19	24	42	31	32	42
Domestic	265	345	287	566	312	801
Commercial	62	[a]	65	[a]	68	[a]
Minerals	190	44	221	86	255	133
Public lands	22	11	27	14	28	14
Fish hatcheries	7	NE	9	NE	11	NE
Other	0	43	0	68	0	83
Fresh-water consumption	4,240	3,863	4,320	4,406	4,016	5,119
Agriculture	3,924	3,569	3,959	3,890	3,614	4,358
Steam electric	18	18	9	23	5	62
Manufacturing	5	10	15	13	24	20
Domestic	138	195	150	352	163	505
Commercial	30	[a]	31	[a]	32	[a]
Minerals	103	24	129	52	150	86
Public lands	22	12	27	16	28	16
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	35	0	60	0	72
Ground-water withdrawals	2,335	1,722	NE	1,621	NE	1,538
Evaporation	730	606	764	623	785	616
Instream approximation						
Fish and wildlife	2,287	NE	2,287	NE	2,287	NE

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Upper Colorado Region (14)

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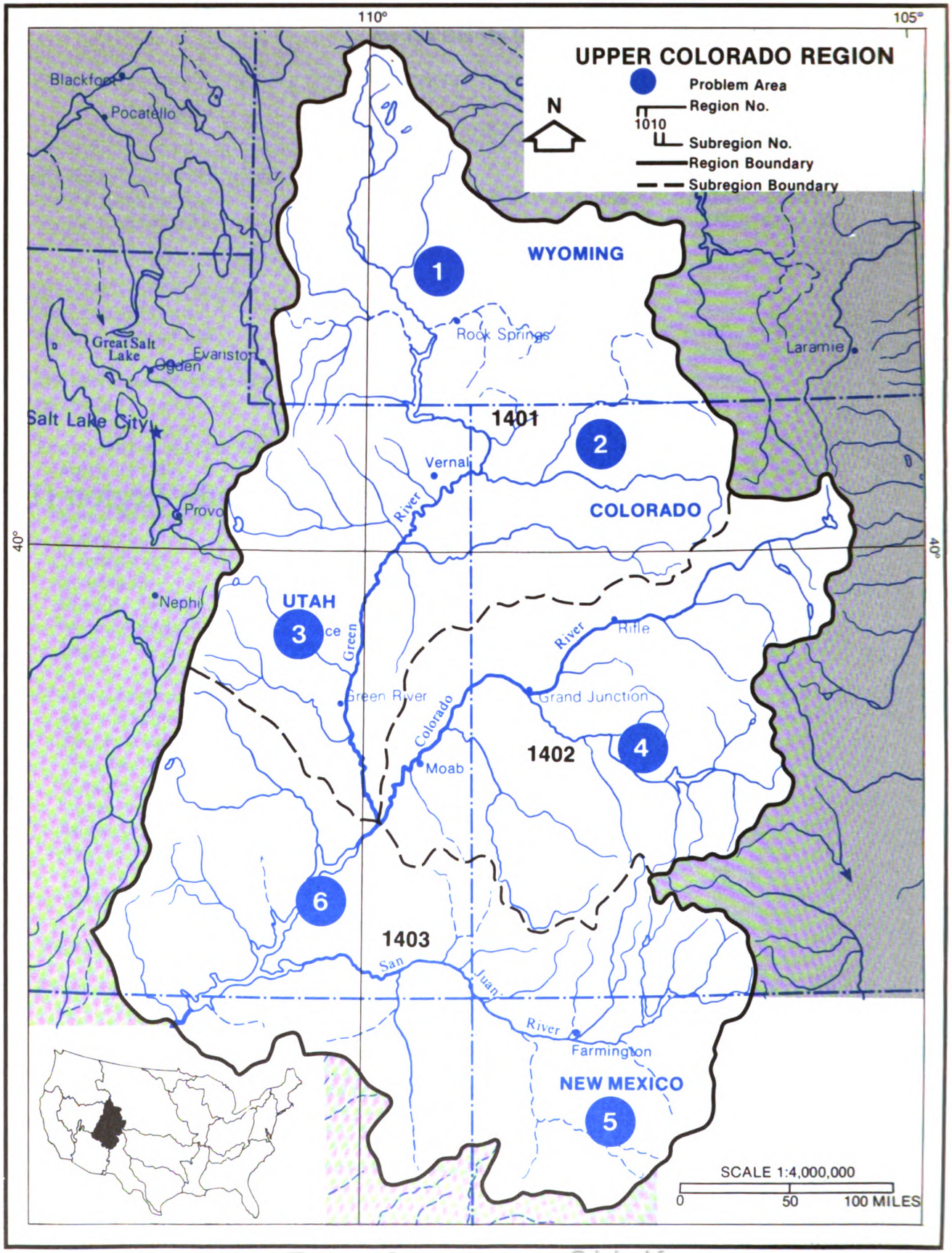

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UPPER COLORADO REGION (14)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1401	Green-White-Yampa	O	O			O	O			O		O		O	
Area 1	Green River, Wyoming	X				X						X		X	X
2	Yampa-White River – Colorado, Wyoming	X				X						X		X	X
3	Uinta Basin, Price, San Rafael, Utah	X				X						X		X	X
Subregion 1402	Colorado-Gunnison	O	O			O	O				O			O	
Area 4	Colorado, Gunnison, Dolores – Colorado	X				X								X	X
Subregion 1403	Colorado-San Juan	O	O			O	O					O		O	O
Area 5	San Juan River – Colorado, New Mexico	X				X						X		X	X
6	Canyon Lands, Utah	X				X						X		X	X

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Upper Colorado Region (14)

Total Area and Major River Systems

The Upper Colorado Region contains almost 66 million acres (102,920 square miles) in Arizona, Colorado, New Mexico, Utah, and Wyoming.[1] The Colorado River and its tributaries are the life blood of the region. The allocation and use of water in the region are governed by various interstate and international treaties and compacts. A number of reservoirs have been constructed to regulate the erratic streamflows, to provide water for irrigation, municipal, industrial, and other uses, and to meet compact commitments to the Lower Colorado Region.

Water Supply Situation

The Colorado River is one of the most highly controlled rivers in the world. Demands on it extend into several other regions (besides the Upper Colorado) and into Mexico. Even though the overall water supply appears sufficient to satisfy projected depletions in the Upper Colorado Region until the year 2000, the comparison of water supply and demand on a regionwide basis is oversimplified and misleading. Water is not uniformly available throughout the Upper Colorado Region, and on many tributaries there is little opportunity to regulate any unused supply. In other parts of the region, such as southeastern Utah, water from the mainstream of the river will have to be conveyed long distances to points of need. The Colorado River rapidly is approaching the point at which it will be unable to supply the demands placed on it. In the future, it is certain that the region will face severe water shortages that will affect resource development plans currently being developed.

Agriculture accounts for the largest functional use of water withdrawals and consumption. Exports from the Upper Colorado Region also significantly deplete the Colorado River supply. Reservoir evaporation is another important water use that depletes streamflow.

Large amounts of bituminous coal, oil shale, tar sands, and uranium are located in all five States of the Upper Colorado Region. Water withdrawals for mineral fuels are projected to increase from 68 mgd in "1975" to 171 mgd in 2000. Since many of the resources are located on public lands, the utilization of the fuel reserves depends largely on Federal leasing and development policies.

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[1] The value 102,920 squares miles is for counties that approximate the Upper Colorado Region. As shown in the region map, the hydrologic boundaries of the region consist of 113,330 square miles.

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Water-related Problems

The water supply in the Upper Colorado is not sufficient to meet projected needs and terms of the Colorado River Compact. Other supply-related problems revolve around the need for improved domestic water sources and increased water requirements for mineral extraction and processing and for agricultural purposes. Excess salinity and sedimentation are two water quality concerns that must be solved. Conflicts exist among various water consumers, such as domestic, industrial, and agricultural users.

The six geographic problem areas identified by the Upper Colorado assessment staff are shown on the Upper Colorado Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

The role of the Federal Government in the resolution of particular problems in the Upper Colorado, such as excess salinity and erosion, is described in the Upper Colorado Regional Report. No Level B studies are recommended and no special data and research needs are identified. The uncertainty over Indian water rights is a major institutional concern that must be resolved.

National and State-Regional Futures

Table V-14 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water use in the Upper Colorado Region.

Because the NF values do not recognize the increased use of domestic water to satisfy the large population increase since 1970, the estimate for present domestic plus commercial use is about 25 mgd less than the SRF. The SRF projects a 55 percent population increase between "1975" and 2000 while the NF projects only a 7 percent increase. The need for domestic water will be determined by the population growth. If the population increases as projected in the SRF, the need for domestic water supplies will almost double to 201 mgd by 2000.

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The water required to meet the SRF projected mineral fuels extraction and processing and steam electric generation needs is generally much greater than that shown by the NF projections. The NF did not project any significant development of mineral fuels in this region. The decisions on use of water for these purposes will depend largely upon a national policy on energy use and conservation that is still to be formulated and adopted. If domestic energy production is encouraged through control of oil and natural gas imports, market place pricing, and production incentives, the mineral fuels of the region will probably be utilized. Under these circumstances, the SRF estimates of water consumption for oil shale processing, coal gasification, and steam electric generation should be equalled or exceeded by 2000.

Consumptive use for agriculture in "1975" is 12 percent less for the SRF than the NF. The SRF values are those generally accepted by the States of the Upper Colorado River Basin and reflect their best judgment of average depletions under the present level of development in the river system.

Projections of future agricultural consumption are larger for the NF than for the SRF. The NF projects a full supply for all irrigated land (1,627 thousand acres) by 2000. On the other hand, the SRF indicates that only about 60 percent of the water-short lands will be fully supplied since there appears to be no practical way to fully supply some of these lands. The NF projection of new irrigated lands is based on the region's meeting a share of the Nation's projected needs for food and fiber. SRF projections are based on presently authorized projects. The National Future estimates for public lands and fish and wildlife needs for instream flows further help to explain water supply problems in the region.

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Table V-14.—Socioeconomic and volumetric data summary: the Upper Colorado Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	344	431	357	523	368	670
Total employment	128	168	140	205	150	280
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	12,440	NE	12,440	NE	12,440	NE
Streamflow at outflow point(s)	10,000	10,077	9,232	8,875	8,901	8,153
Fresh-water withdrawals	6,869	7,949	7,841	9,505	7,519	8,795
Agriculture	6,427	7,639	7,254	8,809	6,706	7,580
Steam electric	103	53	157	172	201	248
Manufacturing	4	<1	2	<1	2	<1
Domestic	70	105	76	159	83	201
Commercial	10	[a]	10	[a]	11	[a]
Minerals	132	120	195	304	355	698
Public lands	103	32	120	61	127	68
Fish hatcheries	20	NE	27	NE	34	NE
Other	0	NE	0	NE	0	NE
Fresh-water consumption	2,440	2,118	3,018	2,890	3,232	3,419
Agriculture	2,221	1,956	2,688	2,479	2,775	2,668
Steam electric	39	50	106	164	151	241
Manufacturing	2	<1	1	<1	2	<1
Domestic	25	39	27	58	29	74
Commercial	3	[a]	4	[a]	4	[a]
Minerals	47	45	72	137	144	376
Public lands	103	27	120	52	127	60
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	NE	0	NE	0	NE
Ground-water withdrawals	126	105	NE	105	NE	105
Exports	805	635	985	866	1,095	1,059
Evaporation	711	662	721	860	728	860
Instream approximation						
Fish and wildlife	7,947	0	7,947	0	7,947	0
Treaties and compacts	6,700	6,698	6,700	6,698	6,700	6,698

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Lower Colorado Region (15)

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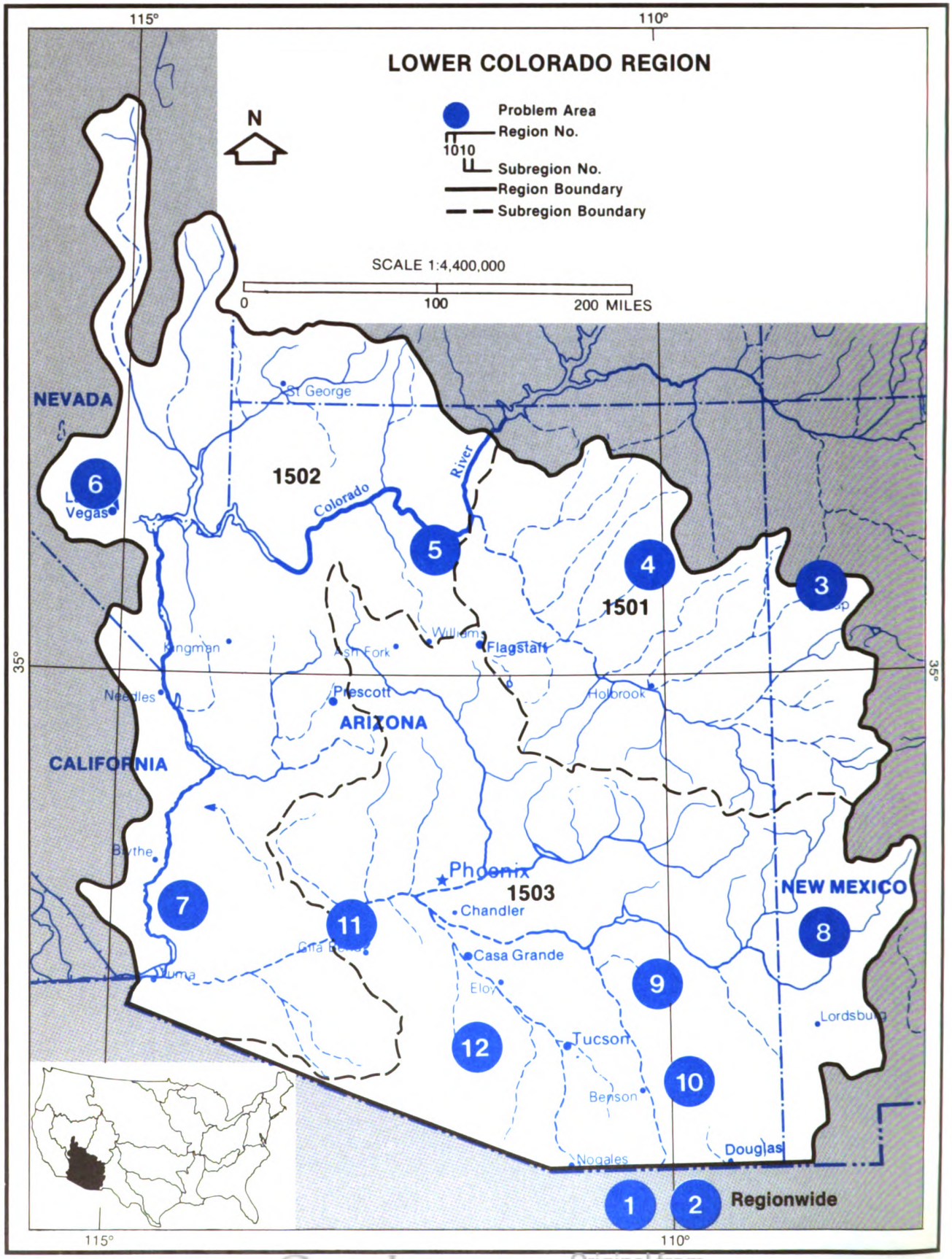

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LOWER COLORADO REGION (15)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Regionwide															
Area 1	Lower Colorado River	X												X	
2	Lower Colorado River					X									
Subregion 1501	Little Colorado	X	X			X						X			X
Area 3	McKinley County, New Mexico	X	X			X	X			X		X			X
4	Apache and Navajo Counties, Arizona	X	X			X	X			X		X			X
Subregion 1502	Lower Colorado Main Stem	O	O			O						O	O		O
Area 5	Coconino County, Arizona	X				X	X			X		X		X	
6	Las Vegas Valley, Nevada	X	X			X	X			X					
7	Lower Colorado River Valley, Arizona & Nevada	X	X			X	X			X	X	X		X	X
Subregion 1503	Gila	O	O			O				O		O	O		O
Area 8	Catron, Grant, Hidalgo Counties, New Mexico	X	X				X			X		X		X	X
9	Greenlee and Graham Counties, Arizona	X	X			X	X			X		X		X	X
10	Cochise County, Arizona		X							X		X		X	X
11	Maricopa County, Arizona	X	X			X	X			X		X		X	X
12	Pima-Pinal Counties, Arizona	X	X			X	X			X		X		X	X

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Lower Colorado Region (15)

Total Area and Major River Systems

The Lower Colorado Region encompasses a total area of over 99 million acres. It includes several closed basins in Arizona, western New Mexico, southern Nevada, southwestern Utah, and some areas in Arizona and New Mexico that drain into Mexico. Except for a portion in southern California, the region is hydrologically defined by the drainage area of the Colorado River below Lee Ferry, Arizona. The Lower Colorado River Basin receives an annual apportionment of Colorado River water as established by the Colorado River Compact.

Water Supply Situation

The Colorado River System is one of the most controlled, overburdened, and oversubscribed river systems in the Nation. Over half of the West is largely dependent on Colorado River water. In spite of the river's meager supply, a greater percentage of its water is exported than is exported from any other major river system in the United States. Current water uses are exceeding available renewable supplies. Overdraft of the ground-water supply in central Arizona and southern Nevada is currently making up the difference.

Water withdrawals are used mainly for irrigation. Almost half of the irrigated acres in the region depend entirely on dwindling ground-water supplies. Exports from the Lower Colorado Region also significantly deplete the Colorado River's water supply.

Water-related Problems

The average annual water supply of the Colorado River is inadequate to meet compact apportionments and treaty entitlements. Present available surface- and ground-water supplies are insufficient to meet present uses, and aquifers are being overdrafted. As ground-water levels drop, problems of increased pumping costs, land subsidence, and earth fissures become more prevalent. A major water quality concern stems from high levels of dissolved mineral salts. The Lower Colorado also has flooding and erosion and sedimentation.

The 12 geographic problem areas identified by the Lower Colorado Assessment Staff are shown on the Lower Colorado Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

The Federal role in providing cooperative analysis and aid in the resolution of high priority problems should be continued in the Lower Colorado Region. Specific conclusions and recommendations are made regarding needed solutions to various regional problems, such as ground-water considerations. No Level B studies are identified. Research is needed to develop more complete and accurate modeling of the surface- and ground-water system.

National and State-Regional Futures

Table V-15 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Lower Colorado Region.

The total withdrawal requirements of the SRF and NF for 1985 are in close agreement. SRF withdrawal values for the year 2000 are 13 percent higher than the NF values. Even with similar total withdrawal values, significant internal differences exist.

The SRF projections of domestic and manufacturing requirements for withdrawal and consumption are consistently higher than the NF; the SRF reflect higher populations and a slightly higher per capita consumption.

The SRF and NF differ significantly on water requirements for the minerals industry. The SRF water requirements came from a survey of the mining companies to collect data for the Arizona State Water Plan. About 97 percent of the water for the region's minerals industry is used in Arizona. The basic difference is the degree of recycling assumed in the two projections. In the region, water for mining is generally in short supply and expensive. The water is recycled several times during ore processing before finally being conveyed to lined evaporative disposal ponds. Except for sand and gravel operations, little water is returned to streams or ground-water aquifers. It is not now nor will it be acceptable to return the waste water from mining activities to streams or ground-water aquifers as implied in the NF projections.

The NF consumptive use coefficient is based on optimum crop growth with 50 percent drought probability. The SRF consumptive use coefficient is lower than the NF. The SRF coefficient is based on an average year and somewhat less than optimum crop growth. These differences apply to the withdrawal requirements as well. The SRF assumes a slightly higher irrigation efficiency.

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The "1975" SRF water withdrawal and consumptive use figures for steam electric power generation are smaller than the NF values by 18 and 16 percent, respectively. The 1985 SRF withdrawal requirements are 11 percent higher than those of the NF. The SRF projections assume that nearly all steam electric plants in the region will continue to use wet cooling towers and to recycle the water. In most of the plants little, if any, water is returned to the stream system. Water quality standards encourage this practice. In the year 2000, the SRF projections of both withdrawal and consumptive use are considerably higher than the NF. The NF assumes that after 1985 new steam electric plants will use dry cooling towers. The SRF projection does not assume that there will be a significant use of dry cooling towers by this date, because of the efficiency loss and high cost.

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Table V-15.—Socioeconomic and volumetric data summary: the Lower Colorado Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	2,412	2,683	2,915	3,740	3,629	5,071
Total employment	940	1,031	1,165	1,491	1,466	2,044
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	6,170	NE	6,170	NE	6,170	NE
Streamflow at outflow point(s)	1,550	1,340[a]	-1,433	1,340[a]	-1,544	1,340[a]
Fresh-water withdrawals	8,917	7,962	8,528	8,522	7,857	8,882
Agriculture	8,036	6,955	7,351	6,838	6,403	6,635
Steam electric	68	56	150	167	154	267
Manufacturing	89	124	92	192	138	247
Domestic	423	580[b]	520	879[b]	658	1,110[b]
Commercial	75		92		114	
Minerals	184	156	252	281	311	436
Public lands	20	23	49	57	56	65
Fish hatcheries	22	NE	22	NE	23	NE
Other	0	68	0	108	0	122
Fresh-water consumption	4,595	4,891	4,754	5,268	4,708	5,556
Agriculture	4,073	4,229	4,014	4,161	3,780	4,062
Steam electric	63	53	134	162	126	250
Manufacturing	55	63	54	94	104	123
Domestic	199	317[b]	245	440[b]	310	544[b]
Commercial	35		43		54	
Minerals	151	142	217	262	280	412
Public lands	19	23	47	56	54	65
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	64	0	93	0	100
Ground-water withdrawals	5,008	4,324	NE	2,447	NE	3,609
Exports	4,498	4,465	4,129	3,929	4,032	3,929
Evaporation	1,202	1,230	1,222	1,232	1,236	1,240
Instream approximation						
Fish and wildlife	6,864	0	6,864	0	6,864	0

NE - Not estimated.

[a] SRF streamflow is the minimum flow required by the Mexican Water Treaty.
[b] SRF domestic water use includes commercial and institutional requirements.

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Great Basin Region (16)

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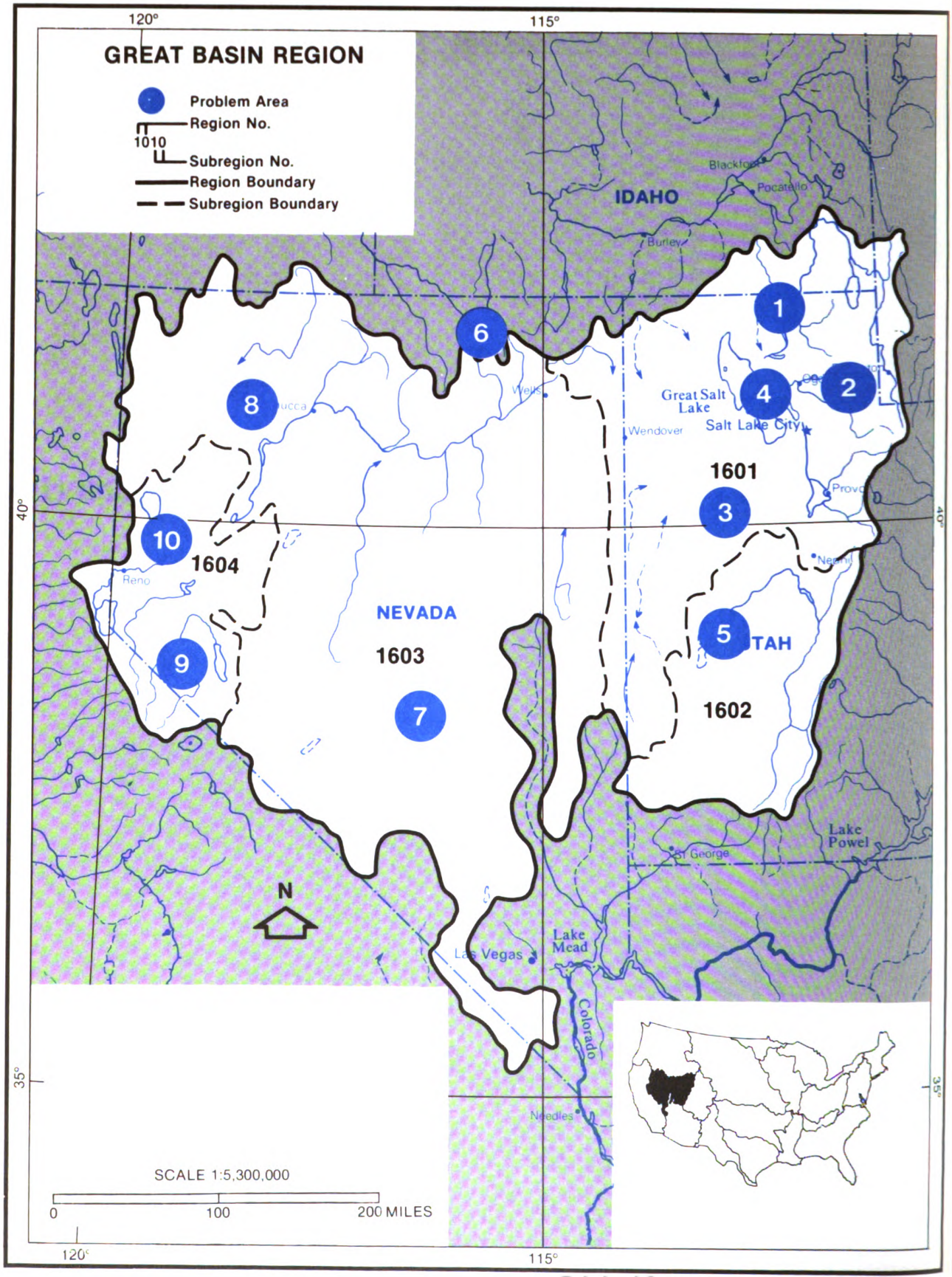

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GREAT BASIN REGION (16)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1601	Bear-Great Salt Lake	O	O			O				O		O			O
Area 1	Bear River	X				X	X			X		X			X
2	Weber-Davis					X				X					
3	Jordan River	X	X			X				X					X
4	Great Salt Lake				X	X				X					X
Subregion 1602	Sevier Lake	O	O			O				O		O			O
Area 5	Sevier-Beaver	X	X			X				X		X			X
Subregion 1603	Humboldt-Tonopah Desert	O	O			O				O					O
Area 6	Snake River Basin	X								X		X			X
7	Central Region		X				X			X					X
8	Humboldt River Basin	X	X			X	X			X	X	X			X
Subregion 1604	Central Lahonton	O								O		O			O
Area 9	Walker River Basin	X	X				X			X	X	X			X
10	Carson-Truckee River Basins	X	X				X			X		X			X

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Great Basin Region (16)

Total Area and Major River Systems

The Great Basin Region encompasses about 89 million acres in Utah, Nevada, and Idaho. Most of the streamflow in the region originates in the high mountains at its eastern and western edges. The region is part of a hydrologically closed basin, so all of the rivers and streams eventually end in terminal lakes or sinks where evaporation creates high salinities.

Water Supply Situation

The available water supply in the region is not sufficient to meet needs in many areas. Streamflows vary seasonally and diminish drastically in late summer; therefore, surface-water resources are poorly distributed in time and location. Ground water supports most developments located away from the base of the mountains, but recharge rates are low, and stores are depleted in central parts of the region.

Irrigation is by far the largest functional use of withdrawals from surface- and ground-water sources.

Water-related Problems

The scarcity of water in the region generates competition for its use and for land that is located near a water supply source. In several areas, lack of water is impeding further economic development, and urbanization of agricultural lands is causing conflicts. The region's ample land resources cannot be used to the fullest extent for agricultural purposes because water availability is limited. Water quality varies from excellent in mountain headwater streams to poor in lower stream reaches and terminal lakes. Principal pollutants are salts, sediment, excess nutrients, and heat. Flooding is a serious and widespread problem. Other important water-related issues concern institutional and financial arrangements.

The 10 geographic problem areas identified by the Nevada and Utah State Divisions of Water Resources are shown on the Great Basin Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

In the Great Basin Region, the Federal Government should aid in solving water matters only when the States are unable to effect remedies. Ten specific conclusions, emphasizing the importance of local entities in water resources management, are listed in the Great Basin Regional Report. No additional Level B studies are needed.

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National and State-Regional Futures

Table V-16 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Great Basin Region.

The NF estimate for total water withdrawals is 75 percent of the SRF estimate in "1975." The NF projections call for a declining total water withdrawal for 1985 and 2000, whereas SRF projections call for a small increase in total water withdrawals. For the year 2000, the SRF estimates are about 58 percent larger than those of the NF. A portion of the NF projected decrease in total water withdrawals is due to expected reductions of agricultural withdrawals by about 16 percent between "1975" and 2000. The comparable figures for the SRF calls for only a 2 percent reduction.

Total NF water consumption estimates are consistently less than the SRF estimates for the next 25 years. NF agricultural consumption estimates alone are less than the SRF figures by 16 percent in "1975" and by 21 percent in 2000. The SRF estimates are double those of the NF for the consumption of water for steam electric purposes in "1975." However, values for the year 2000 show a complete reversal of anticipated needs, as NF estimates for steam electric purposes are double those of the SRF. Despite these large differences, the amount of water involved in this use is small compared to other uses. Much of the difference between NF and SRF water requirements is attributable to the exclusion of marshland water use from the NF estimates. According to the SRF, there is a considerable amount of water use for managed and unmanaged marshlands between the last gaging station on the major streams and the terminal lakes. The most drastic difference in the SRF and NF figures concerns ground-water withdrawals; whereas the NF estimates 1,424 mgd for "1975," the SRF estimates only 20 mgd.

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Table V-16.—Socioeconomic and volumetric data summary: the Great Basin Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	1,262	1,374	1,464	1,781	1,739	2,445
Total employment	517	550	626	756	767	1,059
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	5,750	NE	5,750	NE	5,750	NE
Streamflow at outflow point(s)	2,562	2,562	2,057	NE	1,858	NE
Fresh-water withdrawals	7,991	10,683	7,316	10,813	7,258	11,490
Agriculture	7,002	7,063	6,154	6,946	5,861	6,93[illegible]
Steam electric	33	8	65	12	82	22
Manufacturing	112	89	93	148	98	327
Domestic	340	348[a]	399	452[a]	475	613[a]
Commercial	38		45		55	
Minerals	145	187	206	285	273	37[illegible]
Public lands	319	363	351	400	411	467
Fish hatcheries	2	2	3	3	3	3
Other	0	2,623	0	2,567	0	2,756
Fresh-water consumption	3,779	6,805	3,765	7,088	4,036	7,368
Agriculture	3,258	3,857	3,116	4,029	3,232	4,087
Steam electric	3	6	42	10	52	20
Manufacturing	24	25	42	51	77	135
Domestic	130	155[a]	151	202[a]	178	273[a]
Commercial	17		19		22	
Minerals	28	61	44	105	64	99
Public lands	319	361	351	398	411	464
Fish hatcheries	0	0	0	0	0	0
Other	0	2,340	0	2,293	0	2,290
Ground-water withdrawals	1,424	20	NE	24	NE	28
Evaporation	327	2,469	331	2,411	333	2,336
Instream approximation						
Fish and wildlife	3,389	0	3,389	0	3,389	0

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Pacific Northwest Region (17)

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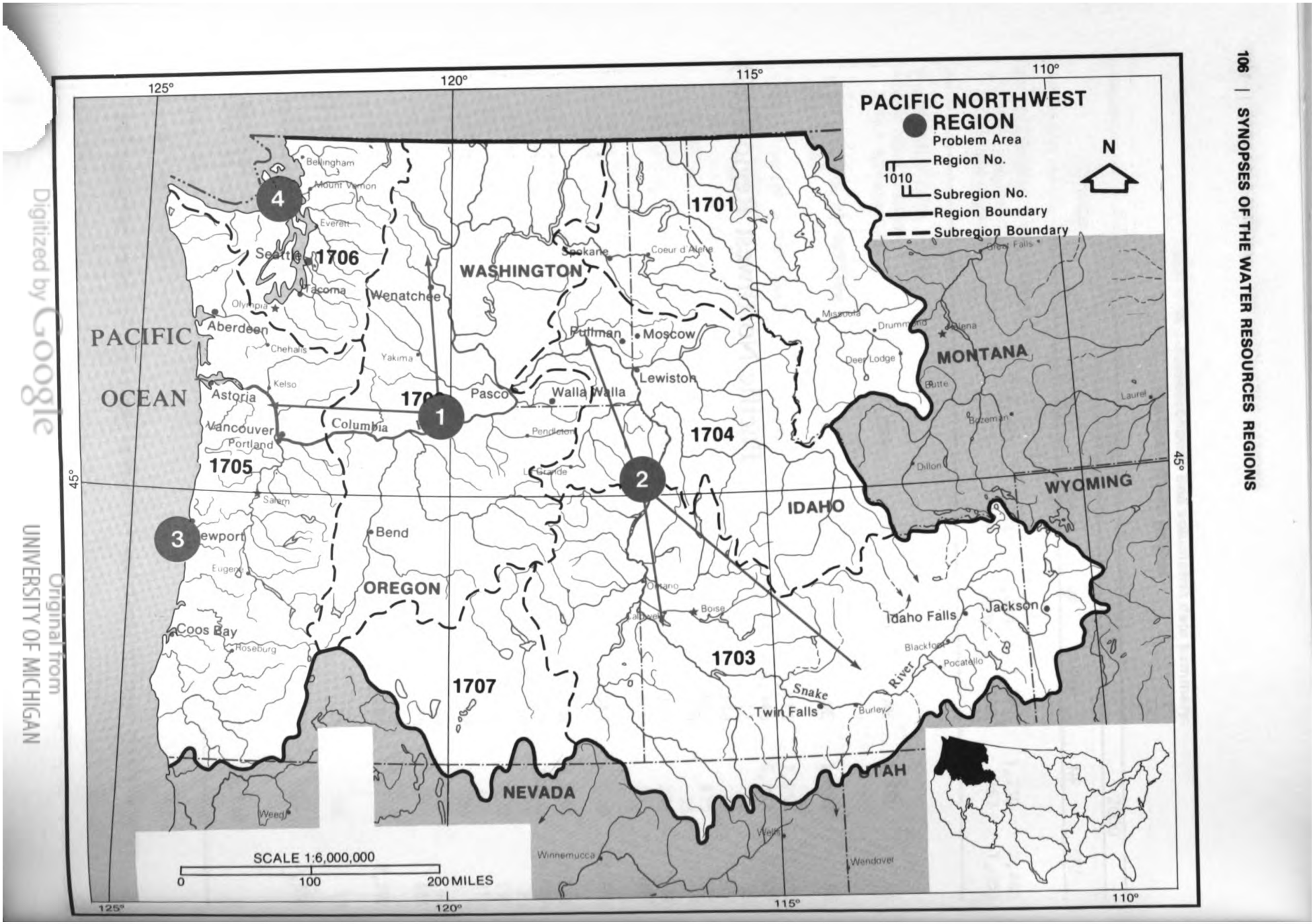

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PACIFIC NORTHWEST REGION (17)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1701	Clark Fork-Kootenai	O				O						O			O
Subregion 1702	Upper/Middle Columbia	O	O			O				O	O				O
Area 1	Columbia River	X				X								X	X
Subregion 1703 and 1704	Upper Central Snake Lower Snake	O				O				O		O			O
Area 2	Snake River	X				X								X	X
Subregion 1705	Coast-Lower Columbia	O				O		O		O	O		O		O
Area 3	Oregon Coast					X		X		X		X	X	X	X
Subregion 1706	Puget Sound	O				O		O		O		O	O		O
Area 4	Puget Sound				X	X		X		X		X		X	X
Subregion 1707	Oregon Closed Basin	O				O									O

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Pacific Northwest Region (17)

Total Area and Major River Systems

The Pacific Northwest Region occupies over 173 million acres in the northwestern portion of the United States. The region's major rivers are the Columbia and the Snake. The Puget Sound area is a unique resource of great significance to the region.

Water Supply Situation

The region as a whole has an abundant supply of water on an average annual basis. The supply, however, is not equally distributed throughout the year or throughout the region. In some areas, the maldistribution of surface supplies is compensated for by the presence of ground-water supplies. In many areas, however, particularly east of the Cascade Range, the lack of surface- and ground-water supplies causes seasonal shortages of water, particularly for irrigation. This causes conflicts between competing instream and offstream uses.

Irrigation is the principal offstream use of water while fisheries, recreation, hydroelectric power, and navigation are the principal instream uses.

Water-related Problems

During the summer, the need for irrigation conflicts with the need for sufficient streamflows to maintain high water quality for the salmon fishery. Additional reservoirs can be constructed only in areas of prime wildlife habitat or of high scenic value. Many water quality problems have been remedied already; major remaining difficulties are enrichment of streamflow, sedimentation, and estuarine pollution. Major land-use conflicts occur between development and conservation uses. The legal status of water flowing through Federal reserved lands and Indian reservations is unclear.

The four geographic problem areas identified by the Pacific Northwest River Basins Commission are shown on the Pacific-Northwest Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

In the Pacific Northwest, it is recommended that the Federal Government continue to discharge its statutory responsibilities, but concede leadership in water resource matters to the states of the Pacific Northwest River Basins Commission. The Commission, as necessary, should coordinate the efforts of the Federal and State agencies. Because current studies address the problem areas identified, no new Level B studies are proposed. Data collection and research should be expanded in the Oregon coastal area, the Puget Sound area, the Snake River, and the Columbia River. New institutional arrangements are needed to improve cooperation among various governmental levels dealing with water issues.

National and State-Regional Futures

Table V-17 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Pacific Northwest Region. Only limited SRF information comparable to NF information is available, so no real comparison between the two is possible.

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Table V-17.—Socioeconomic and volumetric data summary: the Pacific Northwest Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	6,703	6,783	6,991	8,089	7,589	9,78[illegible]
Total employment	2,642	2,440	2,958	2,931	3,345	3,60[illegible]
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	266,556	NE	266,556	NE	266,556	NE
Streamflow at outflow point(s)	255,270	239,570	251,905	NE	251,291	NE
Fresh-water withdrawals	37,495	37,495	38,098	NE	33,852	NE
Agriculture	33,253	33,253	34,725	NE	30,063	NE
Steam electric	260	260	203	NE	580	NE
Manufacturing	2,324	2,324	1,321	NE	1,132	NE
Domestic	804	804	863	NE	957	NE
Commercial	274	274	282	NE	307	NE
Minerals	118	118	141	NE	167	NE
Public lands	190	190	262	NE	332	NE
Fish hatcheries	272	272	301	NE	314	NE
Other	0	0	0	NE	0	NE
Fresh-water consumption	11,913	11,913	14,610	NE	15,196	NE
Agriculture	11,098	11,098	13,448	NE	13,315	NE
Steam electric	13	13	104	NE	344	NE
Manufacturing	329	329	501	NE	880	NE
Domestic	210	210	220	NE	238	NE
Commercial	55	55	56	NE	60	NE
Minerals	18	18	19	NE	27	NE
Public lands	190	190	262	NE	332	NE
Fish hatcheries	0	0	0	NE	0	NE
Other	0	0	0	NE	0	NE
Ground-water withdrawals	7,348	7,348	NE	NE	NE	NE
Evaporation	2,014	1,915	2,055	1,915	2,083	1,915
Instream approximation						
Fish and wildlife	214,004	214,004	214,004	214,004	214,004	214,004

NE - Not estimated.

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California Region (18)

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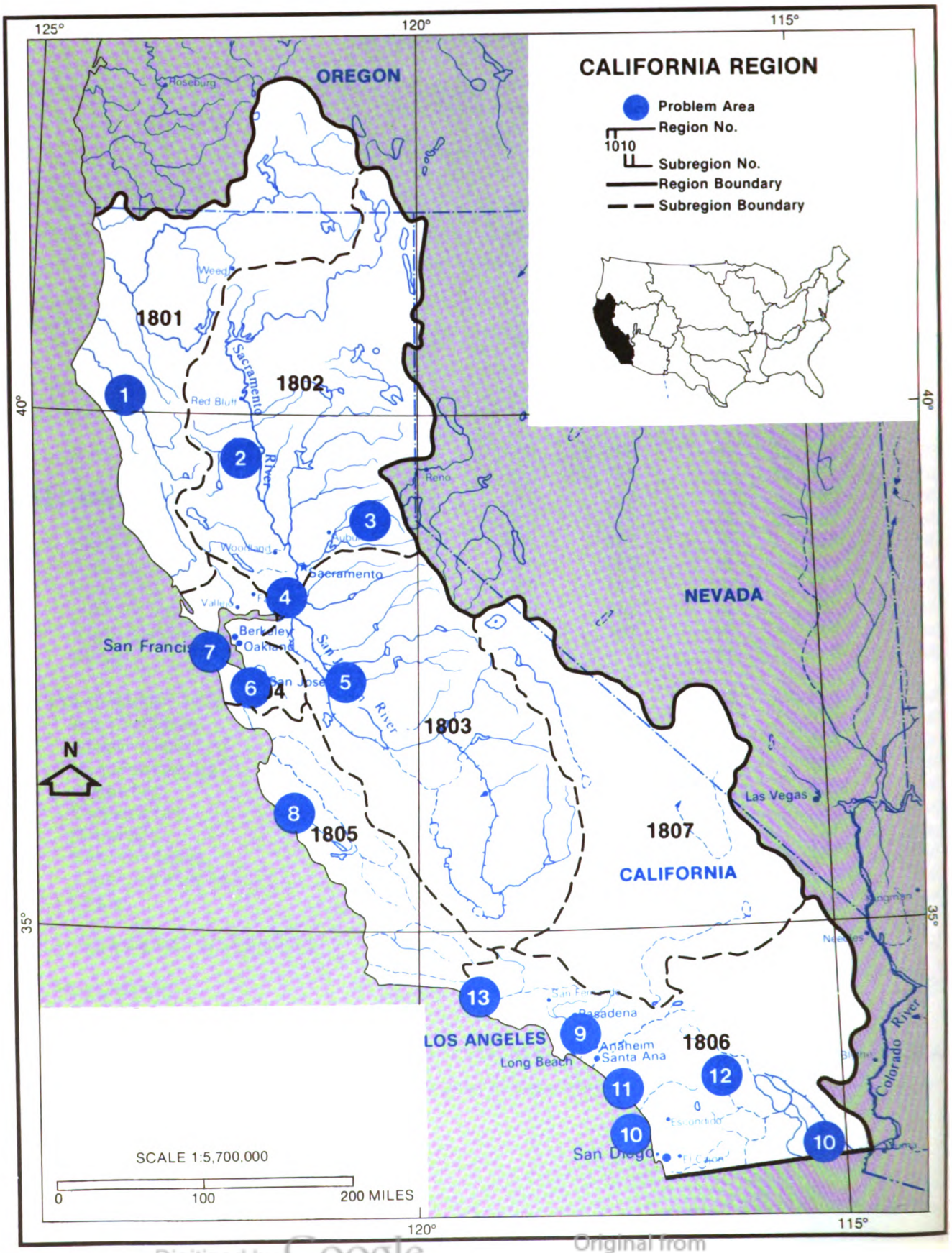

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CALIFORNIA REGION (18)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative														
		Water quantity				Water quality				Related lands						
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Subsidence	Water related use conflicts	Other
Subregion 1801	Klamath-North Coastal	O				O				O	O	O				
Area 1	Trinity and Eel River Basins	X								X		X				X
Subregion 1802	Sacramento-Lahontan	O	O			O	O			O	O		O			
Area 2	Sacramento Valley	X			X					X	X	X			X	X
3	Lake Tahoe (Designated 208 Area)					X						X				
4	Sacramento – San Joaquin Delta					X				X						X
Subregion 1803	San Joaquin-Tulare	O	O				O			O	O	O				
Area 5	San Joaquin Valley	X	X			X	X			X	X			X	X	X
Subregion 1804	San Francisco Bay	O	O			O	O	O		O			O			
Area 6	Santa Clara County	X	X			X				X						X
7	San Francisco Bay							X		X		X	X	X		X
Subregion 1805	Central California Coast	O	O				O			O		O	O			
Area 8	Salinas, Pajaro, and Carmel Valleys		X				X			X						X
Subregion 1806	Southern California	O	O			O	O	O		O		O	O			
Area 9	Santa Ana River Basin		X				X			X						X
10	Colorado River – Salinity Impact on California	X														X
11	Coastal Lagoons	X						X			X	X				X
12	Salton Sea															X
13	Santa Clara River Basin (Designated 208 Area)		X				X									X
Subregion 1807	Lahontan–South	O	O			O						O				

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California Region (18)

Total Area and Major River Systems

The California Region encompasses about 105 million acres with 1,050 miles of coastline. Two important, intensively developed rivers are the Sacramento and the San Joaquin which drain California's central valley and flow to the delta at San Francisco Bay. Other significant rivers in the northern coastal area, such as the Klamath and the Eel, are not as extensively utilized.

Water Supply Situation

Water supplies are poorly distributed in place and time with respect to need. Water surplus areas are in the northern part of the region, while areas of primary water demand are in the central and southern portions. Similarly, the largest irrigation demand occurs in late summer, while peak supply occurs in the winter. Reservoir storage and extensive conveyance facilities have been developed to permit effective use of surface water. Ground water has also been widely developed.

Fresh-water withdrawals go mainly to irrigation.

Water-related Problems

One of the region's major concerns is the discrepant distribution of water supplies. The quality of most of the water in the region is superior to the average quality of waters in the Nation, but it ranges from extremely high quality in alpine lakes to low quality along the southern coast and in the lower parts of closed basins. Erosion and sedimentation, flooding, shortages of ground water, and needs for recreation water surface area and drainage are problems faced by various areas in the region. Other major issues include allocation of limited inland waters for powerplant cooling, water rights, waste-water reclamation, and environmental protection.

The 13 geographic problem areas identified by the California Department of Water Resources are shown on the California Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

Recommendations on the Federal role, planning, data and research, and institutional matters focus on specific activities, such as legislation, funding, and studies that the Congress and Federal agencies should emphasize.

National and State-Regional Futures

Table V-18 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the California Region.

The NF estimates for total fresh-water withdrawals are 3 percent over the SRF estimates for "1975." Both the NF and SRF projections call for an increase in fresh-water withdrawals. For the year 2000, the SRF estimate is about 10 percent larger than that of the NF. Between "1975" and 2000, NF withdrawals for agriculture are expected to remain about the same. The comparable figures for the SRF call for a 14 percent increase.

The consumption situation is different. For "1975," the NF estimate exceeds that of SRF by 24 percent and for the year 2000, by 15 percent. Agricultural consumption estimates follow the trend set by total consumption. NF projections exceed SRF projections by 31 percent in "1975" and by 22 percent in the year 2000. Both forecast increases in domestic, commercial, and institutional consumption. However, SRF estimates are larger by 17 percent in "1975" and 32 percent in the year 2000.

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Table V-18.—Socioeconomic and volumetric data summary: the California Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	21,160	21,168	23,703	24,422	27,093	29,344
Total employment	8,828	8,894	10,226	10,604	12,080	13,093
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	71,819	NE	71,819	NE	71,819	NE
Streamflow at outflow point(s)	47,375	47,320	43,508	NE	41,546	NE
Fresh-water withdrawals	39,636	38,351	40,549	41,792	41,265	45,468
Agriculture	34,709	29,955	34,981	32,290	34,900	34,282
Steam electric	42	2,492	158	2,581	367	2,732
Manufacturing	796	859	830	897	828	893
Domestic	3,014	3,986	3,395	4,885	3,890	6,383
Commercial	374	[a]	414	[a]	470	[a]
Minerals	297	NE	359	NE	375	NE
Public lands	363	NE	371	NE	394	NE
Fish hatcheries	41	NE	41	NE	41	NE
Other	0	1,059[b]	0	1,139[b]	0	1,181[b]
Fresh-water consumption	26,641	21,544	27,932	23,629	29,699	25,849
Agriculture	24,380	18,675	25,252	20,223	26,447	21,638
Steam electric	25	48	101	147	242	302
Manufacturing	257	206	375	296	567	446
Domestic	1,279	1,673	1,436	1,955	1,641	2,421
Commercial	155	[a]	174	[a]	198	[a]
Minerals	183	NE	225	NE	213	NE
Public lands	362	NE	369	NE	391	NE
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	942[b]	0	1,008[b]	0	1,042[b]
Ground-water withdrawals	19,160	12,510	NE	NE	NE	NE
Evaporation	669	1,122	679	1,186	686	1,186
Instream approximation						
Fish and wildlife	32,607	32,607	32,607	32,607	32,607	32,607

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.
[b] SRF other water use includes recreation and wildlife.

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Alaska Region (19)

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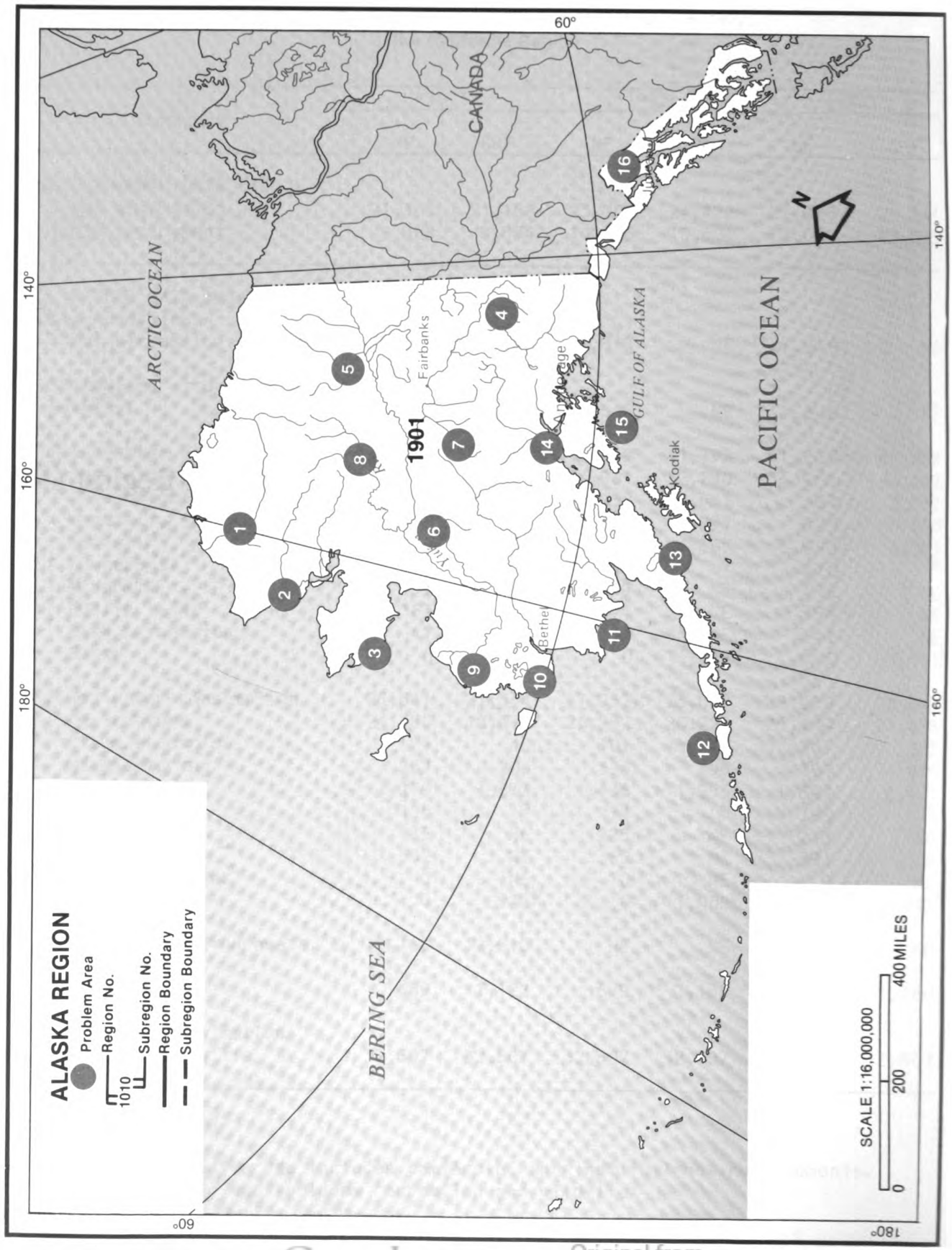

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ALASKA REGION (19)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 1901	Alaska	O	O			O	O			O					O
Area 1	Arctic	X			X	X				X		X		X	X
2	Kotzebue Sound	X		X		X	X	X		X		X			
3	Norten Sound	X	X			X	X	X		X		X		X	
4	Upper Yukon – Canada											X			
5	Upper Yukon		X							X		X		X	X
6	Central Yukon	X	X			X	X			X		X		X	X
7	Tanana	X	X			X	X			X		X	X	X	X
8	Koyukuk	X	X			X	X					X		X	
9	Lower Yukon	X	X			X	X			X		X			X
10	Kuskokwim Bay	X	X			X	X	X		X			X		X
11	Bristol Bay	X	X	X	X	X	X	X						X	
12	Aleutian														
13	Kodiak-Shelikof	X	X			X	X	X		X		X	X	X	X
14	Cook Inlet	X	X			X		X		X	X	X	X	X	X
15	Gulf of Alaska	X	X			X	X	X		X		X	X	X	X
16	Southeast	X			X	X		X		X	X	X	X		

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Alaska Region (19)

Total Area and Major River Systems

The Alaska Region accounts for one-sixth of the total area of the United States or over 375 million acres. Except for the Yukon and Porcupine, all major streams in the region originate in Alaska. The Alsek, Taku, and Stikine streams also have their headwaters in Canada. All of the rivers and streams flow into either the Arctic Ocean, the Bering Sea, or the Pacific Ocean.

Water Supply Situation

The apparent availability of water in Alaska, with its myriad lakes and streams, is deceiving to the uninformed. In some places, an adequate source of water for year-round use frequently may be difficult to obtain. A combination of effects of geology and climate produces results often unanticipated by persons with temperate and tropical climate experience.

Alaska has surface-water resources estimated at roughly one-third of the Nation's fresh-water supply, but they are scattered over an area equal to one-sixth of the Nation's total land area. When viewed as a statewide total amount of water, supplies substantially exceed demands. A great deal of the available water in Alaska occurs in southern coastal and southeastern areas; for the vast majority of Alaska land areas, water is in the form of snow or ice most of the year.

Manufacturing accounts for the largest use of water withdrawals. Coal mines, refineries, and petrochemical plants have significant water requirements.

Water-related Problems

A major concern of the region is the lack of safe water sources for remote villages. Another is the need for legislation to clarify the allocation of water for instream uses, which often are overlooked in the competition for water supply. Recently, energy development has had a major effect on land and water resources in Alaska. The potential for environmental disruptions from oil, gas, and coal development is tremendous. In many areas with semiarid conditions or extended cold periods, frequent water shortages may limit the energy development possible in these locations. Numerous places in Alaska have flooding. Harbors, maintenance facilities, and well marked channels are needed for Alaska's commercial and recreation boating activities. There are potentially serious water conflicts between forestry and fishery interests.

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The 16 geographic problem areas identified by the Alaska Water Study Committee are shown on the Alaska Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

Conclusions and Recommendations

Conclusions and recommendations are made regarding Federal-State-local roles, planning, data and research, and institutional arrangements for remote village water supplies, instream water, energy, water availability, flooding, and navigation and ports. A program such as the Water Resources Council's comprehensive coordinated joint planning program should be established in Alaska. No new Level B studies are proposed. However, data and planning efforts should give priority to water development for municipal and industrial water supplies, port development, hydroelectric power, and enhancement of natural flow for fish and wildlife.

National and State-Regional Futures

Table V-19 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Alaska Region.

SRF estimates of total withdrawals are greater than the corresponding NF estimates for "1975," 1985, and 2000. No information about fish hatchery water withdrawals is available on the national level. On the other hand, State sources indicate fish hatchery withdrawals are comparable to those of domestic plus commercial use. If these significant fish hatchery withdrawals are excluded from the SRF total withdrawal figures, the SRF and NF totals become less discrepant. By the year 2000, remaining differences are accounted for largely by the SRF projected increases in agriculture, steam electric, and manufacturing water uses. NF values indicate a decrease or no change in these functional use categories between "1975" and 2000.

Because no estimates of water consumption were developed by the SRF, no meaningful comparisons between SRF and NF consumptive use can be made.

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Table V-19.—Socioeconomic and volumetric data summary: the Alaska Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	307	409	361	606	438	992
Total employment	135	186	164	267	205	426
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	905,058	NE	905,058	NE	905,058	NE
Streamflow at outflow point(s)	905,000	816,000	904,851	NE	904,599	NE
Fresh-water withdrawals	305	345	433	711	745	1,243[a]
Agriculture	4	5	4	76	5	304
Steam electric	36	34	20	41	11	81
Manufacturing	134	88	93	125	86	149
Domestic	84	72[b]	105	107[b]	137	177[b]
Commercial	7		9		10	
Minerals	30	61	192	230	476	361
Public lands	10	NE	10	NE	20	NE
Fish hatcheries	0	85[c]	0	132[c]	0	171[c]
Other	0	0	0	0	0	0
Fresh-water consumption	58	NE	207	NE	459	NE
Agriculture	3	NE	3	NE	4	NE
Steam electric	0	NE	2	NE	5	NE
Manufacturing	26	NE	41	NE	68	NE
Domestic	6	NE	8	NE	10	NE
Commercial	1	NE	2	NE	2	NE
Minerals	12	NE	141	NE	350	NE
Public lands	10	NE	10	NE	20	NE
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	NE	0	NE	0	NE
Ground-water withdrawals	44	NE	NE	NE	NE	NE
Evaporation	0	NE	0	NE	0	NE
Instream approximation						
Fish and wildlife	859,000	NE	859,000	NE	859,000	NE

NE - Not estimated.

[a] SRF considered two levels of development. Data are presented for high level development. Total withdrawals are estimated at 1,071 mgd for low level development.

[b] SRF domestic water use includes commercial and institutional requirements.

[c] SRF estimates based on average maximum water requirements (10 cubic feet per second or 6.5 mgd).

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Hawaii Region (20)

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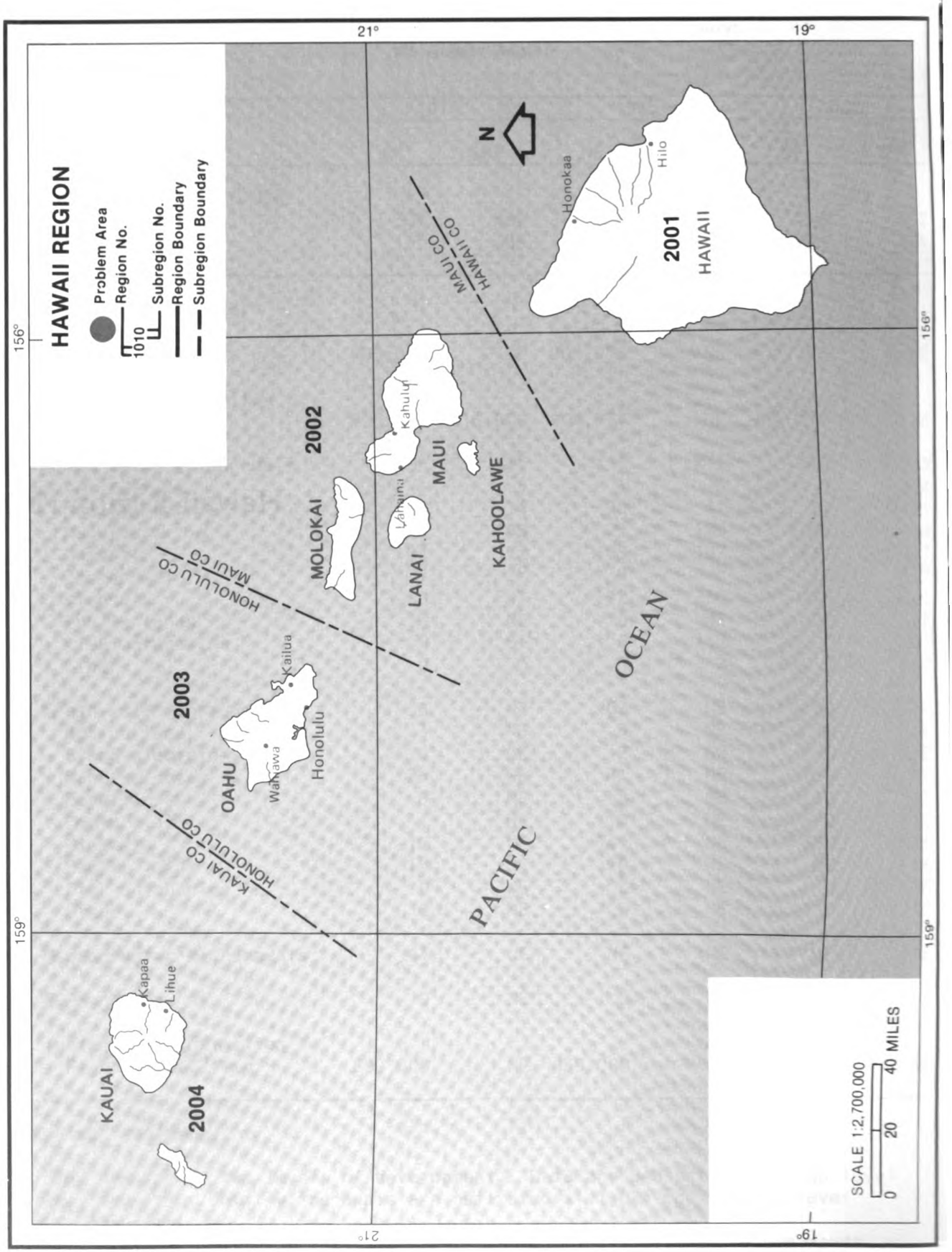

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HAWAII REGION (20)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 2001	Hawaii County	O				O		O		O		O		O	O
Subregion 2002	Maui County	O				O	O	O		O		O		O	O
Subregion 2003	Honolulu County	O				O	O	O		O		O		O	O
Subregion 2004	Kauai County	O				O		O		O		O		O	O

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Hawaii Region (20)

Total Area and Major River Systems

The Hawaiian Archipelago contains 132 islands, shoals, and reefs, which equal about four million acres within the State of Hawaii. There are more than 200 perennial and temporary streams, but no large watersheds comparable to mainland stream systems.

Water Supply Situation

Rainfall in Hawaii is ample to supply the present and foreseeable future water requirements of all the major islands. Any supply problems are due to inequalities in the distribution of rainfall rather than to insufficient quantities. Surface water diverted from streams represents the major source of water; streams are perennial and abundant where rainfall is plentiful and well distributed through the year and where the ground is not extremely porous. Ground water occurs as basal water, dike-impounded water, and as perched water; pumping from these supplies is currently within safe limits. Hawaii's unique combination of geology and rainfall makes it difficult to apply normal water-soil relationships.

Irrigation is the largest user of water withdrawals.

Water-related Problems

Except for the island of Oahu, all islands have sufficient water supplies to meet demands until the year 2000. Many water systems, however, rely on surface-water supplies that sometimes have undesirable taste, odor, and turbidity. Other water systems obtain supplies from aquifers that are sometimes in potential danger of contamination. Flood damage in Hawaii has been extensive, making flood forecasting an important endeavor. Degradation of environmental quality due to siltation, sewage, chemical and thermal pollution, and conflicting land use that threatens endangered species are major concerns. With increasing demands for water, the question over whether to develop or to preserve fresh-water habitat becomes more pressing.

No geographic problem areas were identified by the Hawaii Department of Land and Natural Resources. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by Federal representatives for the entire subregions.

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Conclusions and Recommendations

Conclusions and recommendations for the Hawaii Region are made regarding water supply, water quality, floods, environmental degradation, and endangered species. No new Level B Studies are recommended (a Level B Study for Hawaii was completed in 1977). Most water-related problems and opportunities are being addressed by ongoing programs, e.g., the coastal zone management plan, the areawide waste treatment plan, and ongoing urban studies. Gaps in Hawaii's data program include the lack of raw data and the lack of adequate data storage, retrieval, dissemination, and analysis capabilities; these gaps are particularly significant in the data areas of environmental and land and water use.

National and State-Regional Futures

Table V-20 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Hawaii Region.

The State-Regional Future was extracted from the Hawaii Water Resources Regional Plan, but because the plan did not include 1985 as a time period, totals were not available for that year. The plan projected figures for water withdrawals for the year 2000; these can be compared with the National Future. No projections are available for consumptive water use.

One of the main differences between the NF and the SRF is the population growth. NF projections show lower growth for the region than the SRF (38 percent), while the study team for the economic analysis of the regional plan, which consisted of State and county planners, predicts population to increase by 57 percent between "1975" and 2000.

What is not shown in the tables is the effect of the visitor industry. In "1975" visitors averaged 60,000 per day in the region. In the year 2000 it is estimated that this total will substantially increase. The effect of the visitor industry is demonstrated in the volumetric requirements for domestic water, which accounts for the great differences in the total withdrawals.

A major goal of the region is to encourage more agricultural development. This is reflected in the difference between the NF and SRF irrigation withdrawals projected for the year 2000.

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Table V-20.—Socioeconomic and volumetric data summary: the Hawaii Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	787	865	911	1,058	1,085	1,355
Total employment	365	347	431	451	519	599
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	7,352	NE	7,352	NE	7,352	NE
Streamflow at outflow point(s)	6,747	NE	6,716	NE	6,686	NE
Fresh-water withdrawals	1,879	1,516	1,619	NE	1,349	2,129
Agriculture	1,449	948	1,229	NE	954	1,354
Steam electric	0	0	0	NE	0	0
Manufacturing	252	321	181	NE	139	241
Domestic	148	226	172	NE	209	436
Commercial	29	[a]	36	NE	46	[a]
Minerals	1	1	1	NE	1	NE
Public lands	0	0	0	NE	0	0
Fish hatcheries	0	0	0	NE	0	0
Other	0	20	0	NE	0	98
Fresh-water consumption	605	NE	636	NE	666	NE
Agriculture	476	NE	484	NE	476	NE
Steam electric	0	NE	0	NE	0	NE
Manufacturing	74	NE	88	NE	112	NE
Domestic	44	NE	52	NE	63	NE
Commercial	11	NE	12	NE	15	NE
Minerals	0	NE	0	NE	0	NE
Public lands	0	NE	0	NE	0	NE
Fish hatcheries	0	NE	0	NE	0	NE
Other	0	NE	0	NE	0	NE
Ground-water withdrawals	790	882	NE	NE	NE	NE
Evaporation	1	NE	1	NE	1	NE
Instream approximation						
Fish and wildlife	4,590	NE	4,590	NE	4,590	NE

NE - Not estimated.

[a] SRF domestic water use includes commercial and institutional requirements.

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Caribbean Region (21)

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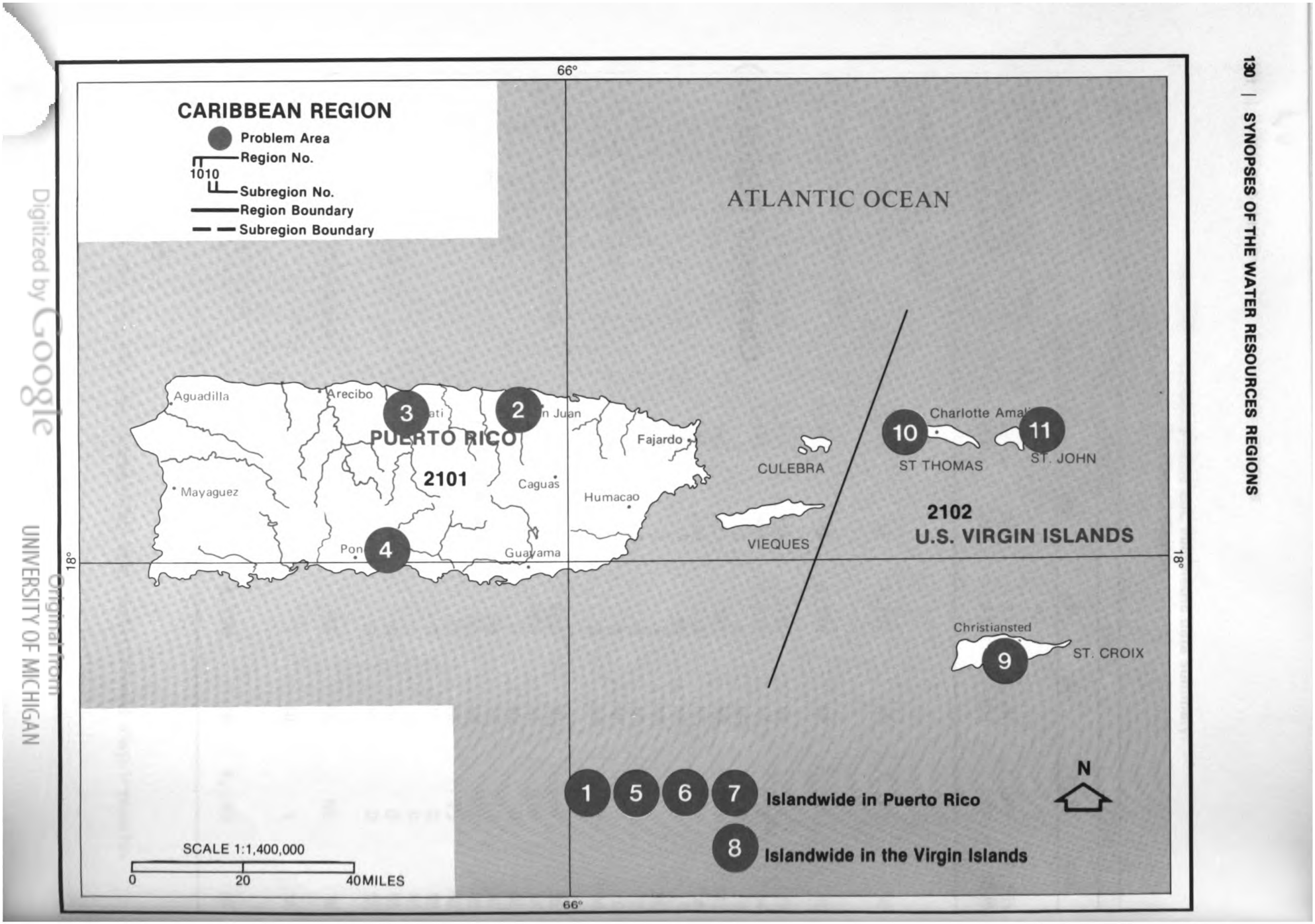

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CARIBBEAN REGION (21)

PROBLEM MATRIX

Problem area		Problem issues O= Identified by Federal Agency Representative X= Identified by State-Regional Representative													
		Water quantity				Water quality				Related lands					
No. on map	Name	Fresh surface	Ground	Marine and estuarine	Surface/depth	Fresh surface	Ground	Marine and estuarine	Surface/depth	Flooding	Drainage	Erosion and sedimentation	Dredge and fill	Water related use conflicts	Other
Subregion 2101	Puerto Rico	O	O			O	O	O		O					O
Area 1	Puerto Rico														X
2	San Juan Area, Puerto Rico	X				X	X	X		X	X	X	X	X	
3	Barceloneta Area, Puerto Rico		X			X	X	X		X	X		X	X	
4	South Coast Area, Puerto Rico	X	X			X	X	X		X	X	X	X	X	
5	Islandwide Puerto Rico: Flooding									X					
6	Islandwide Puerto Rico: Waterborne Pathogens					X	X	X							
7	Islandwide P.R.: Sedimentation & Eutrophication					X						X			
Subregion 2102	Virgin Islands	O	O				O	O							
Area 8	Virgin Islands														X
9	St. Croix, Virgin Islands	X	X			X	X	X		X		X	X		
10	St. Thomas, Virgin Islands	X	X			X	X	X		X		X	X		
11	St. John, Virgin Islands	X	X			X		X		X					

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Caribbean Region (21)

Total Area and Major River Systems

Puerto Rico, the larger of the two subregions of the Caribbean Region, has a territory of slightly more than 2 million acres. The U.S. Virgin Islands consist of a total area of about 85,000 acres. Most of the rivers in Puerto Rico are short in length, and none are very large in size or flow. The largest river, the Rio Grande de Loiza, has a drainage area of only 310 square miles. Streamflow in the Virgin Islands is ephemeral, and stream channels respond quickly to rainfall due to the extremely steep topography and tiny watershed areas.

Water Supply Situation

Because of the lack of islandwide distribution systems in Puerto Rico, water supplies, which are ample overall cannot fulfill the needs of heavy demand areas. If managed wisely, Puerto Rico's water resources are sufficient to support significantly increased levels of population and economic activity. The Virgin Islands, however, have very limited water supplies. Water sources include raw and desalinated sea water, rainwater collection, waste-water recycling, and water imported by barges. The distribution facilities are very poor in this subregion, and the desalination plants often break down.

Irrigation accounts for the largest use of water withdrawals.

Water-related Problems

In Puerto Rico, institutional problems are the most severe impediment to resolution of water and related land-resource issues. Water quality is another major concern since surface waters are used as waste depositories and for domestic and agricultural needs. Both subregions have flooding and erosion and sedimentation. In the Virgin Islands, the most crucial water resource problems are related to the poor condition of the water supply and distribution system.

The 11 geographic problem areas identified by the Puerto Rico Department of Natural Resources are shown on the Caribbean Region map and in the problem matrix. The problem matrix shows water quantity, water quality, related land, and other issues as tabulated by State-regional representatives for each of the geographic problem areas and by Federal representatives for entire subregions.

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Conclusions and Recommendations

Because the Federal role in water programs is well developed already in the Caribbean, a significant enlargement of this role seems inappropriate. A Level B study has been proposed for Puerto Rico; no Level B studies are recommended for the Virgin Islands. In Puerto Rico, data collection and research are needed in various fields, especially in the inefficient management of irrigation water. The primary research needs in the Virgin Islands are for water conservation methods, aquifer development and management, and water recycling.

National and State-Regional Futures

Table V-21 compares the National Future (NF) and State-Regional Future (SRF) estimates of streamflows and water needs in the Caribbean Region.

National Future estimates of total withdrawals and consumption in "1975" are greater than those of the State-Regional Future. By the year 2000, this situation will be reversed, with the SRF exceeding NF projections. Differences between NF and SRF values are significant in the agricultural and domestic use categories. Both show good agreement on commercial and minerals withdrawal and consumption.

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Table V-21.—Socioeconomic and volumetric data summary: the Caribbean Region

Category	"1975"		1985		2000	
	NF	SRF	NF	SRF	NF	SRF
SOCIOECONOMIC DATA (1000)						
Total population	3,052	3,052	3,614	3,614	4,234	4,234
Total employment	809	809	1,010	1,010	1,190	1,190
VOLUMETRIC DATA (mgd)						
-Base conditions-						
Total streamflow	5,181	NE	5,181	NE	5,181	NE
Streamflow at outflow point(s)	4,851	667	4,807	NE	4,881	NE
Fresh-water withdrawals	907	725	963	901	890	1,086
Agriculture	521	239	498	229	330	232
Steam electric	0	0	0	0	0	0
Manufacturing	0	101	0	124	0	133
Domestic	311	311	376	461	454	618
Commercial	44	44	52	52	60	60
Minerals	31	30	37	35	46	44
Public lands	0	0	0	0	0	0
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Fresh-water consumption	343	299	374	368	300	427
Agriculture	281	147	297	154	206	163
Steam electric	0	0	0	0	0	0
Manufacturing	0	25	0	31	0	33
Domestic	49	114	61	167	75	212
Commercial	9	9	11	11	13	13
Minerals	4	4	5	5	6	6
Public lands	0	0	0	0	0	0
Fish hatcheries	0	0	0	0	0	0
Other	0	0	0	0	0	0
Ground-water withdrawals	254	254	NE	221	NE	241
Evaporation	0	0	0	0	0	0
Instream approximation						
Fish and wildlife	3,706	3,706	3,706	3,706	3,706	3,706

NE - Not estimated.

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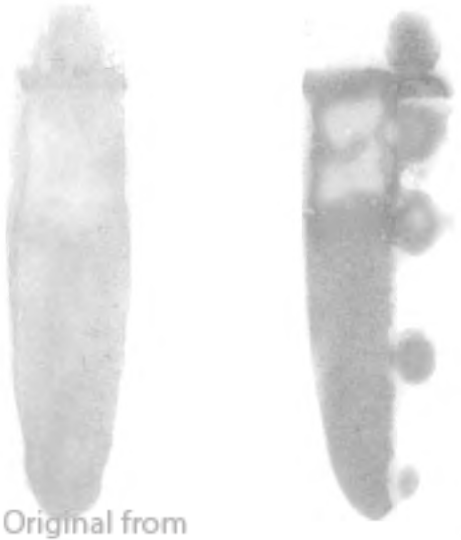

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[1] The Washington staff of the Federal agencies was augmented by field office staff who participated with Washington offices or through the Regional Study Teams.
[2] Several States had representatives on more than one Regional Study Team. Contributions of those not named were greatly appreciated.

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Authorization

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The purpose of the Council is to encourage the conservation, development, and utilization of water and related land resources on a comprehensive and coordinated basis by the Federal government, States, localities, and private enterprises with the cooperation of all affected Federal agencies, States, local government, individual corporations, business enterprises, and others concerned.

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THE NATION'S WATER RESOURCES 1975-2000

Volume 3: Analytical Data Summary

Second National Water Assessment by the U.S. Water Resources Council

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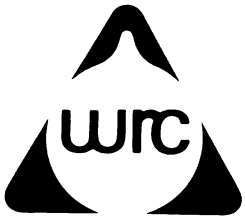

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The Nation's Water Resources—1975-2000

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Volume 3: Analytical Data Summary
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CONTENTS

U.S. Water Resources Council members ------- inside front cover
Glossary and conversion table ---------- iv

Introduction ---------- 1
Contents of this volume ---------- 1
Background of the assessment ---------- 1
Organization of the assessment report ---------- 2
Assumptions and methodology ---------- 7
Scope of the assessment information ---------- 7
Methodology and assumptions ---------- 8
Data sources and Federal agency responsiblities ---------- 9
Hydrologic data collection units ---------- 11
Hydrologic data collection units ---------- 13
Regions ---------- 13
Subregions ---------- 13
Accounting Units ---------- 13
Cataloging units ---------- 13
National summary of analytical data ---------- 19
Abbreviations used in Volume 3 tables ---------- 19
Table I-1 Population, employment, and income ---------- 20
I-2 Earnings by major sectors ---------- 22
I-3 Surface area and land use — 1975 ---------- 25
I-4 Cropland and irrigated farmland ---------- 26
I-5 Sheet erosion by source ---------- 29
I-6 Flood damages by land use ---------- 30
I-7 Recreation requirements and wilderness areas ---------- 32
I-8 Electric power generation by fuel source ---------- 34
I-9 Steam-electric generating plants ---------- 36
I-10 Water quality indicators ---------- 37
I-11 Commercial navigation ---------- 38
Table II-1 Annual water supply data — "1975" ---------- 40
II-2 Annual imports, exports, and net evaporation ---------- 41
II-3 Annual instream flow uses ---------- 41
II-4 Annual water requirements for offstream uses — base conditions ---------- 42
II-5 Annual water adequacy analysis — base conditions ---------- 54
II-6 Natural water supply analysis ---------- 56
II-7 Summary of monthly and annual water adequacy — base conditions and dry conditions ---------- 58
II-8 Water requirements for energy — base conditions ---------- 68
Explanatory notes — Tables I-1 through I-11 ---------- 71
Explanatory notes — Tables II-1 through II-8 ---------- 76
Acknowledgements ---------- inside back cover

ILLUSTRATIONS

1. Sample for subregion 101 — Appendix V, *Streamflow Conditions* ---------- 4
2. Information flow for the Second National Water Assessment --- 9
3. Water resources regions ---------- 11
4. Heirarchy of hydrologic units ---------- 12
5. Assessment subregions ---------- 14
6. Flow patterns for assessment subregions ---------- 16
7. Assessment subareas (county approximations of assessment subregions) ---------- 18
8. Industrial groupings with Standard Industrial Classification (SIC) code ---------- 70

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GLOSSARY AND CONVERSION TABLE

Definitions of terms as used in the Second National Water Assessment

**1975$** — most monetary figures are shown in 1975 dollars; source information was often supplied in 1967 dollars and a factor of 1.533 applied to obtain 1975$.

"1975" — base year for assessment information; represents assumed average conditions, not actual data, so is shown with quotation marks.

1985 — 10-year date from base year "1975" for which water supply, water use, and other assessment information is projected.

2000 — 25-year date from base year "1975" for which water supply, water use, and other assessment information is projected.

annual — average daily value for the year.

aquifer — underground formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

assessed streamflow — see *streamflow-related terms.*

assessment geographic divisions

1. **region** — one of the 21 hydrologic regions as designated by the U.S. Water Resources Council; 18 are within the conterminous United States, plus Alaska, Hawaii, and the Caribbean.
2. **assessment subregion** (ASR) — one of the 106 hydrologic subdivisions of a region; once called aggregated subregion; shortened to subregion for this report.
3. **assessment subarea** (ASA) — one of the 106 county approximations of the assessment subregions; once called aggregated subarea; shortened to subarea for this report.

base conditions — typical or average conditions of fresh-water use; used to compare "1975" base year conditions with projections for 1985 and 2000.

best available technology (BAT) — best available technology economically achievable for industrial discharges; 1983 goal of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

best practicable technology (BPT) — best practicable control technology currently available for industrial discharges; 1977 goal of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

bgd — billion gallons per day.

biochemical oxygen demand (BOD) — a measure of oxygen required for the oxidation of organic matter in water.

consumption — portion of surface or ground water withdrawn for offstream uses that is lost by evapotranspiration or by incorporation into a manufactured product.

conterminous U.S. — (also called *contiguous U.S.*) the 48 States with common boundaries; water resources regions 1-18.

critical month — month in which fish and wildlife instream flow needs are least likely to be met under present or future base conditions.

cropland — land used for agriculture but not in permanent pasture, native hayland, rangeland, or woodland.

current streamflow — see *streamflow-related terms.*

dry conditions — present and future water conditions for a moderate drought that occurs on the average one year in five.

earnings — sum of income accruing from wage and salary, proprietor's income, and other labor income.

evaporation — see *net evaporation.*

evapotranspiration — water loss through evaporation (from soil and surface water bodies) and transpiration (from plants).

exceedance — see *"streamflow exceedance"* given under *streamflow-related terms.*

exports — artificial transfers of fresh water from one region or subregion to another, e.g., by pipes or canals.

frequency analysis — method used to determine *"streamflow exceedance"* given under *streamflow-related terms.*

functional water use — category of offstream use, e.g., domestic, commercial, manufacturing, agriculture, steam electric generation, minerals industry.

future streamflow — } now called
future modified flow (FMF) — } *assessed streamflow.*

gcd — gallons per capita per day.

ground-water overdraft — portion of ground-water withdrawals that exceed recharge; sometimes called ground-water mining.

imports — artificial transfers of fresh water to one region or subregion from another, e.g., by pipes or canals.

instream flow approximations — estimates of monthly flow sufficient to support aquatic life and outdoor recreation; estimated at the outflow point.

instream use — uses of water in the stream channel, e.g. fish and other aquatic life, recreation, navigation, hydroelectric production.

mgd — million gallons per day.

modified central case (MCC) — now called *National Future.*

monthly — a set of average daily values for each month of the year.

NASQAN — National Stream Quality Accounting Network; a data-collection program established by the U.S. Geological Survey to obtain long-term consistent regional and nationwide overviews of the quality of streams.

natural flow depletion — see *streamflow-related terms.*

natural modified flow (NMF) — now called *total streamflow.*

natural outflow — see *streamflow-related terms.*

National Future (NF) — estimates of present and future conditions by the participating Federal agencies; National Future estimates form a nationally consistent information base, which is not necessarily a nationally accepted future; see also *State-Regional Future.*

net evaporation — the difference between rainfall and evaporation, limited to evaporation from manmade reservoirs that have more than 5,000 acre-feet capacity and from farm and stock ponds; zero is used when rainfall exceeds evaporation.

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et exports – } the difference between the water artificially transferred to and from a region or subregion is calculated as a net import or export.
et imports – }

BERS – a collection of current socioeconomic information and demographic and economic projections; the *1972 OBERS Series E* projections are the primary base for information used in the second assessment; *OBERS* is a Water Resources Council publication combining information from the Department of Commerce (Bureau of Economic Analysis) and the Department of Agriculture (Economics, Statistics, and Cooperative Service).

ffstream use – water withdrawn from a source for functional uses such as irrigation, municipal water supply, steam electric generation, etc.

utflow point – see *streamflow-related terms.*

verdraft – see *groundwater overdraft.*

resent modified flow (PMF) – now called *current streamflow.*

ublic lands – includes only Bureau of Land Management (BLM) lands, national forests, and national parks.

egion – see *assessment geographic divisions.*

alinity – a condition in which the water contains more than 1,000 milligrams of dissolved solids per liter, regardless of the nature of the mineral in solution.

State-Regional Future (SRF) – estimates of present and future conditions provided by participating River Basin Commissions, State agencies, and other regional sponsors; see also *National Future.*

STORET (storage and retrieval) – a computerized water quality data system managed by the Environmental Protection Agency.

treamflow-related terms

. **outflow point**

a. **above outflow point** – describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion, plus the sum of values for all upstream regions or subregions.

b. **at outflow point** – the sum of outflows from all of the major streams and rivers draining the area, measured at the downstream boundary of the region or subregion.

2. **streamflow**

a. **streamflow** – statistically derived estimate of surface freshwater discharge rates at the outflow point of the subregions, with adjustments made where actual stream gage locations are not near the outflow point.

b. **current streamflow** – average flow for "1975" derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

c. **assessed streamflow** – a computed flow that includes effects of consumption, water transfers, and evaporation from manmade reservoirs, but not ground-water overdraft.

3. **streamflow as supply**

a. **current streamflow supply** – the "1975" streamflow if consumption were eliminated, but ground-water overdraft flows were continued.

b. **assessed total streamflow** – streamflow that would be available if consumption were eliminated, if "1975" water transfer and reservoir practices were continued, but if ground-water overdrafting were discontinued.

c. **natural outflow** (natural available streamflow) – estimate of streamflow without artificial manmade constraints.

4. **streamflow depletion**

a. **current streamflow depletion** – estimated loss to "1975" current streamflow supply from consumption.

b. **assessed streamflow depletion** – estimated loss to assessed total streamflow from consumption, increases in net exports, and increases in net evaporation.

c. **natural flow depletion** – estimated loss to natural outflows (natural available streamflow) from all offstream demands (consumption, evaporation, and net exports).

5. **streamflow exceedance** – a statistical estimate of flow probability based on a 100-year period; a 5-percent exceedance flow will be exceeded only in five of the 100 years, which represents a very high streamflow condition.

6. **surplus streamflow** – portion of streamflow at region or subregion outflow point after all offstream and instream uses have been met; value does not include covenants and agreement for maintaining flows at downstream points.

subarea – see *"assessment subarea"* given under *assessment geographic divisions.*

subregion – see *"assessment subregion"* given under *assessment geographic divisions.*

surplus streamflow – see *streamflow-related terms.*

suspended solids – small particles of solid materials that contribute to turbidity and resist separation by conventional means.

total streamflow – see *"assessed total streamflow"* given under *streamflow-related terms.*

total suspended solids (TSS) – a measure of suspended solids used to evaluate water quality.

water adequacy – capability of a river system to meet both offstream and instream uses without overdraft of ground-water sources.

water transfers – see *imports, exports.*

withdrawal – water taken from a surface- or ground-water source for offstream use.

CONVERSION TABLE FOR WATER-MEASUREMENT TERMS

QUANTITY		
1 acre-foot	=	325,851 gallons
	=	43,560 cubic feet
1 million gallons	=	3.07 acre-feet
1 cubic foot	=	7.48 gallons
FLOW		
1 million gallons per day (mgd)	=	694.4 gallons per minute
	=	1.55 cubic feet per second
	=	1,120 acre-feet per year
1 billion gallons per day (bgd)	=	1.12 million acre-feet per year
1 cubic foot per second	=	1.98 acre-feet per day

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INTRODUCTION

Contents of this Volume

This volume contains baseline and projected information developed for the Second National Water Assessment under the direction of the U.S. Water Resources Council. It includes national and regional information for social, economic, environmental, water supply, and water use. Information for subregions is contained in the five appendixes to this volume.

Background of the Assessment

The Water Resources Planning Act of 1965 (Public Law 89-80) directs the U.S. Water Resources Council to maintain a continuing study of the Nation's water and related land resources and to prepare periodic assessments to determine the adequacy of these resources to meet present and future water requirements. In 1968, the Water Resources Council reported the results of its initial assessment. The Second National Water Assessment, published a decade later, provides a comprehensive, nationally consistent information base for the water resources of the United States.

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Organization of the Assessment Report

The final report of the Second National Water Assessment consists of four separate volumes, which can assist Federal, State, local, and other program managers, the Administration, and the Congress in establishing and implementing water resources policies and programs.

Volume 1, Summary, gives an overview of the Nation's water supply, water use, and critical water problems for "1975," 1985, and 2000 and summarizes significant concerns.

Volume 2, Water Quantity, Quality, and Related Land Considerations, consists of one publication with five parts:

Part I, Introduction, outlines the origin of the Second National Water Assessment, states its purpose and scope, explains the numerous documents that are part of the assessment, and identifies the individuals and agencies that contributed to the assessment.

Part II, Water-Management Problem Profiles, identifies the 10 general water-problem issues and their implications and potential consequences.

Part III, Water Uses, focuses on the national perspectives regarding existing ("1975") and projected (1985 and 2000) requirements for water to meet offstream, instream, and flow-management needs. State-regional and Federal perspectives are compared.

Part IV, Water Supply and Water Quality Considerations, analyzes the adequacy of fresh-water supplies (ground and surface) to meet existing and future requirements. It contains a national water budget; quantifies surface- and ground-water supplies, reservoir storage, and transfers of water within and between subregions; describes regional requirements and compares them to supplies; evaluates water-quality conditions; and discusses the legal and institutional aspects of water allocation.

Part V, Synopses of the Water Resources Regions, covers existing conditions and future requirements for each of the 21 water resources regions. Within each regional synopsis is a discussion of functional and location-specific water-related problems; regional recommendations regarding planning, research, data, and institutional aspects of solving regional water-related problems; a problem-issue matrix; and a comparative-analysis table.

Volume 3, Analytical Data, consists of six separately published parts—a summary volume and five appendixes. The summary volume describes the methods and procedures used to collect, analyze, and describe the data used in the assessment and also contains the summary tables of national and regional totals extracted from Appendixes I and II. The five separately published appendixes contain data for the regions and subregions as explained below.

Appendix I, Social, Economic, and Environmental Data, contains the socioeconomic baseline ("1975") and growth projections (1985 and 2000) on which the water-supply and water-use projections are based. This appendix presents two sets of data. One set, the National Future, represents the Federal viewpoint; the other set, the State-Regional Future, represents the regional sponsor and/or State viewpoint. Appendix I contains the following tables:

Table I-1	Population, Employment, and Income
I-2	Earnings by Major Sectors
I-3	Surface Area and Land Use — 1975
I-4	Cropland and Irrigated Farmland
I-5	Sheet Erosion by Source
I-6	Flood Damages by Land Use
I-7	Recreation Requirements and Wilderness Areas
I-8	Electric Power Generation by Fuel Source
I-9	Steam Electric Generating Plants
I-10	Water Quality Indicators
I-11	Commercial Navigation

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U.S.Water resources
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The nation's
water resources,1975
-2000. X Analytical
data summary

al Water Supply and Use Analysis, contains baseline water-supply data and baseline and projected water-ter-consumption data used for the assessment. Also included are a water-adequacy analysis, a natural- a critical-month analysis. Appendix II contains the following tables:

Annual Water Supply Data – "1975"
Annual Imports, Exports, and Net Evaporation
Annual Instream Flow Uses
Annual Water Requirements for Offstream Uses – base conditions
Annual Water Adequacy Analysis – base conditions
Natural Water Supply Analysis
Summary of Monthly and Annual Water Adequacy – base conditions
Summary of Monthly and Annual Water Adequacy – dry conditions
Water Requirements for Energy – base conditions

nthly Water Supply and Use Analysis, contains monthly details of the water-supply, water-withdrawal, ıption data contained in Appendix II and includes an analysis of monthly water adequacy. Appendix III wing tables:

Monthly Water Supply Data – "1975"
Monthly Imports, Exports, and Net Evaporation
Monthly Instream Flow Uses
Monthly Water Requirements for Offstream Uses – base conditions
Monthly Water Adequacy Analysis – base conditions

y Conditions Water Supply and Use Analysis, contains all annual and monthly information relating to dry .is. An exception to this is Table II-7 (Appendix II), which contains summary monthly information for both ditions. The dry conditions analysis describes present and future conditions for a moderate drought condi- on the average one year in five. Appendix IV contains the following tables:

	Annual Water Requirements for Offstream Uses – dry conditions
IV-2	Annual Water Adequacy Analysis – dry conditions
IV-3	Monthly Water Requirements for Offstream Uses – dry conditions
IV-4	Monthly Water Adequacy Analysis – dry conditions
IV-5	Water Requirements for Energy – dry conditions

Appendix V, Streamflow Conditions, gives detailed background information on the derivation of the baseline streamflow information for each subregion. Streamflow values from Appendix V are also displayed in Appendix II, Table II-1. A description of streamflow gages used, correction factors applied, periods of record, and extreme flows of record are given. Also included is the State-Regional Future estimate of average streamflow. An example for subregion 101 is included as Figure 1.

Volume 4, Water Resources Regional Reports, consists of separately published reports for each of the 21 regions. Synopses of these reports are given in Volume 2, Part V.

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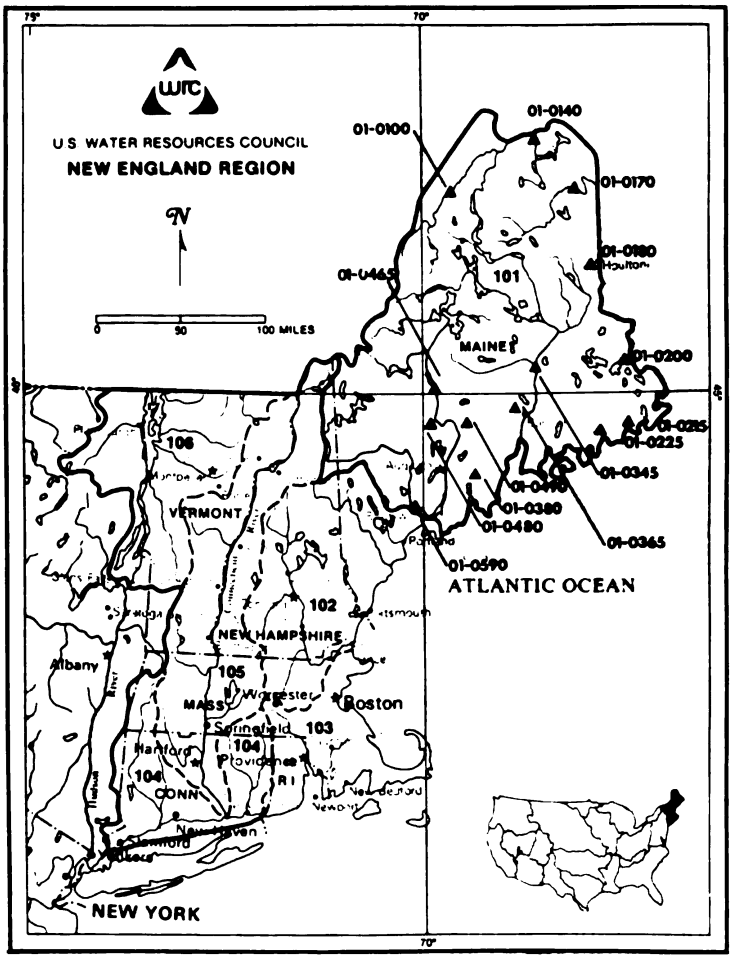

Gages Used – Selected Statistics

GAGE NUMBER	01-0140	01-0590	01-0465	01-0345	OTHERS*
GAGE NAME	ST. JOHN RIVER AT FT. KENT, MAINE	ANDROSCOGGIN R. NEAR AUBURN, MAINE	KENNEBEC RIVER AT BINGHAM, MAINE	PENOBSCOT RIVER AT WEST ENFIELD, MAINE	---
PERIOD OF RECORD	1927-1977	1930-1977	1908-1977	1903-1977	---
DRAINAGE AREA (SQ. MI.)	5,690	3,257	2,710	6,600	6,545
AVERAGE FLOW	6,210	3,950	2,860	7,640	7,380
MAXIMUM 1-MONTH	44,100	21,100	14,300	32,600	46,100
MINIMUM 1-MONTH (MGD)	363	1,130	481	1,160	493
RATIO USED TO COMPUTE ASR OUTFLOW	1.37	1.00	1.10	1.00	---

*01-0100, 01-0170, 01-0180, 01-0200, 01-0215, 01-0225, 01-0365, 01-0380, 01-0480, 01-0490

Figure 1. Sample for Subregion 101 — Appendix V, "Streamflow Conditions"

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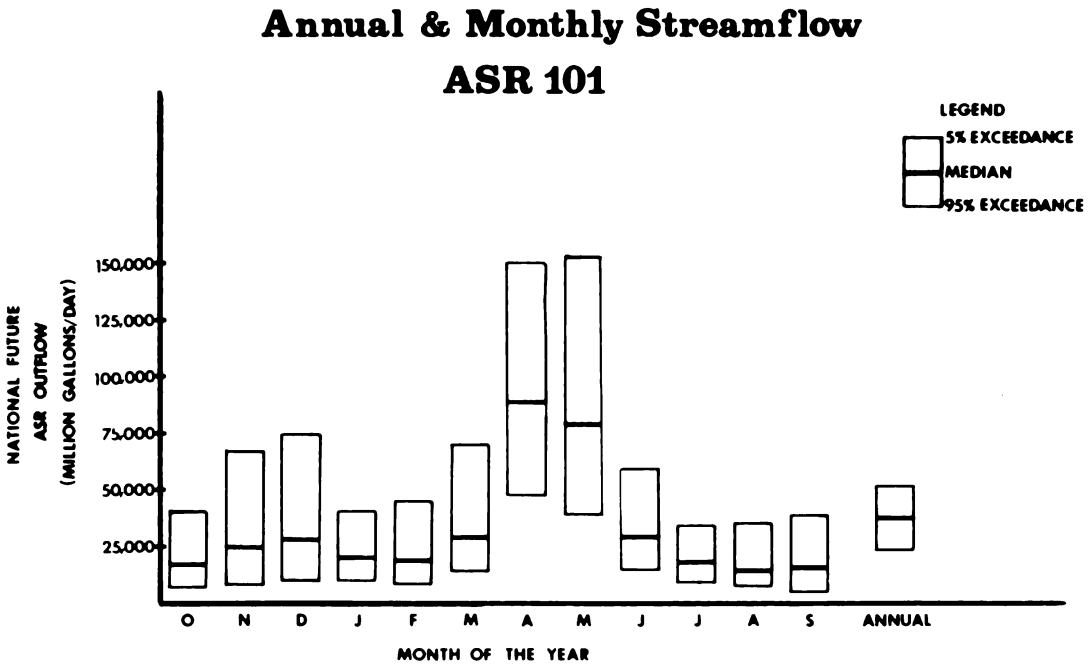

ASSESSMENT SUBREGION (ASR) 101

STATE–REGIONAL FUTURE (SRF) AND NATIONAL FUTURE (NF) OUTFLOWS (MGD)

	MEAN VALUES		NF EXCEEDANCE FREQUENCIES			
	SRF	NF	5%	50%	80%	95%
OCTOBER	22200	22200	42400	18200	11600	7690
NOVEMBER	32800	32800	67800	25700	15300	9310
DECEMBER	36100	36100	75200	29100	17500	10700
JANUARY	25300	25300	42300	22400	15400	11000
FEBRUARY	24300	24300	47100	21200	14200	9820
MARCH	34300	34300	70300	30700	21100	14900
APRIL	98200	98200	151000	90500	64600	47800
MAY	89200	89200	153000	80800	56400	39600
JUNE	33700	33700	60100	30600	21400	15400
JULY	20400	20400	35200	18700	13600	10200
AUGUST	18800	18800	36300	16400	11500	8530
SEPTEMBER	19400	19400	39300	15900	10300	6980
NF ANNUAL	–	37900	52500	38100	31000	24700
SRF ANNUAL	37900	–	"	"	"	"

CRITICAL PERIOD ANALYSIS 1903–1977

EXTREME RUNOFF VOLUMES
EXPRESSED AS AVERAGE FLOWS FOR THE PERIOD INDICATED (MGD)

	1–MO	6–MO	18–MO	30–MO	54–MO	90–MO
MAXIMUM	168000	79300	61600	55500	50000	46600
MINIMUM	5730	8540	22000	25100	29300	32700

TREND: INSIGNIFICANT

FOOTNOTE: VALUES ROUNDED TO THREE SIGNIFICANT FIGURES

Figure 1. Sample for Subregion 101 — Appendix V, "Streamflow Conditions" continued)

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ASSUMPTIONS AND METHODOLOGY

Scope of the Assessment Information

The Second National Water Assessment and its information base constitute a major step in the identification and definition of water-resources problems by the many State, regional, and Federal institutions involved. However, much of the information in this assessment is general and broad in scope; thus, its application should be viewed in that context, particularly in the area of water quality. Further, the information reflects areas of deficiencies in availability and reliability of data. For these reasons, State, regional, and Federal planners should view the information as indicative, but not the only source to be considered. When policy decisions are to be made, the effects at State, regional, and local levels should be considered.

In a national study it is difficult to reflect completely the regional variations within the national aggregation. For example, several regional reviewers did not agree with the national projections made for their regions. These disagreements can be largely attributed either to different assumptions by the regional reviewers or to lack of representation of the national information at the regional level. Therefore, any regional or State resources-management planning effort should consider the State-regional reports developed during phase II and summarized in Volume 4 as well as the nationally consistent data base and other information presented in this assessment.

Additional years of information and experience show that considerable change has occurred since the first assessment was prepared in 1968. The population has not grown at the rate anticipated, and the projections of future water requirements for this second assessment are considerably lower than those made for the first assessment. Also, greater awareness of environmental values, water quality, ground-water overdraft, limitations of available water supplies, and energy concerns are having a dramatic effect on water-resources management. Conservation, reuse, recycling, and weather modification are considerations toward making better use of, or expanding, available supplies.

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Methodology and Assumptions

The second assessment was conducted in three phases, as seen in Figure 2.

Phase I: Nationwide Analysis — The U.S. Water Resources Council member agencies researched, analyzed, and prepared estimates of current and projected water requirements and problems and the implications of the estimates for the future. The Nationwide Analysis utilized a nationally consistent set of estimates of supplies and current and future water requirements for scenarios for "1975," 1985, and 2000. These estimates were based on the following assumptions:

- The national population will grow at slightly less than 1 percent per year and will reach zero growth early in the next century. For the year 2000, this assumes 268 million people.
- The Gross National Product will increase at about 4 percent per year, doubling by the year 2000.
- The water quality goals of the Water Pollution Control Act Amendments of 1972 (Public Law 92-500) will be largely achieved by 1985.
- The attainment of goals for water quality and the higher cost for water will improve water use efficiency.
- Agricultural production and marketing will reflect recent (1971-1973) trends in per capita consumption and export levels.
- Fish and wildlife and recreation needs will continue as they have in the past 10 years.
- Increased levels of flood-plain regulations will reduce dependence on structural measures for flood control.

Phase II: Specific Problem Analysis — Regional sponsors, one for each of the 21 water resources regions, surveyed and analyzed State and regional viewpoints about (1) current and future water problems, (2) conflicts that may arise in meeting State and regional objectives, and (3) problems and conflicts needing resolution.

State-Regional Futures were prepared by regional study teams. Detailed discussions of the assumptions and methodologies used in the State-Regional Futures analyses are provided in technical memos prepared by the study teams. The general framework for each regional study was as follows:

- A problem identification survey based on regional views on population growth, economic activity, and environmental concerns was conducted.
- Problem issues and areas were selected for further evaluation.
- Information was developed to describe the severity of problem issues within selected problem areas.

Phase III: National Problem Analysis — The Water Resources Council conducted this final phase in three steps: (1) an evaluation of phases I and II; (2) an analysis that identified and evaluated the Nation's most serious water resources problems; and (3) the preparation of this final report, entitled *The Nation's Water Resources — 1975-2000.*

From the findings of the Nationwide Analysis and the Specific Problem Analysis, the Council identified and evaluated the Nation's most serious water resources problems. Where major differences between the Nationwide Analysis and the Specific Problem Analysis appeared, every effort was made to reconcile the differences. If the differences could not be satisfactorily resolved, the differences are cited appropriately in the assessment report.

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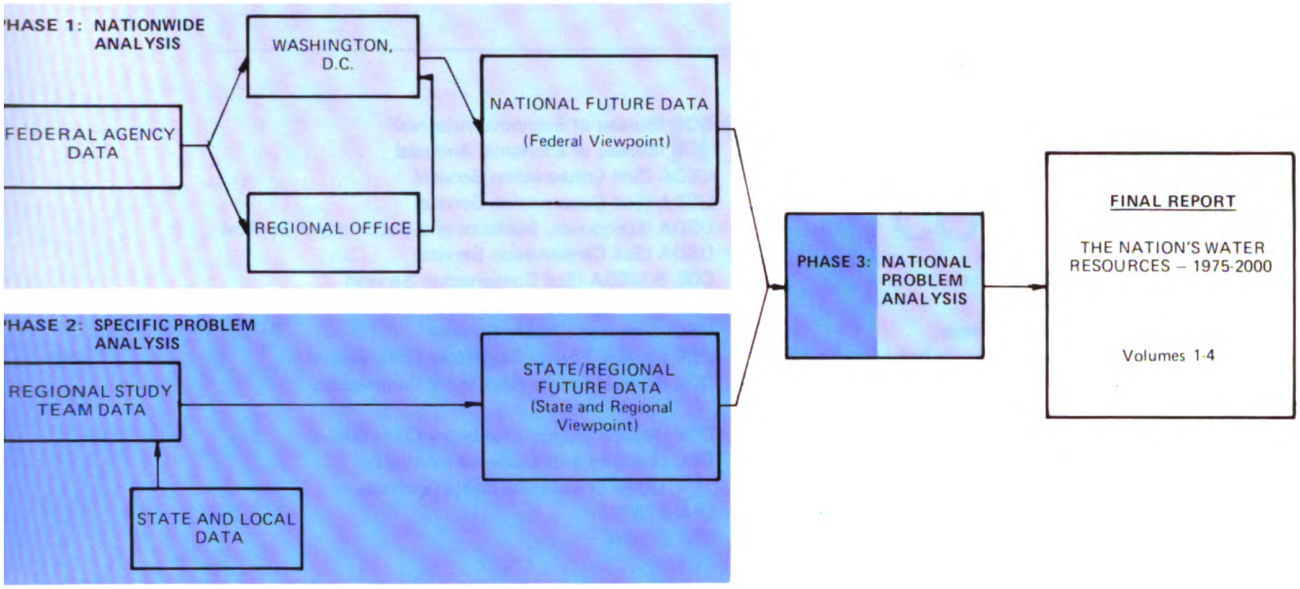

igure 2. Information Flow for the Second National Water Assessment

Data Sources and Federal Agency Responsibilities

The lead Federal agency for an assigned task assembled pertinent information, considered the assessment assumptions, developed methodologies to determine present and future conditions, and made the necessary computations and analyses.

There were extremely wide variations in (1) the type of information that was available, (2) the number and scope of assumptions that could or should be applied, and (3) the availability and the applicability of accepted or possible methodologies. It would be impractical to assemble and describe fully these procedures in a report; appropriate information is available from the Federal agencies as indicated on the following page.

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Federal Agency Responsibilities for Data

Appendix I — Social, Economic, and Environmental Data

Table I-1	population, employment, and per capita income	DOC (Bureau of Economic Analysis)
I-2	earnings by major sectors	DOC (Bureau of Economic Analysis)
I-3	surface area and land use	USDA (Soil Conservation Service)
I-4	cropland and irrigated farmland	USDA (Soil Conservation Service)
		USDA (Economics, Statistics and Cooperatives Service)
I-5	sheet erosion by source	USDA (Soil Conservation Service)
I-6	flood damages by land use	COE & USDA (Soil Conservation Service)
I-7	recreation requirements	USDI (Heritage, Conservation, and Recreation Service)
	designated wilderness areas	USDI (Fish and Wildlife Service)
I-8	electric power generation by fuel source	DOE (Federal Energy Regulatory Commission)
I-9	steam electric generating plants	DOE (Federal Energy Regulatory Commission)
I-10	residual heat discharged from steam electric generating plants	DOE (Federal Energy Regulatory Commission)
	heat discharged by manufacturing plants	DOC (Industry and Trade Administration, Office of Business Policy Analysis)
	biochemical oxygen demand (BOD)	EPA & WRC
	total suspended solids (TSS)	EPA & WRC
I-11	commercial navigation	COE

Appendix II — Annual Water Supply and Use Analysis

Table II-1	mean streamflow	USDI (U.S. Geological Survey) & WRC
	streamflow frequency analysis	WRC
	existing surface storage	COE
	normal pool surface area, ground-water storage and withdrawals	USDI (U.S. Geological Survey)
	ground-water overdraft	WRC
II-2	water imports and exports	USDI (Bureau of Reclamation)
	net evaporation - reservoirs	USDI (U.S. Geological Survey) & WRC
	net evaporation - farm/stock ponds	USDA (Soil Conservation Service) & WRC
II-3	instream flow - fish and wildlife	USDI (Fish and Wildlife Service)
	instream flow - navigation	COE
	instream flow - treaties and compacts	WRC
II-4	withdrawals and consumption for:	
	agriculture	USDA (Soil Conservation Service)
	steam electric	DOE (Federal Energy Regulatory Commission)
	manufacturing	DOC (Industry and Trade Administration, Office of Business Policy Analysis)
	domestic - central	USDI (U.S. Geological Survey) & WRC
	domestic - noncentral	USDA (Soil Conservation Service)
	commercial	WRC
	minerals	USDI (Bureau of Mines)
	public lands - BLM lands	USDI (Bureau of Land Management)
	public lands - national forests	USDA (Forest Service)
	public lands - national parks	USDI (National Park Service)
	fish hatcheries	USDI (Fish and Wildlife Service)
	total saline (withdrawals only)	DOE (Federal Energy Regulatory Commission)
		DOC (Industry and Trade Administration, Office of Business Policy Analysis)

Explanation of Agency Abbreviations

COE	Department of the Army, Corps of Engineers
DOC	Department of Commerce
DOE	Department of Energy
EPA	Environmental Protection Agency
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
WRC	Water Resources Council

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HYDROLOGIC DATA COLLECTION UNITS

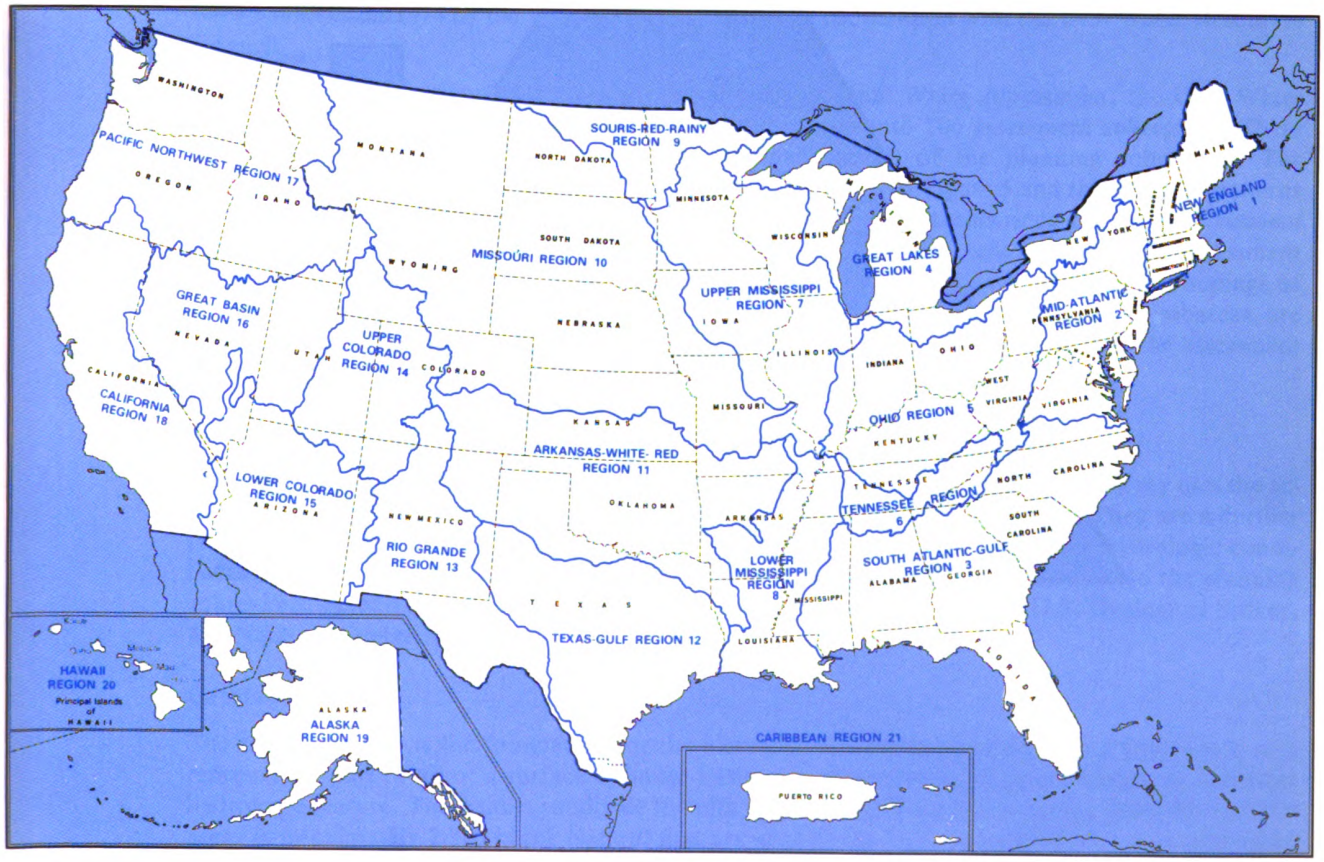

Figure 3. Water Resources Regions

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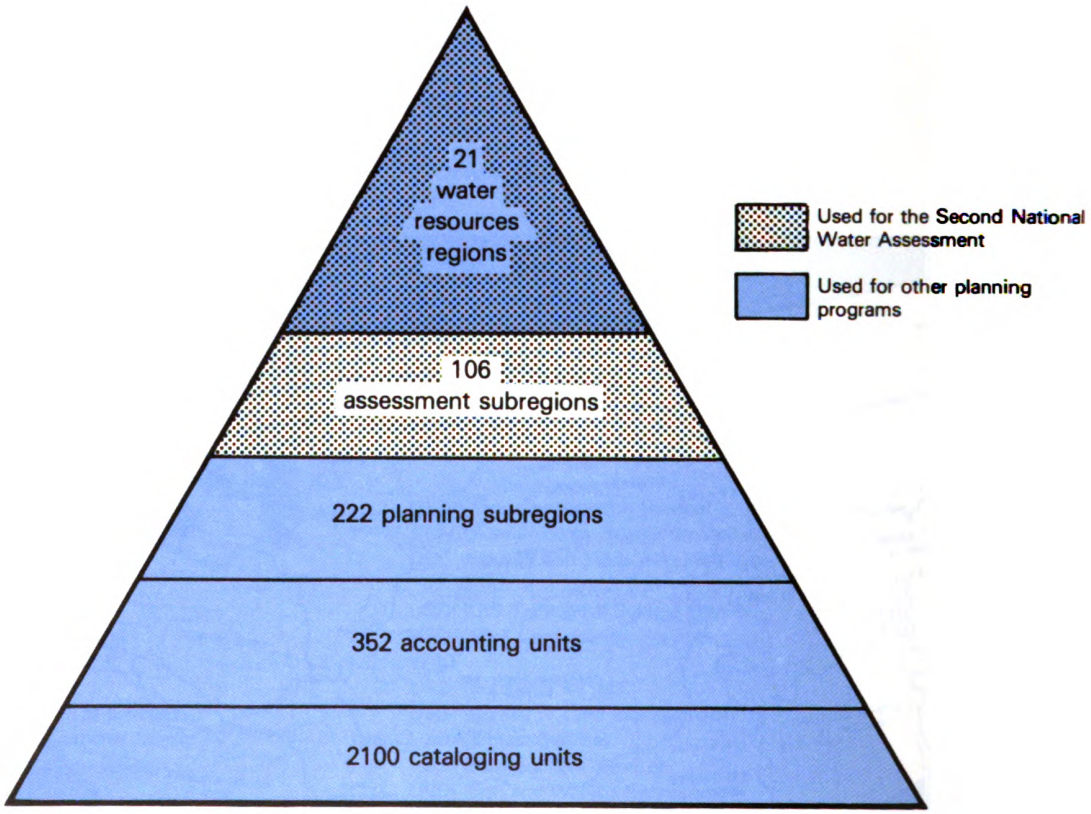

Figure 4. Hierarchy of Hydrologic Units

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Hydrologic Data Collection Units

The hierarchical structure of geographic units used to collect and organize hydrologic data is shown in Figure 4. Four basic units are used: regions, subregions, accounting units, and cataloging units.

Regions

The first level of classification divides the Nation into 21 major geographic areas — 18 in the conterminous United States and one each for Alaska, Hawaii, and the Caribbean (see Figure 3). All water resources regional boundaries are hydrologic (based on surface topography) except where discontinued at international boundaries. These hydrologic areas contain either the drainage area of a major river, such as the Missouri Region; or the combined drainage areas of a series of rivers, such as the South Atlantic-Gulf Region, which includes a number of rivers draining directly into the Atlantic Ocean or the Gulf of Mexico. The U.S. Water Resources Council designated these water resources regional boundaries in July 1970.

Subregions

The second level of classification divides the regions into 222 planning subregions. A planning subregion includes that area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area. All planning subregional boundaries are hydrologic except where discontinued at international boundaries. These planning subregions were designated by the U.S. Water Resources Council in July 1970, were reorganized in 1974, and are delineated on Hydrologic Unit Maps for each of the States. The maps were published in 1974 by the U.S. Geological Survey in cooperation with the U.S. Water Resources Council.

To simplify analysis of information for the Second National Water Assessment, the U.S. Water Resources Council reclassified the 222 planning subregions into 106 **assessment subregions.** These assessment subregions are groupings (larger drainage areas) of the planning subregions. The boundaries and names of the assessment subregions are shown in Figure 5 and the drainage patterns in Figure 6. ***Please note that the 106 assessment subregions are exclusive to the Second National Water Assessment; in this report the term "subregion" always refers to the 106 assessment subregions.*** Socioeconomic data collected for the assessment subregions was based on groupings of counties to approximate the subregion boundaries. These groupings, called assessment subareas, are shown in Figure 7. Maps showing the boundaries of the assessment subregions and the assessment subareas are available from the Water Resources Council.

Accounting Units

Although not used in the Second National Water Assessment, the U.S. Geological Survey uses the accounting units for designing and managing the National Water Data Network. They are a further refinement (subdivision) of the water resources regions based on size and unique hydrologic conditions. There are 352 hydrologic accounting units that nest within or are equivalent to the planning subregions. A map showing the accounting units can be obtained from the U.S. Geological Survey, 417 National Center, Reston, Virginia 22092.

Cataloging Units

The cataloging unit is the foundation for the hierarchy of hydrologic units. It is a geographic area representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. These units subdivide the planning subregions and accounting units into smaller areas (approximately 2,100 in the Nation) that are used by the U.S. Geological Survey in cataloging water-data acquisition activities for its "Catalog of Information on Water Data." For further information on these units, contact the U.S. Geological Survey at the above address.

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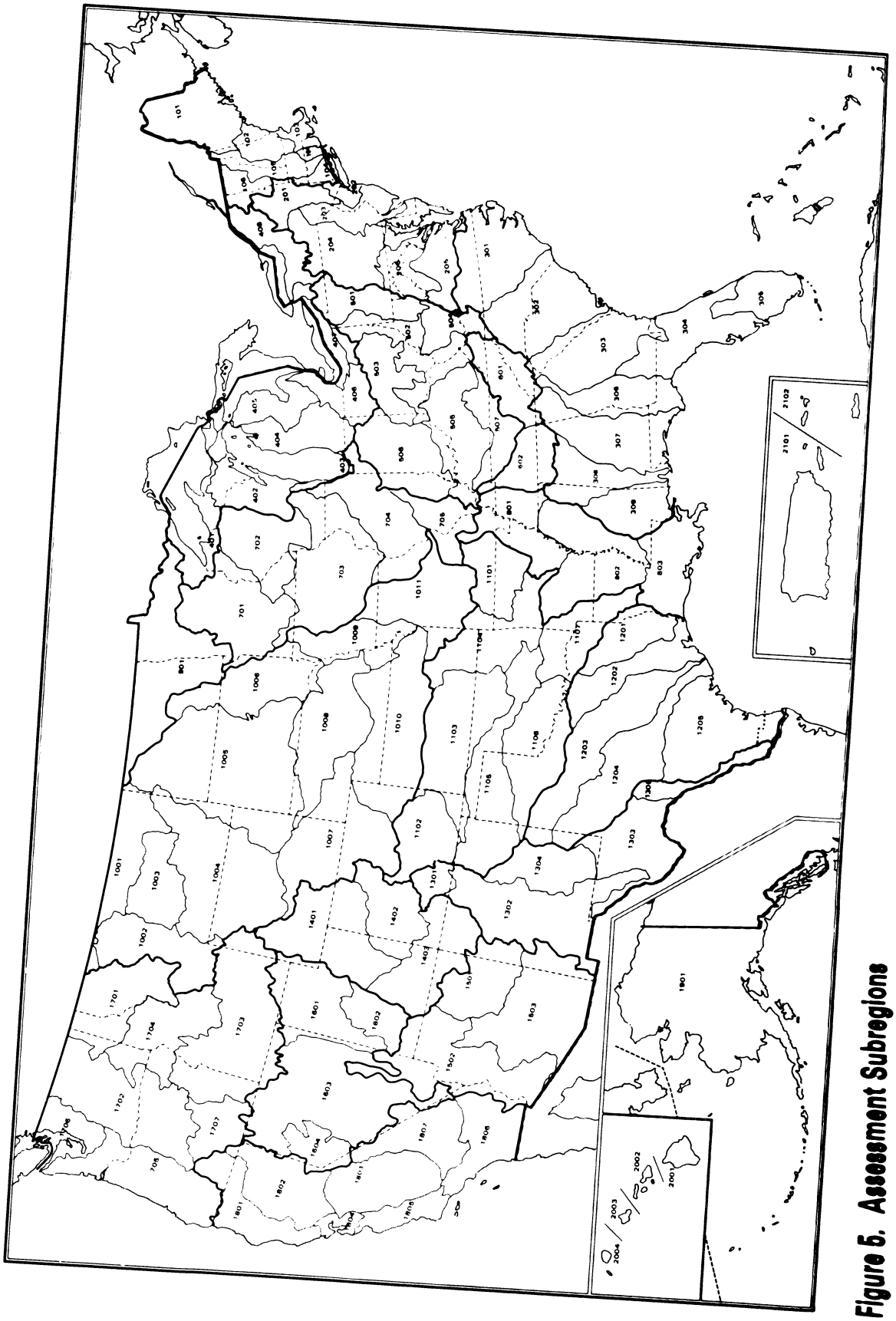

Figure 6. Assessment Subregions

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New England Region (1)

0101 Northern Maine
0102 Saco-Merrimack
0103 Massachusetts-Rhode Island Coastal
0104 Housatonic-Thames
0105 Connecticut River
0106 Richelieu

Mid Atlantic Region (2)

0201 Upper Hudson
0202 Lower Hudson-Long Island-North New Jersey
0203 Delaware
0204 Susquehanna
0205 Upper and Lower Chesapeake
0206 Potomac

South Atlantic-Gulf Region (3)

0301 Roanoke-Cape Fear
0302 Pee Dee-Edisto
0303 Savannah-St Marys
0304 St Johns-Suwannee
0305 Southern Florida
0306 Apalachicola
0307 Alabama-Choctawhatchee
0308 Mobile-Tombigbee
0309 Pascagoula-Pearl

Great Lakes Region (4)

0401 Lake Superior
0402 NW Lake Michigan
0403 SW Lake Michigan
0404 Eastern Lake Michigan
0405 Lake Huron
0406 St Clair-Western Lake Erie
0407 Eastern Lake Erie
0408 Lake Ontario

Ohio Region (5)

0501 Ohio Headwaters
0502 Upper Ohio-Big Sandy
0503 Muskingum-Scioto-Miami
0504 Kanawha
0505 Kentucky-Licking-Green-Ohio
0506 Wabash
0507 Cumberland

Tennessee Region (6)

0601 Upper Tennessee
0602 Lower Tennessee

Upper Mississippi Region (7)

0701 Mississippi Headwaters
0702 Black-Root-Chippewa-Wisconsin
0703 Rock-Mississippi-Des Moines
0704 Salt-Sny-Illinois
0705 Lower Upper Mississippi

Lower Mississippi Region (8)

0801 Hatchie-Mississippi-St Francis
0802 Yazoo-Mississippi-Ouachita
0803 Mississippi Delta

Souris-Red-Rainy Region (9)

0901 Souris-Red-Rainy

Missouri Region (10)

1001 Missouri-Milk-Saskatchewan
1002 Missouri-Marias
1003 Missouri-Musselshell
1004 Yellowstone
1005 Western Dakotas
1006 Eastern Dakotas
1007 North and South Platte
1008 Niobrara-Platte-Loup
1009 Middle Missouri
1010 Kansas
1011 Lower Missouri

Arkansas-White-Red Region (11)

1101 Upper White
1102 Upper Arkansas
1103 Arkansas-Cimarron
1104 Lower Arkansas
1105 Canadian
1106 Red-Washita
1107 Red-Sulphur

Texas-Gulf Region (12)

1201 Sabine-Neches
1202 Trinity-Galveston Bay
1203 Brazos
1204 Colorado (Texas)
1205 Nueces-Texas Coastal

Rio Grande Region (13)

1301 Rio Grande Headwaters
1302 Middle Rio Grande
1303 Rio Grande-Pecos
1304 Upper Pecos
1305 Lower Rio Grande

Upper Colorado Region (14)

1401 Green-White-Yampa
1402 Colorado-Gunnison
1403 Colorado-San Juan

Lower Colorado Region (15)

1501 Little Colorado
1502 Lower Colorado Main Stem
1503 Gila

Great Basin Region (16)

1601 Bear-Great Salt Lake
1602 Sevier Lake
1603 Humboldt-Tonopah Desert
1604 Central Lahontan

Pacific Northwest Region (17)

1701 Clark Fork-Kootenai
1702 Upper / Middle Columbia
1703 Upper / Central Snake
1704 Lower Snake
1705 Coast-Lower Columbia
1706 Puget Sound
1707 Oregon Closed Basin

California Region (18)

1801 Klamath-North Coastal
1802 Sacramento-Lahontan
1803 San Joaquin-Tulare
1804 San Francisco Bay
1805 Central California Coast
1806 Southern California
1807 Lahontan-South

Alaska Region (19)

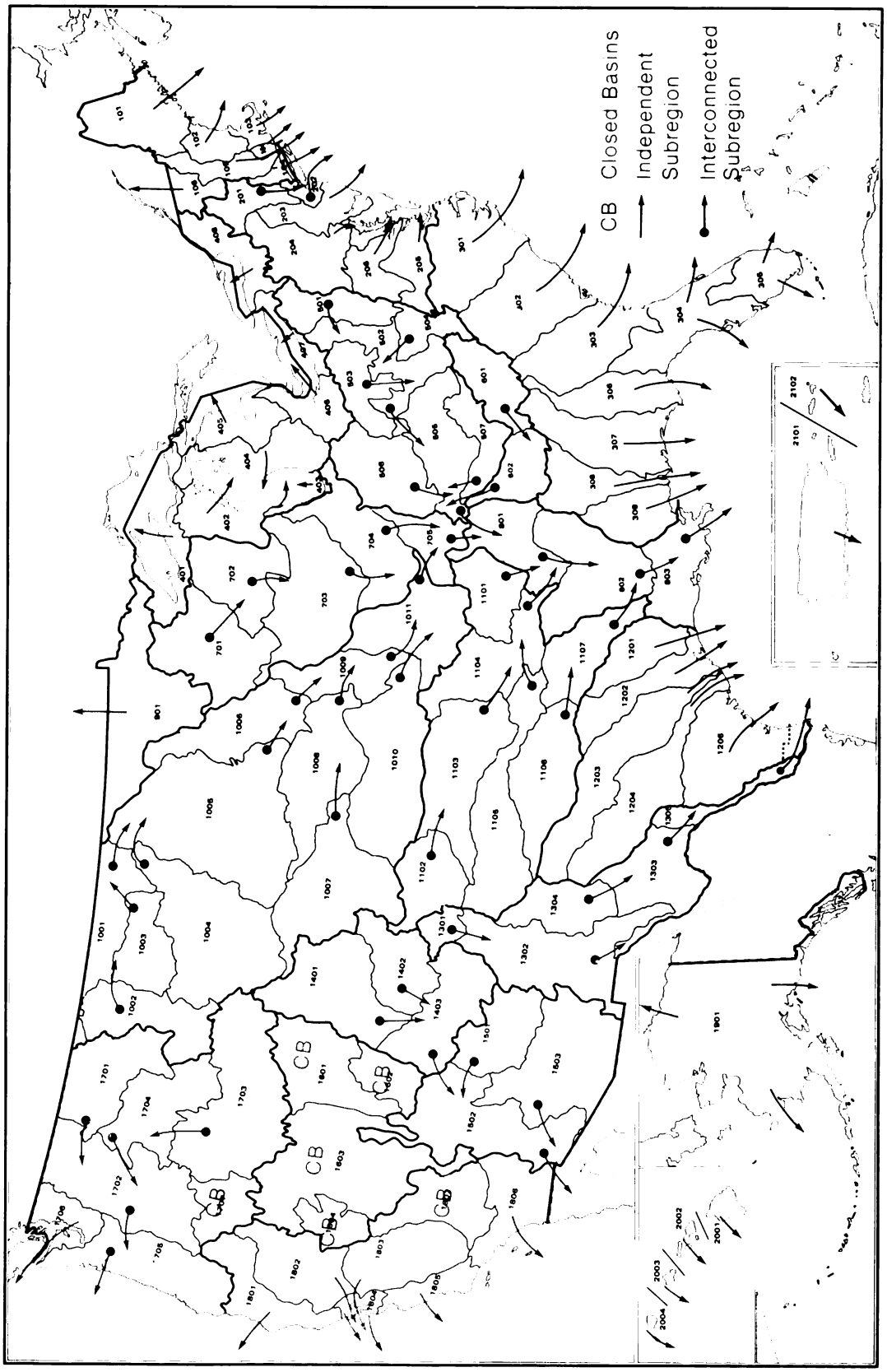
1901 Alaska

Hawaii Region (20)

2001 Hawaii County
2002 Maui County
2003 Honolulu County
2004 Kauai County

Caribbean Region (21)

2101 Puerto Rico
2102 Virgin Islands



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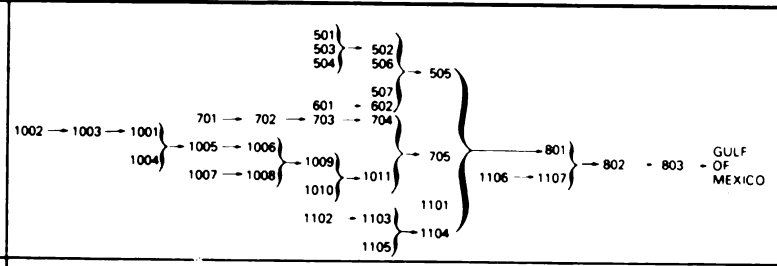
REGIONS	SUBREGIONS NETWORK
NEW ENGLAND REGION (1)	101 → ATLANTIC OCEAN 102 → ATLANTIC OCEAN 103 → ATLANTIC OCEAN 104 → ATLANTIC OCEAN 105 → ATLANTIC OCEAN 106 → CANADA
MID ATLANTIC REGION (2)	201 → 202 → ATLANTIC OCEAN 203 → ATLANTIC OCEAN 204 → CHESAPEAKE BAY/ATLANTIC OCEAN 205 → CHESAPEAKE BAY/ATLANTIC OCEAN 206 → CHESAPEAKE BAY/ATLANTIC OCEAN
SOUTH ATLANTIC GULF REGION (3)	301 → ATLANTIC OCEAN 302 → ATLANTIC OCEAN 303 → ATLANTIC OCEAN 304 → ATLANTIC OCEAN/GULF OF MEXICO 305 → ATLANTIC OCEAN/GULF OF MEXICO 306 → GULF OF MEXICO 307 → GULF OF MEXICO 308 → GULF OF MEXICO 309 → GULF OF MEXICO
GREAT LAKES REGION (4)	401 → LAKE SUPERIOR 402 → LAKE MICHIGAN 403 → LAKE MICHIGAN 404 → LAKE MICHIGAN 405 → LAKE HURON 406 → LAKE ERIE 407 → LAKE ERIE 408 → LAKE ONTARIO
OHIO REGION (5)	501, 503, 504 → 502; 502, 506, 507 → 505 → 801
TENNESSEE REGION (6)	601 → 602 → 505
UPPER MISSISSIPPI REGION (7)	701 → 702 → 703 → 704 → 705 → 801
LOWER MISSISSIPPI REGION (8)	801 → 802 → 803 → GULF OF MEXICO
SOURIS-RED-RAINY REGION (9)	901 → CANADA
MISSOURI REGION (10)	1002 → 1003 → 1001, 1004 → 1005 → 1006, 1007 → 1008 → 1009, 1010 → 1011 → 705

REGIONS	SUBREGIONS NETWORK
ARKANSAS WHITE RED REGION (11)	1101 → 801 1102 → 1103, 1105 → 1104 → 801 1106 → 1107 → 802
TEXAS GULF REGION (12)	1201 → GULF OF MEXICO 1202 → GULF OF MEXICO 1203 → GULF OF MEXICO 1204 → GULF OF MEXICO 1205 → GULF OF MEXICO
RIO GRANDE REGION (13)	1301 → 1302, 1304 → 1303 → 1305 → GULF OF MEXICO
UPPER COLORADO REGION (14)	1401, 1402 → 1403 → 1502
LOWER COLORADO REGION (15)	1501, 1503 → 1502 → MEXICO
GREAT BASIN REGION (16)	CLOSED BASINS 1601, 1602, 1603, 1604
PACIFIC NORTHWEST REGION (17)	CLOSED BASINS 1707 1706 → PUGET SOUND/PACIFIC OCEAN 1701, 1703 → 1702 → 1705 → PACIFIC OCEAN
CALIFORNIA SOUTH PACIFIC REGION (18)	CLOSED BASINS 1807 1801 → PACIFIC OCEAN 1802 → SAN FRANCISCO BAY/PACIFIC OCEAN 1803 → SAN FRANCISCO BAY/PACIFIC OCEAN 1804 → SAN FRANCISCO BAY/PACIFIC OCEAN 1805 → PACIFIC OCEAN 1806 → PACIFIC OCEAN
ALASKA REGION (19)	1901 → ARTIC OCEAN/GULF OF ALASKA/BERING SEA
HAWAII REGION (20)	2001 → PACIFIC OCEAN 2002 → PACIFIC OCEAN 2003 → PACIFIC OCEAN 2004 → PACIFIC OCEAN
CARIBBEAN REGION (21)	2101 → ATLANTIC OCEAN 2102 → ATLANTIC OCEAN

MAJOR DRAINAGE BASINS	SUBREGIONS NETWORK
MISSISSIPPI DRAINAGE BASIN OHIO REGION (5) TENNESSEE REGION (6) UPPER MISSISSIPPI REGION (7) LOWER MISSISSIPPI REGION (8) MISSOURI REGION (10) ARKANSAS-WHITE-RED REGION (11)	
COLORADO DRAINAGE BASIN UPPER COLORADO REGION (14) LOWER COLORADO REGION (15)	1401, 1402 → 1403, 1501, 1503 → 1502 → MEXICO

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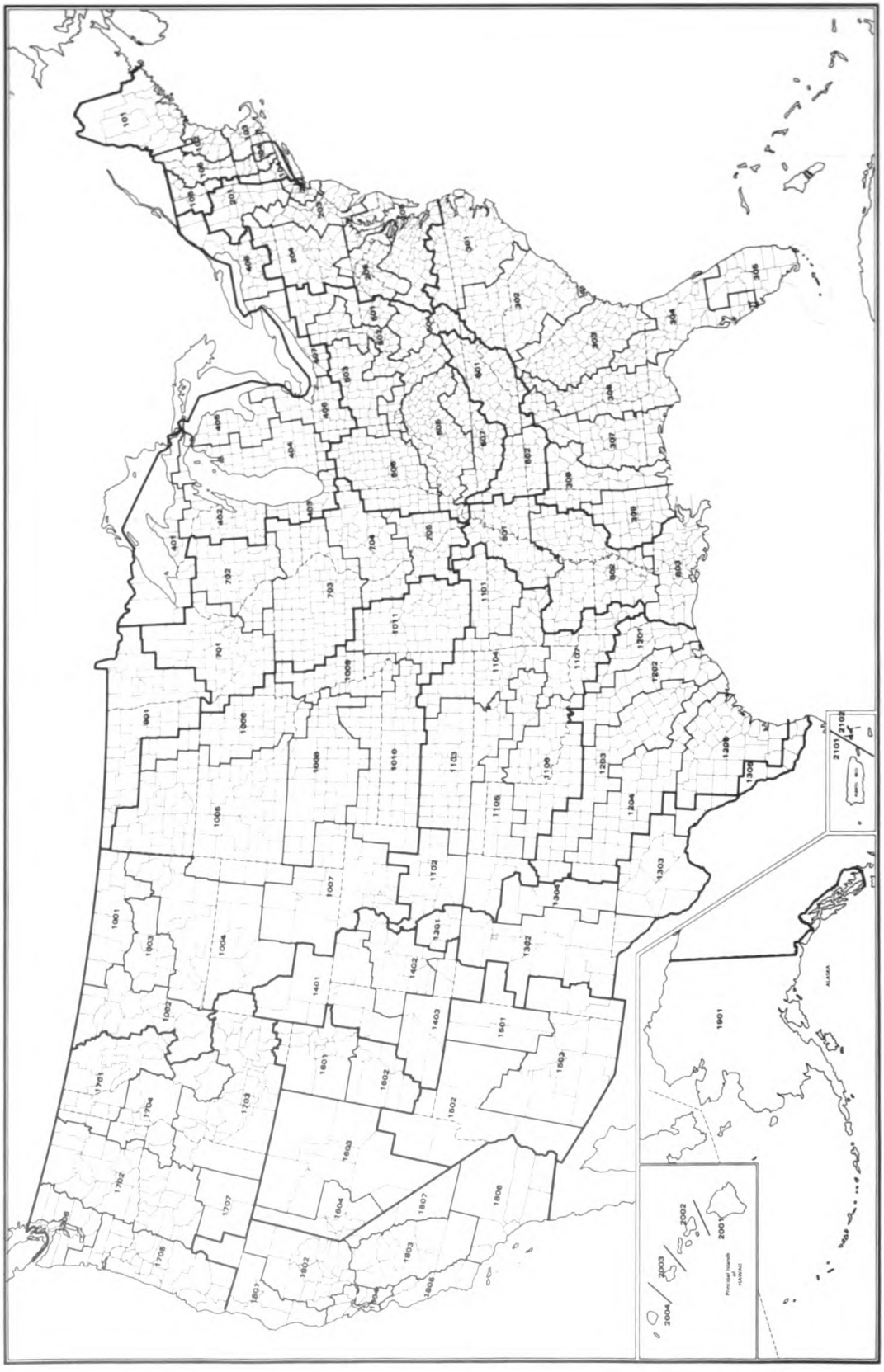

Figure 7. Assessment Subareas
(... of assessment subregions)

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NATIONAL SUMMARY OF ANALYTICAL DATA

Abbreviations Used in Volume 3 Tables

AC – acres
AGR. – agriculture, agricultural
ATLANT. – Atlantic
BASE) – base conditions
BGD – billion gallons per day
BIL GAL – billion gallons
BOD – biochemical oxygen demand
CLS.BSN – closed basin (terminal lakes)
DEPLETN – depletion
DEV. LAND – developed land
DRY) – dry conditions
ELECT. – electric
EVAP. – evaporation
FISH HATCH. – Federal fish hatcheries
GEN. – generation
GRND WTR – ground water
GT.LKS – Great Lakes
G.W. – ground water
HATCH. – hatcheries
HYDRO. UNIT – hydrologic unit; refers to a region or subregion
IFA – instream flow approximation
IN HYDRO. UNIT – within the region or subregion (hydrologic unit)
LBS. – pounds
MANUFACT. – manufacturing
MAX. – maximum
MFG – manufacturing
MGD – million gallons per day
MISC. – miscellaneous
N/A – not available; note that if information is not available for one subregion, the regional and national totals will usually be N/A
N/C – not calculated; usually due to dividing by zero
NAT. FLOW DEPLETN – natural flow depletion
NAT. FORESTS – National Forests
NAT. PARKS – National Parks
NF – National Future; see glossary
NO. – number
OUTFLW PT. – outflow point
OVRDRFT – overdraft
PRIM.METALS – primary metals
SIC – Standard Industrial Classification coding system for manufacturing and other industries; see Figure 8
SRF – State-Regional Future; see glossary
STRMFLW – streamflow
TOT. – total
TRANSPORT. – transportation
TRIL GAL – trillion gallons
TSS – total suspended solids
WITHDRAW – withdrawal
WITHIN HYDRO.UNIT – within the region or subregion (hydrologic unit)
YR – year

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TABLE I-1 POPULATION, EMPLOYMENT, AND INCOME

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL POPULATION THOUSANDS "1975"	1985	2000	POPULATION CHANGE PERCENT 1975-1985	1975-2000	POPULATION DENSITY PER SQ MI OF LAND AREA "1975"	1985	2000
NEW ENGLAND	1	NF	12492	13613	15313	9%	23%	192	209	235
		SRF	12380	13442	14965	"	21%	190	206	230
MID-ATLANTIC	2	NF	39612	43873	49939	11%	26%	395	438	498
		SRF	38933	42265	46709	9%	20%	388	422	466
SOUTH ATLANTIC-GULF	3	NF	25423	29334	34680	15%	36%	98	113	133
		SRF	26164	30736	36761	17%	41%	102	119	143
GREAT LAKES	4	NF	30391	32855	36351	8%	20%	233	252	279
		SRF	"	"	"	"	"	"	"	"
OHIO	5	NF	21158	22722	24791	7%	17%	133	143	156
		SRF	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	3565	4034	4615	13%	29%	86	97	111
		SRF	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	13387	14408	15822	8%	18%	76	82	90
		SRF	13228	14096	15716	7%	19%	75	80	89
LOWER MISSISSIPPI	8	NF	6417	6767	7142	5%	11%	64	67	71
		SRF	6536	7094	8156	9%	25%	67	73	84
SOURIS-RED-RAINY	9	NF	649	625	595	-4%	-8%	12	12	11
		SRF	"	"	"	"	"	"	"	"
MISSOURI	10	NF	8832	9298	10044	5%	14%	17	18	20
		SRF	9066	10046	11762	11%	30%	18	20	23
ARKANSAS-WHITE-RED	11	NF	6846	7268	7815	6%	14%	28	30	32
		SRF	7350	8321	9819	13%	34%	31	35	41
TEXAS-GULF	12	NF	9911	11162	12907	13%	30%	57	64	74
		SRF	10233	12470	15990	22%	56%	59	72	92
RIO GRANDE	13	NF	1695	1780	1875	5%	11%	12	13	14
		SRF	1868	2678	3630	43%	94%	14	20	27
UPPER COLORADO	14	NF	344	357	368	4%	7%	3	3	4
		SRF	431	523	670	21%	55%	4	5	7
LOWER COLORADO	15	NF	2412	2915	3629	21%	50%	16	19	24
		SRF	2683	3740	5071	39%	89%	17	24	33
GREAT BASIN	16	NF	1262	1464	1739	16%	38%	9	11	13
		SRF	1374	1781	2448	30%	78%	10	12	17
PACIFIC NORTHWEST	17	NF	6703	6991	7589	4%	13%	25	26	28
		SRF	6783	8089	9780	19%	44%	"	30	37
CALIFORNIA	18	NF	21160	23703	27093	12%	28%	130	146	167
		SRF	21168	24422	29344	15%	39%	131	152	182
ALASKA	19	NF	307	361	438	18%	43%	1	1	1
		SRF	409	606	992	48%	143%	"	"	2
HAWAII	20	NF	787	911	1085	16%	38%	123	142	170
		SRF	865	1058	1355	22%	57%	131	160	205
CARIBBEAN	21	NF	3052	3614	4234	18%	39%	859	1018	1192
		SRF	"	"	"	"	"	874	1035	1212
NATIONAL TOTAL REGIONS 1-18		NF	212259	233169	262307	10%	24%	72	79	88
		SRF	213960	239939	277173	12%	30%	"	81	93
NATIONAL TOTAL REGIONS 1-21		NF	216405	238055	268064	10%	24%	61	67	76
		SRF	218286	245217	283754	12%	30%	"	69	80

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TABLE I-1 POPULATION, EMPLOYMENT, AND INCOME (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL EMPLOYMENT THOUSANDS "1975"	1985	2000	EMPLOYMENT CHANGE PERCENT 1975-1985	1975-2000	PER CAPITA INCOME DOLLARS (1975$) "1975"	1985	2000
NEW ENGLAND	1	NF	5460	6204	7209	14%	32%	6669	8925	13339
		SRF	"	"	"	"	"	N/A	N/A	N/A
MID-ATLANTIC	2	NF	17097	19730	23307	15%	36%	7133	9399	13864
		SRF	17108	"	"	"	"	6170	9285	13530
SOUTH ATLANTIC-GULF	3	NF	10345	12282	14727	19%	42%	5269	7128	10962
		SRF	10518	12682	15542	21%	48%	5350	7190	11053
GREAT LAKES	4	NF	12796	14446	16583	13%	30%	6773	9049	13495
		SRF	"	"	"	"	"	"	"	"
OHIO	5	NF	8313	9429	10838	13%	30%	5645	7633	11712
		SRF	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	1359	1617	1943	19%	43%	4548	6299	9912
		SRF	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	5615	6325	7202	13%	28%	6218	8317	12529
		SRF	"	"	"	"	"	6854	9262	13641
LOWER MISSISSIPPI	8	NF	2285	2553	2863	12%	25%	4783	6500	10187
		SRF	2330	2572	3043	10%	31%	4720	6641	10147
SOURIS-RED-RAINY	9	NF	241	244	246	1%	2%	5001	6632	10346
		SRF	"	"	"	"	"	"	"	"
MISSOURI	10	NF	3695	4084	4573	11%	24%	5954	7933	12051
		SRF	3936	5061	5759	29%	46%	5027	8087	12382
ARKANSAS-WHITE-RED	11	NF	2670	2987	3369	12%	26%	5237	7052	10904
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TEXAS-GULF	12	NF	4109	4827	5767	17%	40%	5802	7778	11792
		SRF	4022	5180	6769	29%	68%	5620	7797	11787
RIO GRANDE	13	NF	599	659	732	10%	22%	4761	6377	9920
		SRF	620	792	1017	28%	64%	4272	N/A	N/A
UPPER COLORADO	14	NF	128	140	150	9%	17%	5044	6701	10377
		SRF	168	205	280	22%	67%	4829	6577	10026
LOWER COLORADO	15	NF	940	1165	1466	24%	56%	5819	7604	11162
		SRF	1031	1491	2044	45%	98%	5813	7614	11169
GREAT BASIN	16	NF	517	626	767	21%	48%	5628	7544	11465
		SRF	550	756	1058	37%	92%	6063	7860	11251
PACIFIC NORTHWEST	17	NF	2642	2958	3345	12%	27%	5934	8110	12272
		SRF	2440	2931	3607	20%	48%	5511	8120	12298
CALIFORNIA	18	NF	8828	10226	12080	16%	37%	6986	9144	13524
		SRF	8894	10604	13093	19%	47%	6969	9098	13431
ALASKA	19	NF	135	164	205	21%	52%	7555	9719	14307
		SRF	186	267	426	44%	129%	7579	9658	14257
HAWAII	20	NF	365	431	519	18%	42%	7208	9259	13529
		SRF	347	451	599	30%	73%	6659	8891	12571
CARIBBEAN	21	NF	809	1010	1190	25%	47%	3225	N/A	N/A
		SRF	"	"	"	"	"	3221	"	"
NATIONAL TOTAL REGIONS 1-18		NF	87639	100502	117167	15%	34%	6233	8318	12511
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	88948	102107	119081	15%	34%	6195	N/A	N/A
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	"	"

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TABLE I-2 EARNINGS BY MAJOR SECTORS

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL EARNINGS MILLIONS (1975$) "1975"	1985	2000	CHANGE IN TOTAL EARNINGS PERCENT 1975-1985	1975-2000	MANUFACTURING EARNINGS MILLIONS (1975$) "1975"	1985	2000
NEW ENGLAND	1	NF	63560	91999	153447	45%	141%	18558	24538	35403
		SRF	53125	76851	128102	"	"	N/A	N/A	N/A
MID-ATLANTIC	2	NF	222633	323088	540139	45%	143%	52528	71293	105598
		SRF	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	104884	159742	281453	52%	168%	25954	38949	64366
		SRF	108230	167451	300548	55%	178%	26484	39105	64720
GREAT LAKES	4	NF	167825	238640	386985	42%	131%	62655	85076	126510
		SRF	"	"	"	"	"	"	"	"
OHIO	5	NF	94992	136344	225192	44%	137%	32025	44877	69438
		SRF	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	12873	19915	35363	55%	175%	4519	6927	11560
		SRF	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	65300	92961	151971	42%	133%	18481	26084	40235
		SRF	71279	90104	163774	26%	130%	20327	28387	43477
LOWER MISSISSIPPI	8	NF	23884	33888	55441	42%	132%	5158	7680	12579
		SRF	24837	38296	64426	54%	159%	5301	8230	14043
SOURIS-RED-RAINY	9	NF	2442	3094	4562	27%	87%	227	319	486
		SRF	"	"	"	"	"	"	"	"
MISSOURI	10	NF	40965	56924	92442	39%	126%	6791	9643	15521
		SRF	"	"	"	"	"	"	"	"
ARKANSAS-WHITE-RED	11	NF	26965	38265	63159	42%	134%	5425	8057	13334
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TEXAS-GULF	12	NF	45824	68365	118193	49%	158%	9589	14373	23759
		SRF	43804	73697	141543	68%	223%	9706	16173	29675
RIO GRANDE	13	NF	6349	8826	14276	39%	125%	567	854	1408
		SRF	5766	8860	14785	54%	156%	535	872	1568
UPPER COLORADO	14	NF	1332	1818	2874	36%	116%	77	113	186
		SRF	1606	2656	5139	65%	220%	96	111	202
LOWER COLORADO	15	NF	11267	17554	31614	56%	181%	1539	2450	4254
		SRF	12687	22572	43627	78%	244%	1708	2869	5655
GREAT BASIN	16	NF	5991	9137	16123	53%	169%	787	1142	1829
		SRF	7030	11908	23771	69%	238%	1089	1791	3673
PACIFIC NORTHWEST	17	NF	30918	43610	70840	41%	129%	6814	9383	14125
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CALIFORNIA	18	NF	115392	167271	279441	45%	142%	25141	35251	53916
		SRF	115189	171021	300561	48%	161%	24983	35644	57120
ALASKA	19	NF	2152	3164	5453	47%	153%	144	207	330
		SRF	3097	5855	14142	89%	357%	N/A	N/A	N/A
HAWAII	20	NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"
CARIBBEAN	21	NF	7674	N/A	N/A	N/A	N/A	2908	N/A	N/A
		SRF	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	1043396	1511441	2523515	45%	142%	276835	387009	594507
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"

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TABLE I-2 EARNINGS BY MAJOR SECTORS (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION			AGRICULTURE EARNINGS MILLIONS (1975$) "1975"	1985	2000	MINING EARNINGS MILLIONS (1975$) "1975"	1985	2000	OTHER EARNINGS MILLIONS (1975$) "1975"	1985	2000
NEW ENGLAND	1	NF	726	722	835	59	76	100	44217	66663	117109
		SRF	440	422	511	"	"	"	N/A	N/A	N/A
MID-ATLANTIC	2	NF	1938	1935	2258	396	447	560	167771	249413	431723
		SRF	"	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	4583	4628	5504	444	543	709	73903	115622	210874
		SRF	4575	5001	5964	449	534	711	76742	122811	229153
GREAT LAKES	4	NF	2044	1980	2255	573	661	797	102553	150923	257423
		SRF	"	"	"	"	"	"	"	"	"
OHIO	5	NF	2494	2433	2800	2486	2623	3367	57987	86411	149587
		SRF	"	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	439	423	484	198	228	311	7717	12337	23008
		SRF	"	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	4646	4638	5461	414	459	585	41759	61780	105690
		SRF	5294	5264	6149	428	478	609	45230	55975	113539
LOWER MISSISSIPPI	8	NF	2309	2286	2670	737	843	980	15680	23079	39212
		SRF	1715	1688	2013	731	846	1001	17090	27532	47369
SOURIS-RED-RAINY	9	NF	514	500	583	6	6	6	1695	2269	3487
		SRF	"	"	"	"	"	"	"	"	"
MISSOURI	10	NF	4386	4378	5159	416	491	597	29372	42412	71165
		SRF	"	"	"	"	"	"	"	"	"
ARKANSAS-WHITE-RED	11	NF	1937	1868	2139	801	828	879	18802	27512	46807
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TEXAS-GULF	12	NF	1738	1690	1934	1355	1485	1656	33142	50817	90844
		SRF	1682	1769	2201	1324	1550	1898	31092	54205	107769
RIO GRANDE	13	NF	538	549	653	151	155	163	5093	7268	12052
		SRF	468	595	794	208	282	364	4555	7111	12059
UPPER COLORADO	14	NF	154	160	200	146	164	206	955	1381	2282
		SRF	157	172	219	190	496	976	1163	1877	3742
LOWER COLORADO	15	NF	450	447	531	448	574	772	8830	14083	26057
		SRF	456	477	543	449	575	774	10074	18651	36655
GREAT BASIN	16	NF	187	187	224	183	219	278	4834	7589	13792
		SRF	256	383	632	189	373	536	5496	9361	18930
PACIFIC NORTHWEST	17	NF	1453	1427	1647	150	167	198	22501	32633	54870
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CALIFORNIA	18	NF	3456	3447	4055	483	522	578	86312	128051	220892
		SRF	3536	3794	4912	494	556	672	86176	131027	237857
ALASKA	19	NF	28	34	44	55	86	138	1925	2837	4941
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"	"
CARIBBEAN	21	NF	302	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	33992	33698	39392	9446	10491	12742	723123	1080243	1876874
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"	"

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TABLE I-3 SURFACE AREA AND LAND USE - 1975 PAGE 25

(REGIONS 1-21) NATIONAL SUMMARY

REGION			SURFACE AREA 1,000 ACRES TOTAL	WATER	LAND	LAND USE 1,000 ACRES CROPLAND	PASTURE +RANGE	FOREST+ WOODLAND	OTHER AGR	URBAN	OTHER
NEW ENGLAND	1	NF	44162	2458	41704	2769	957	32582	617	2705	2074
		SRF	–	–	41666	"	–	–	–	"	–
MID-ATLANTIC	2	NF	66139	1977	64162	11688	4939	35466	2059	4418	5592
		SRF	–	–	"	"	–	–	–	"	–
SOUTH ATLANTIC-GULF	3	NF	173630	6807	166823	25259	15344	105334	4293	4747	11846
		SRF	–	–	164956	"	–	–	–	"	–
GREAT LAKES	4	NF	85871	2526	83345	24907	3358	39152	4778	4333	6817
		SRF	–	–	"	"	–	–	–	"	–
OHIO	5	NF	102436	943	101493	32877	13995	43143	3011	3351	5116
		SRF	–	–	"	"	–	–	–	"	–
TENNESSEE	6	NF	27290	675	26615	4431	3532	14404	908	668	2672
		SRF	–	–	"	"	–	–	–	"	–
UPPER MISSISSIPPI	7	NF	115631	2687	112944	64062	11644	24473	3643	2151	6971
		SRF	–	–	113466	"	–	–	–	5896	–
LOWER MISSISSIPPI	8	NF	67292	2783	64509	20409	9928	27099	3828	895	2350
		SRF	–	–	62471	22138	–	–	–	2408	–
SOURIS-RED-RAINY	9	NF	35021	1232	33789	20791	3376	6831	681	70	2040
		SRF	–	–	33895	"	–	–	–	925	–
MISSOURI	10	NF	327133	3399	323734	105660	161774	29937	4006	1397	20960
		SRF	–	–	"	"	–	–	–	"	–
ARKANSAS-WHITE-RED	11	NF	156163	1855	154308	44480	66559	33545	2244	1636	5844
		SRF	–	–	154226	42053	–	–	–	N/A	–
TEXAS-GULF	12	NF	113726	2692	111034	25021	58632	20176	2160	2485	2560
		SRF	–	–	111291	N/A	–	–	–	N/A	–
RIO GRANDE	13	NF	87764	542	87222	2869	63190	15048	611	396	5108
		SRF	–	–	86935	2216	–	–	–	N/A	–
UPPER COLORADO	14	NF	65848	558	65290	1951	35369	17881	415	47	9627
		SRF	–	–	65521	N/A	–	–	–	N/A	–
LOWER COLORADO	15	NF	99103	456	98647	1485	52243	26749	2732	621	14817
		SRF	–	–	"	"	–	–	–	608	–
GREAT BASIN	16	NF	89181	1760	87421	2623	61269	12251	267	378	10633
		SRF	–	–	91799	3285	–	–	–	"	–
PACIFIC NORTHWEST	17	NF	173366	2329	171037	19159	51008	85041	1289	1055	13465
		SRF	–	–	"	"	–	–	–	"	–
CALIFORNIA	18	NF	105497	1607	103890	10885	28021	43227	1218	3328	17211
		SRF	–	–	103151	N/A	–	–	–	2645	–
ALASKA	19	NF	375304	12787	362517	21	238186	58635	29	68	65578
		SRF	–	–	375000	20	–	–	–	N/A	–
HAWAII	20	NF	4126	31	4095	321	728	1774	67	21	1184
		SRF	–	–	4240	"	–	–	–	149	–
CARIBBEAN	21	NF	2283	10	2273	514	880	565	49	126	139
		SRF	–	–	2235	"	–	–	–	87	–
NATIONAL TOTAL REGIONS 1-18		NF	1935253	37286	1897967	421326	645138	612339	38760	34681	145723
		SRF	–	–	1898410	N/A	–	–	–	N/A	–
NATIONAL TOTAL REGIONS 1-21		NF	2316966	50114	2266852	422182	884932	673313	38905	34896	212624
		SRF	–	–	2279885	N/A	–	–	–	N/A	–

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TABLE 1-4 CROPLAND AND IRRIGATED FARMLAND

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL CROPLAND 1,000 ACRES "1975"	1985	2000	CHANGE IN CROPLAND PERCENT 1975-1985	1975-2000	CROPLAND HARVESTED 1,000 ACRES "1975"	1985	2000
NEW ENGLAND	1	NF	2769	2691	2579	-3%	-7%	1663	2020	1897
		SRF	"	2694	"	"	"	"	"	"
MID-ATLANTIC	2	NF	11688	11590	11179	-1%	-4%	9171	10902	10534
		SRF	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	25259	25747	27515	2%	9%	17478	18908	23686
		SRF	"	"	"	"	"	"	18308	"
GREAT LAKES	4	NF	24907	25357	25365	2%	2%	18700	21056	24034
		SRF	"	"	"	"	"	"	"	"
OHIO	5	NF	32877	32977	33020	<1%	<1%	24802	30260	30996
		SRF	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	4431	4384	4443	-1%	<1%	2484	2588	3190
		SRF	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	64062	64310	64687	<1%	1%	54396	62316	61825
		SRF	"	"	"	"	"	"	"	"
LOWER MISSISSIPPI	8	NF	20409	21919	22538	7%	10%	18223	20464	18120
		SRF	22138	24293	25143	10%	14%	16223	18017	19188
SOURIS-RED-RAINY	9	NF	20791	20875	20946	<1%	1%	13614	16973	18283
		SRF	"	"	"	"	"	"	"	"
MISSOURI	10	NF	105660	105271	105050	<1%	-1%	73286	77246	82639
		SRF	"	"	"	"	"	"	"	"
ARKANSAS-WHITE-RED	11	NF	44480	44642	45051	<1%	1%	27793	34340	37364
		SRF	42053	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TEXAS-GULF	12	NF	25021	24938	24585	<1%	-2%	13942	20026	17942
		SRF	N/A	N/A	N/A	N/A	N/A	17444	21354	24774
RIO GRANDE	13	NF	2869	2809	2811	-2%	-2%	2376	2114	2087
		SRF	2216	N/A	N/A	N/A	N/A	2216	N/A	N/A
UPPER COLORADO	14	NF	1951	2102	2104	8%	8%	1322	1902	1960
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LOWER COLORADO	15	NF	1485	1444	1393	-3%	-6%	1227	1199	1258
		SRF	"	"	"	"	"	"	"	"
GREAT BASIN	16	NF	2623	2834	2800	8%	7%	1781	2194	2119
		SRF	3285	3288	3297	<1%	<1%	"	"	"
PACIFIC NORTHWEST	17	NF	19159	19086	18927	<1%	-1%	12037	12357	13231
		SRF	"	"	"	"	"	"	"	"
CALIFORNIA	18	NF	10885	10633	10355	-2%	-5%	8979	9243	8947
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ALASKA	19	NF	21	35	37	67%	76%	17	25	25
		SRF	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	321	320	320	<1%	<1%	321	320	320
		SRF	"	"	"	"	"	"	"	"
CARIBBEAN	21	NF	514	453	399	-12%	-22%	353	304	256
		SRF	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	421326	423609	425348	1%	1%	303274	346108	360112
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	422182	424417	426104	1%	1%	303965	346757	360713
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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TABLE I-4 CROPLAND AND IRRIGATED FARMLAND (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION			IRRIGATED FARMLAND 1,000 ACRES "1975"	1985	2000	FOREST CLEARED + DRAINED 1,000 ACRES 1975-1985	1975-2000	PASTURE DRAINED 1,000 ACRES 1975-1985	1975-2000
NEW ENGLAND	1	NF	43	48	57	0	0	0	0
		SRF	"	"	"	"	"	"	"
MID-ATLANTIC	2	NF	264	362	476	0	0	0	77
		SRF	297	418	563	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	2035	2563	3040	123	1948	330	777
		SRF	2371	3020	3644	"	"	"	"
GREAT LAKES	4	NF	164	243	334	252	730	122	384
		SRF	"	"	"	"	"	"	"
OHIO	5	NF	57	76	102	136	218	201	684
		SRF	"	"	"	"	"	"	"
TENNESSEE	6	NF	15	19	23	0	103	55	130
		SRF	5	10	10	"	"	"	"
UPPER MISSISSIPPI	7	NF	204	307	434	249	586	461	1089
		SRF	244	523	638	"	"	"	"
LOWER MISSISSIPPI	8	NF	1968	2508	2862	603	1429	352	832
		SRF	2481	2632	2817	N/A	N/A	N/A	N/A
SOURIS-RED-RAINY	9	NF	36	106	311	106	250	90	212
		SRF	"	"	454	"	"	"	"
MISSOURI	10	NF	9695	10957	11505	71	179	179	459
		SRF	11464	14287	17402	"	"	"	"
ARKANSAS-WHITE-RED	11	NF	4765	5380	5545	81	191	333	787
		SRF	5722	N/A	N/A	N/A	N/A	N/A	N/A
TEXAS-GULF	12	NF	4770	4188	3440	0	0	40	40
		SRF	5297	5920	8129	"	"	"	"
RIO GRANDE	13	NF	1984	1870	1865	0	0	0	0
		SRF	2178	2377	2708	"	"	"	"
UPPER COLORADO	14	NF	1365	1513	1627	0	0	0	0
		SRF	1497	1668	1831	"	"	"	"
LOWER COLORADO	15	NF	1283	1183	1127	0	0	0	0
		SRF	1327	1353	1361	"	"	"	"
GREAT BASIN	16	NF	1739	1513	1621	0	0	0	0
		SRF	2208	2211	2219	"	"	"	"
PACIFIC NORTHWEST	17	NF	6186	7424	7759	0	0	0	0
		SRF	7490	8684	9718	"	"	"	"
CALIFORNIA	18	NF	8729	9342	10079	0	0	0	0
		SRF	8995	9806	10452	"	"	"	"
ALASKA	19	NF	4	4	4	0	0	0	0
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	142	147	150	0	0	0	0
		SRF	"	"	"	"	"	"	"
CARIBBEAN	21	NF	70	73	78	0	0	0	0
		SRF	"	"	"	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-18		NF	45302	49602	52207	1621	5634	2163	5471
		SRF	51876	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	45518	49826	52439	1621	5634	2163	5471
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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TABLE 1-5 SHEET EROSION BY SOURCE

(REGIONS 1-21) NATIONAL SUMMARY

REGION			SHEET EROSION FROM CROPLAND HARVESTED TONS/ACRE/YEAR "1975"	1985	2000	CHANGE IN EROSION FROM CROPLAND HARVESTED PERCENT 1975-1985	1975-2000	SHEET EROSION FROM FOREST-RANGE LANDS TONS/ACRE/YEAR "1975"
NEW ENGLAND	1	NF	7	3	1	-57%	-86%	2
		SRF	"	N/A	"	N/A	"	N/A
MID-ATLANTIC	2	NF	14	6	3	-57%	-79%	.5
		SRF	"	N/A	"	N/A	"	"
SOUTH ATLANTIC-GULF	3	NF	18	7	6	-61%	-67%	.3
		SRF	"	"	"	"	"	"
GREAT LAKES	4	NF	5	2	2	-60%	-60%	.2
		SRF	"	N/A	"	N/A	"	"
OHIO	5	NF	9	4	3	-56%	-67%	.4
		SRF	8	N/A	"	N/A	-63%	"
TENNESSEE	6	NF	19	5	4	-74%	-79%	.3
		SRF	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	10	5	3	-50%	-70%	.6
		SRF	"	N/A	"	N/A	"	"
LOWER MISSISSIPPI	8	NF	23	12	6	-48%	-74%	.3
		SRF	N/A	N/A	N/A	N/A	N/A	N/A
SOURIS-RED-RAINY	9	NF	2	1	1	-50%	-50%	.6
		SRF	"	N/A	"	N/A	"	"
MISSOURI	10	NF	7	4	3	-43%	-57%	1.5
		SRF	"	N/A	"	N/A	"	"
ARKANSAS-WHITE-RED	11	NF	6	3	2	-50%	-67%	1.0
		SRF	"	N/A	"	N/A	"	"
TEXAS-GULF	12	NF	7	5	3	-29%	-57%	.7
		SRF	"	N/A	"	N/A	"	"
RIO GRANDE	13	NF	2	3	3	50%	50%	.9
		SRF	"	N/A	"	N/A	"	"
UPPER COLORADO	14	NF	2	3	3	50%	50%	2.8
		SRF	"	N/A	"	N/A	"	"
LOWER COLORADO	15	NF	2	1	1	-50%	-50%	2.0
		SRF	"	N/A	"	N/A	"	"
GREAT BASIN	16	NF	2	2	2	0%	0%	4.1
		SRF	"	N/A	"	N/A	"	"
PACIFIC NORTHWEST	17	NF	2	4	4	100%	100%	1.2
		SRF	"	N/A	"	N/A	"	"
CALIFORNIA	18	NF	1	1	1	0%	0%	2.6
		SRF	"	N/A	"	N/A	"	"
ALASKA	19	NF	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"
HAWAII	20	NF	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"
CARIBBEAN	21	NF	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	9	4	3	-56%	-67%	.9
		SRF	"	N/A	"	N/A	"	"
NATIONAL TOTAL REGIONS 1-21		NF	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"

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TABLE I-6. FLOOD DAMAGES BY LAND USE

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL FLOOD DAMAGES THOUSANDS (1975$) "1975"	1985	2000	CHANGE IN TOTAL PERCENT 1975-85	1975-2000	CHANGE IN URBAN PERCENT 1975-85	1975-2000	CHANGE IN AGR PERCENT 1975-85	1975-2000
NEW ENGLAND	1	NF	92035	121060	153435	32%	67%	34%	65%	-4%	3%
		SRF	87884	112392	142060	28%	62%	N/A	N/A	N/A	N/A
MID-ATLANTIC	2	NF	183484	212909	296204	16%	61%	22%	76%	-8%	-2%
		SRF	"	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	484102	527585	657657	9%	36%	21%	61%	-4%	7%
		SRF	"	"	"	"	"	"	"	"	"
GREAT LAKES	4	NF	105039	125121	145689	19%	39%	22%	41%	-4%	22%
		SRF	105074	120476	145483	15%	38%	"	"	N/A	N/A
OHIO	5	NF	186065	201311	232243	8%	25%	16%	38%	2%	9%
		SRF	"	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	71712	76491	92871	7%	30%	16%	47%	-8%	-2%
		SRF	"	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	235128	258427	302470	10%	29%	11%	23%	5%	21%
		SRF	"	"	"	"	"	"	"	"	"
LOWER MISSISSIPPI	8	NF	399113	419973	469234	5%	18%	16%	41%	<1%	7%
		SRF	373818	457928	553045	23%	48%	36%	94%	16%	27%
SOURIS-RED-RAINY	9	NF	39323	41494	46634	6%	19%	8%	16%	2%	10%
		SRF	"	"	"	"	"	"	"	"	"
MISSOURI	10	NF	350245	357597	413447	2%	18%	13%	36%	-4%	6%
		SRF	350133	357473	413297	"	"	N/A	N/A	N/A	N/A
ARKANSAS-WHITE-RED	11	NF	234454	249111	302673	6%	29%	30%	69%	-7%	-1%
		SRF	"	"	"	"	"	"	"	"	"
TEXAS-GULF	12	NF	275891	282433	301804	2%	9%	-6%	<1%	1%	6%
		SRF	"	"	"	"	"	"	"	"	"
RIO GRANDE	13	NF	66554	66979	71558	1%	8%	10%	28%	-3%	<1%
		SRF	"	"	"	"	"	"	"	"	"
UPPER COLORADO	14	NF	5488	6394	7848	17%	43%	19%	54%	9%	27%
		SRF	"	"	"	"	"	"	"	"	"
LOWER COLORADO	15	NF	122135	137038	158000	12%	29%	15%	41%	2%	1%
		SRF	"	"	"	"	"	"	"	"	"
GREAT BASIN	16	NF	9995	11334	13679	13%	37%	19%	51%	8%	19%
		SRF	"	"	"	"	"	"	"	"	"
PACIFIC NORTHWEST	17	NF	126058	134021	158127	6%	25%	17%	45%	-4%	6%
		SRF	"	"	"	"	"	"	"	"	"
CALIFORNIA	18	NF	416905	433270	482078	4%	16%	4%	6%	1%	14%
		SRF	"	"	"	"	"	"	"	"	"
ALASKA	19	NF	12692	3236	4671	-75%	-63%	-76%	-64%	0%	0%
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	9712	10164	11274	5%	16%	13%	33%	-5%	-5%
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CARIBBEAN	21	NF	2705	3285	4359	21%	61%	33%	102%	11%	25%
		SRF	"	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	3403726	3662548	4305651	8%	26%	15%	38%	-2%	7%
		SRF	3374203	3687066	4377731	9%	30%	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	3428835	3679233	4325955	7%	26%	14%	37%	-2%	7%
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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TABLE I-6 FLOOD DAMAGES BY LAND USE (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION			URBAN FLOOD DAMAGES THOUSANDS (1975$) "1975"	1985	2000	AGRICULTURE FLOOD DAMAGES THOUSANDS (1975$) "1975"	1985	2000	OTHER FLOOD DAMAGES THOUSANDS (1975$) "1975"	1985	2000
NEW ENGLAND	1	NF	77079	103382	127555	2700	2587	2788	12256	15091	23092
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MID-ATLANTIC	2	NF	130188	158356	229327	28469	26226	27973	24827	28327	38904
		SRF	"	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	110148	133169	177099	263746	254302	281281	110208	140114	199277
		SRF	"	"	"	"	"	"	"	"	"
GREAT LAKES	4	NF	78975	96086	111411	19819	19075	24196	6245	9960	10082
		SRF	"	"	"	N/A	N/A	N/A	N/A	N/A	N/A
OHIO	5	NF	59647	69117	82386	86260	87705	94202	40158	44489	55655
		SRF	"	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	19883	23134	29317	35055	32260	34269	16774	21097	29285
		SRF	"	"	"	"	"	"	"	"	"
UPPER MISSISSIPPI	7	NF	69623	77092	85845	108210	113938	130552	57295	67397	86073
		SRF	"	"	"	"	"	"	"	"	"
LOWER MISSISSIPPI	8	NF	62678	72697	88303	254745	255976	272605	81690	91300	108326
		SRF	75480	102666	146642	246450	285270	313548	51888	69992	92855
SOURIS-RED-RAINY	9	NF	5807	6250	6762	29014	29630	31831	4502	5614	8041
		SRF	"	"	"	"	"	"	"	"	"
MISSOURI	10	NF	51923	58833	70408	222692	213998	235315	75630	84766	107724
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ARKANSAS-WHITE-RED	11	NF	38691	50288	65356	145795	134914	144440	49968	63909	92877
		SRF	"	"	"	"	"	"	"	"	"
TEXAS-GULF	12	NF	49725	46754	49873	176167	177496	187524	49999	58183	64407
		SRF	"	"	"	"	"	"	"	"	"
RIO GRANDE	13	NF	12090	13259	15443	43639	42257	43553	10825	11463	12562
		SRF	"	"	"	"	"	"	"	"	"
UPPER COLORADO	14	NF	1291	1538	1985	2945	3220	3734	1252	1636	2129
		SRF	"	"	"	"	"	"	"	"	"
LOWER COLORADO	15	NF	56193	64671	78981	38056	38769	38391	27886	33598	40628
		SRF	"	"	"	"	"	"	"	"	"
GREAT BASIN	16	NF	3488	4150	5268	3554	3840	4234	2953	3344	4177
		SRF	"	"	"	"	"	"	"	"	"
PACIFIC NORTHWEST	17	NF	41983	48979	61075	66749	64404	70710	17326	20638	26342
		SRF	"	"	"	"	"	"	"	"	"
CALIFORNIA	18	NF	259376	268596	275203	101163	102189	115293	56366	62485	91582
		SRF	"	"	"	"	"	"	"	"	"
ALASKA	19	NF	12558	3077	4469	14	14	14	120	145	188
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	5366	6050	7120	4333	4098	4132	13	16	22
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CARIBBEAN	21	NF	742	986	1501	1450	1614	1814	513	685	1044
		SRF	"	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	1128788	1296351	1561597	1628778	1602786	1742891	646160	763411	1001163
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	1147454	1306464	1574687	1634575	1608512	1748851	646806	764257	1002417
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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TABLE I-7 RECREATION REQUIREMENTS AND WILDERNESS AREAS

(REGIONS 1-21) NATIONAL SUMMARY

REGION			TOTAL WATER-RELATED 1,000 ACTIVITY OCCASIONS "1975"	1985	2000	WATER-DEPENDENT 1,000 ACTIVITY OCCASIONS "1975"	1985	2000	WATER-ENHANCED 1,000 ACTIVITY OCCASIONS "1975"	1985	2000
NEW ENGLAND	1	NF	105440	118737	139397	69750	77884	91032	35690	40853	48365
		SRF	"	"	"	"	"	"	"	"	"
MID-ATLANTIC	2	NF	332953	377597	445183	217923	246575	289290	115030	131022	155893
		SRF	"	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	218447	260373	320421	160522	191978	235100	57925	68395	85321
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GREAT LAKES	4	NF	326927	366175	433653	220377	247105	294980	106550	119070	138673
		SRF	"	"	"	"	"	"	"	"	"
OHIO	5	NF	200968	223847	258355	142092	158320	182810	58876	65527	75545
		SRF	"	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	30541	35808	43249	22504	26402	31916	8037	9406	11333
		SRF	N/A	N/A	N/A	29460	44520	74620	N/A	N/A	N/A
UPPER MISSISSIPPI	7	NF	144961	164956	187784	97346	111957	126423	47615	52999	61361
		SRF	509082	612505	772179	461467	559506	710818	"	"	"
LOWER MISSISSIPPI	8	NF	55187	60057	66922	40715	44280	49368	14472	15777	17554
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SOURIS-RED-RAINY	9	NF	7027	7007	7072	4720	4710	4765	2307	2297	2307
		SRF	"	"	"	"	"	"	"	"	"
MISSOURI	10	NF	94696	103232	118012	61946	67499	77214	32750	35733	40798
		SRF	157716	180894	217900	88082	99642	116993	69634	81252	100907
ARKANSAS-WHITE-RED	11	NF	62518	68243	78008	44521	48568	55819	17997	19675	22189
		SRF	"	"	"	"	"	"	"	"	"
TEXAS-GULF	12	NF	84922	99087	120940	62575	73058	89236	22347	26029	31704
		SRF	"	"	"	"	"	"	"	"	"
RIO GRANDE	13	NF	16635	18230	20374	10710	11723	13056	5925	6507	7318
		SRF	"	"	"	"	"	"	"	"	"
UPPER COLORADO	14	NF	3589	3853	4257	2187	2346	2568	1402	1507	1689
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LOWER COLORADO	15	NF	25198	31581	41651	15353	19242	25380	9845	12339	16271
		SRF	"	"	"	"	"	"	"	"	"
GREAT BASIN	16	NF	13203	15877	19944	8045	9674	12160	5158	6203	7784
		SRF	19386	28146	43402	11441	16610	25614	7945	11536	17788
PACIFIC NORTHWEST	17	NF	70059	75728	87072	42684	46116	53084	27375	29612	33988
		SRF	"	"	"	"	"	"	"	"	"
CALIFORNIA	18	NF	221163	256946	310861	134750	156576	189529	86413	100370	121332
		SRF	307400	404900	613100	219000	288400	437000	88400	116500	176100
ALASKA	19	NF	3206	3908	5033	1953	2380	3066	1253	1528	1967
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAWAII	20	NF	24148	27406	33632	18231	20766	25609	5917	6640	8023
		SRF	"	29606	38833	"	22345	29283	"	7261	9550
CARIBBEAN	21	NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	2014434	2287334	2703155	1358720	1544013	1823730	655714	743321	879425
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		NF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SRF	"	"	"	"	"	"	"	"	"

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TABLE I-7. RECREATION REQUIREMENTS AND WILDERNESS AREAS (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION			WATER SURFACE AREA NEEDS 1,000 ACRES "1975"	1985	2000	DEV. LAND AREA NEEDS 1,000 ACRES "1975"	1985	2000	DESIGNATED WILDERNESS AREAS NUMBER "1975"	1,000 ACRES "1975"
NEW ENGLAND	1	NF	560.0	681.0	929.0	19.2	22.5	28.4	5	39
		SRF	519.0	1437.0	2333.0	32.2	41.3	52.1	"	43
MID-ATLANTIC	2	NF	1679.0	2106.0	2702.0	63.4	74.1	96.3	5	110
		SRF	"	"	"	"	"	"	"	"
SOUTH ATLANTIC-GULF	3	NF	958.0	1208.0	1665.0	33.3	41.3	53.9	19	529
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	"	N/A
GREAT LAKES	4	NF	1284.0	1504.0	1888.0	42.5	56.3	70.6	8	912
		SRF	"	"	"	"	"	"	"	"
OHIO	5	NF	961.0	1129.0	1404.0	29.9	34.9	42.8	3	35
		SRF	"	"	"	"	"	"	"	"
TENNESSEE	6	NF	0.0	0.0	45.0	3.9	4.9	6.5	5	32
		SRF	22.0	41.0	194.0	N/A	N/A	N/A	"	"
UPPER MISSISSIPPI	7	NF	509.0	585.0	783.0	23.1	27.0	33.1	1	4
		SRF	"	"	"	"	"	"	"	"
LOWER MISSISSIPPI	8	NF	182.0	226.0	292.0	9.3	10.0	11.7	4	19
		SRF	163.0	396.0	816.0	101.6	151.7	227.0	"	N/A
SOURIS-RED-RAINY	9	NF	0.0	0.0	0.0	1.9	1.9	1.9	3	12
		SRF	"	"	"	"	"	"	"	"
MISSOURI	10	NF	6.0	10.0	22.0	11.5	13.1	16.0	15	2216
		SRF	"	"	"	"	"	"	"	"
ARKANSAS-WHITE-RED	11	NF	250.0	300.0	382.0	8.1	9.5	11.4	5	70
		SRF	"	"	"	"	"	"	"	"
TEXAS-GULF	12	NF	539.0	678.0	901.0	11.7	14.2	18.3	0	0
		SRF	"	"	"	"	"	"	"	"
RIO GRANDE	13	NF	129.0	142.0	160.0	3.4	3.8	4.4	9	366
		SRF	"	"	"	"	"	"	"	"
UPPER COLORADO	14	NF	0.0	0.0	0.0	.4	.4	.4	9	1350
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	"	"
LOWER COLORADO	15	NF	94.0	128.0	185.0	6.2	8.0	11.1	12	1056
		SRF	"	"	"	"	"	"	"	"
GREAT BASIN	16	NF	1.0	2.0	5.0	2.7	3.4	4.6	1	65
		SRF	10.0	16.0	30.0	8.2	14.1	26.4	"	"
PACIFIC NORTHWEST	17	NF	98.0	138.0	232.0	10.3	11.9	15.1	27	5192
		SRF	424.0	464.0	558.0	10.4	12.0	15.2	"	"
CALIFORNIA	18	NF	806.0	977.0	1244.0	35.8	43.3	54.5	27	2324
		SRF	2367.0	3429.0	5707.0	17.1	29.1	59.7	"	"
ALASKA	19	NF	0.0	0.0	0.0	.6	.8	1.2	8	77
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	"	N/A
HAWAII	20	NF	0.0	0.0	0.0	0.0	.4	1.4	1	19
		SRF	"	"	"	"	1.4	4.0	"	0
CARIBBEAN	21	NF	N/A	N/A	N/A	N/A	N/A	N/A	0	0
		SRF	"	"	"	"	"	"	"	"
NATIONAL TOTAL REGIONS 1-18		NF	8056.0	9814.0	12839.0	316.6	380.5	481.2	153	14331
		SRF	N/A	N/A	N/A	N/A	N/A	N/A	"	N/A
NATIONAL TOTAL REGIONS 1-21		NF	N/A	N/A	N/A	N/A	N/A	N/A	162	14427
		SRF	"	"	"	"	"	"	"	N/A

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PAGE 34 TABLE I–8. ELECTRIC POWER GENERATION BY FUEL SOURCE

(REGIONS 1–21) NATIONAL SUMMARY

REGION			TOTAL GENERATION GIGAWATT HOURS "1975"	1985	2000	CHANGE IN TOTAL GEN PERCENT 1975–1985	1975–2000	NUCLEAR PORTION OF TOTAL PERCENT "1975"	1985	2000
NEW ENGLAND	1	NF	66619	125883	294620	89%	342%	30%	57%	68%
		SRF	67003	"	"	88%	340%	–	–	–
MID–ATLANTIC	2	NF	200336	405683	902534	103%	351%	19%	52%	72%
		SRF	"	"	"	"	"	–	–	–
SOUTH ATLANTIC–GULF	3	NF	237703	675164	1773352	184%	646%	13%	49%	57%
		SRF	"	"	1773908	"	"	–	–	–
GREAT LAKES	4	NF	208843	374084	841846	79%	303%	17%	53%	75%
		SRF	N/A	N/A	N/A	N/A	N/A	–	–	–
OHIO	5	NF	304458	505594	1056700	66%	247%	0%	15%	50%
		SRF	"	"	"	"	"	–	–	–
TENNESSEE	6	NF	68135	163374	262684	140%	286%	4%	67%	73%
		SRF	"	"	"	"	"	–	–	–
UPPER MISSISSIPPI	7	NF	113951	249613	666729	119%	485%	22%	49%	76%
		SRF	"	"	"	"	"	–	–	–
LOWER MISSISSIPPI	8	NF	53811	120854	366073	125%	580%	0%	33%	80%
		SRF	"	"	"	"	"	–	–	–
SOURIS–RED–RAINY	9	NF	956	352	0	–63%	–100%	0%	0%	0%
		SRF	"	"	"	"	"	–	–	–
MISSOURI	10	NF	75235	186691	448618	148%	496%	8%	19%	50%
		SRF	"	N/A	"	N/A	"	–	–	–
ARKANSAS–WHITE–RED	11	NF	72816	165039	404432	127%	455%	7%	27%	73%
		SRF	N/A	N/A	N/A	N/A	N/A	–	–	–
TEXAS–GULF	12	NF	123994	274679	824516	122%	565%	0%	21%	75%
		SRF	131688	312997	639346	138%	386%	–	–	–
RIO GRANDE	13	NF	10773	5354	26794	–50%	149%	0%	0%	87%
		SRF	12328	20074	40321	63%	227%	–	–	–
UPPER COLORADO	14	NF	23864	58204	90568	144%	280%	0%	0%	15%
		SRF	23215	59275	104550	155%	350%	–	–	–
LOWER COLORADO	15	NF	32649	64818	102878	99%	215%	0%	11%	41%
		SRF	"	"	"	"	"	–	–	–
GREAT BASIN	16	NF	3537	24751	124491	600%	3420%	0%	58%	92%
		SRF	2849	5143	10797	81%	279%	–	–	–
PACIFIC NORTHWEST	17	NF	138234	189111	408621	37%	196%	2%	24%	58%
		SRF	"	"	"	"	"	–	–	–
CALIFORNIA	18	NF	120801	227032	343787	88%	185%	5%	37%	64%
		SRF	122892	"	"	85%	180%	–	–	–
ALASKA	19	NF	1427	3298	15423	131%	981%	0%	0%	0%
		SRF	3300	6100	36500	85%	1006%	–	–	–
HAWAII	20	NF	5167	10301	25873	99%	401%	0%	0%	0%
		SRF	"	"	"	"	"	–	–	–
CARIBBEAN	21	NF	9937	30862	93574	211%	842%	0%	33%	62%
		SRF	"	"	"	"	"	–	–	–
NATIONAL TOTAL REGIONS 1–18		NF	1856715	3816280	8939243	106%	381%	9%	38%	65%
		SRF	N/A	N/A	N/A	N/A	N/A	–	–	–
NATIONAL TOTAL REGIONS 1–21		NF	1873246	3860741	9074113	106%	384%	9%	38%	65%
		SRF	N/A	N/A	N/A	N/A	N/A	–	–	–

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TABLE I-8. ELECTRIC POWER GENERATION BY FUEL SOURCE (CONTINUED) PAGE 35

(REGIONS 1-21) NATIONAL SUMMARY

REGION			FOSSIL GIGAWATT HOURS "1975"	FOSSIL GIGAWATT HOURS 1985	FOSSIL GIGAWATT HOURS 2000	NUCLEAR GIGAWATT HOURS "1975"	NUCLEAR GIGAWATT HOURS 1985	NUCLEAR GIGAWATT HOURS 2000	CONVENTIONAL HYDROPOWER GIGAWATT HOURS "1975"	CONVENTIONAL HYDROPOWER GIGAWATT HOURS 1985	CONVENTIONAL HYDROPOWER GIGAWATT HOURS 2000
NEW ENGLAND	1	NF	44196	51630	89900	20241	72250	201710	2182	2003	3010
		SRF	–	–	–	–	–	–	–	–	–
MID-ATLANTIC	2	NF	157809	190995	248745	37258	210625	649598	5269	4063	4191
		SRF	–	–	–	–	–	–	–	–	–
SOUTH ATLANTIC-GULF	3	NF	189757	328585	747660	30344	331477	1010231	17602	15102	15461
		SRF	–	–	–	–	–	–	–	–	–
GREAT LAKES	4	NF	147857	155765	186118	35135	197635	635044	25851	20684	20684
		SRF	–	–	–	–	–	–	–	–	–
OHIO	5	NF	299003	424389	521651	0	75361	527353	5455	5844	7696
		SRF	–	–	–	–	–	–	–	–	–
TENNESSEE	6	NF	46041	38847	56705	2722	109101	190553	19372	15426	15426
		SRF	–	–	–	–	–	–	–	–	–
UPPER MISSISSIPPI	7	NF	87825	125908	156084	24879	122255	509195	1247	1450	1450
		SRF	–	–	–	–	–	–	–	–	–
LOWER MISSISSIPPI	8	NF	53363	80349	72488	0	40140	293220	448	365	365
		SRF	–	–	–	–	–	–	–	–	–
SOURIS-RED-RAINY	9	NF	956	352	0	0	0	0	0	0	0
		SRF	–	–	–	–	–	–	–	–	–
MISSOURI	10	NF	49935	137914	208709	5916	34711	225843	19384	14066	14066
		SRF	–	–	–	–	–	–	–	–	–
ARKANSAS-WHITE-RED	11	NF	60877	115400	101570	4878	43810	296900	7061	5829	5962
		SRF	–	–	–	–	–	–	–	–	–
TEXAS-GULF	12	NF	122873	215690	205180	0	58166	618420	1121	823	916
		SRF	–	–	–	–	–	–	–	–	–
RIO GRANDE	13	NF	10638	5110	3190	0	0	23360	135	244	244
		SRF	–	–	–	–	–	–	–	–	–
UPPER COLORADO	14	NF	22545	56877	73855	0	0	13490	1319	1327	3223
		SRF	–	–	–	–	–	–	–	–	–
LOWER COLORADO	15	NF	23762	48294	51480	0	7438	42556	8887	9086	8842
		SRF	–	–	–	–	–	–	–	–	–
GREAT BASIN	16	NF	3083	9764	9464	0	14460	114500	454	527	527
		SRF	–	–	–	–	–	–	–	–	–
PACIFIC NORTHWEST	17	NF	6292	9732	17813	3310	44907	235145	128236	134472	155663
		SRF	–	–	–	–	–	–	–	–	–
CALIFORNIA	18	NF	78693	114712	91704	6070	83775	219929	36038	28545	32154
		SRF	–	–	–	–	–	–	–	–	–
ALASKA	19	NF	1116	2073	7053	0	0	0	311	1225	8370
		SRF	–	–	–	–	–	–	–	–	–
HAWAII	20	NF	5167	10301	25873	0	0	0	0	0	0
		SRF	–	–	–	–	–	–	–	–	–
CARIBBEAN	21	NF	9937	20613	35286	0	10249	58288	0	0	0
		SRF	–	–	–	–	–	–	–	–	–
NATIONAL TOTAL REGIONS 1-18		NF	1405505	2110313	2842316	170753	1446111	5807047	280061	259856	289880
		SRF	–	–	–	–	–	–	–	–	–
NATIONAL TOTAL REGIONS 1-21		NF	1421725	2143300	2910528	170753	1456360	5865335	280372	261081	298250
		SRF	–	–	–	–	–	–	–	–	–

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TABLE I-9 STEAM-ELECTRIC GENERATING PLANTS

(REGIONS 1-21) NATIONAL SUMMARY

REGION		NUCLEAR GENERATING PLANTS NUMBER "1975"	1985	2000	FOSSIL GENERATING PLANTS NUMBER "1975"	1985	2000	PORTION OF STEAM GENERATION USING ONCE-THRU COOLING "1975"	1985	2000
NEW ENGLAND	1	6	8	13	35	28	24	87%	95%	24%
MID-ATLANTIC	2	5	17	36	82	72	52	82%	58%	22%
SOUTH ATLANTIC-GULF	3	5	23	42	88	101	111	72%	31%	13%
GREAT LAKES	4	9	20	38	78	71	66	93%	46%	13%
OHIO	5	0	6	26	103	108	97	59%	34%	7%
TENNESSEE	6	1	7	9	9	9	9	85%	33%	15%
UPPER MISSISSIPPI	7	7	14	35	71	73	70	54%	20%	2%
LOWER MISSISSIPPI	8	0	3	7	36	36	29	78%	69%	50%
SOURIS-RED-RAINY	9	0	0	0	3	3	0	83%	64%	0%
MISSOURI	10	2	4	13	52	60	59	N/A	N/A	N/A
ARKANSAS-WHITE-RED	11	1	3	8	55	62	46	3%	3%	1%
TEXAS-GULF	12	0	4	13	68	78	70	27%	15%	9%
RIO GRANDE	13	0	0	2	13	12	9	N/A	N/A	N/A
UPPER COLORADO	14	0	0	1	10	13	14	1%	<1%	0%
LOWER COLORADO	15	0	1	2	18	20	14	0%	0%	0%
GREAT BASIN	16	0	2	4	5	7	6	6%	0%	0%
PACIFIC NORTHWEST	17	2	5	10	4	5	6	N/A	N/A	N/A
CALIFORNIA	18	3	7	10	35	32	25	84%	73%	53%
ALASKA	19	0	0	0	4	8	12	59%	18%	49%
HAWAII	20	0	0	0	5	5	8	100%	100%	100%
CARIBBEAN	21	0	1	4	6	9	12	100%	67%	20%
NATIONAL TOTAL REGIONS 1-18		41	124	269	765	790	707	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-21		41	125	273	780	812	739	N/A	N/A	N/A

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TABLE I-10 WATER QUALITY INDICATORS

(REGIONS 1-21) NATIONAL SUMMARY

REGION		RESIDUAL HEAT DISCHARGED FROM STEAM-ELECTRIC GENERATING PLANTS: TOTAL RESIDUAL HEAT DISCHARGED TRILLION BTU/YEAR "1975"	1985	2000	RESIDUAL HEAT DISCHARGED TO FRESH WATER TRILLION BTU/YEAR "1975"	1985	2000	RESIDUAL HEAT DISCHARGED TO SALINE WATER TRILLION BTU/YEAR "1975"	1985	2000
NEW ENGLAND	1	486	911	1978	87	73	9	273	688	425
MID-ATLANTIC	2	1382	2782	5894	321	295	158	608	1078	981
SOUTH ATLANTIC-GULF	3	1488	4412	11341	571	527	472	281	594	757
GREAT LAKES	4	1299	2417	5403	985	953	628	0	0	0
OHIO	5	1949	3230	6704	927	874	361	0	0	0
TENNESSEE	6	309	984	1618	212	266	204	0	0	0
UPPER MISSISSIPPI	7	834	1728	4370	366	284	97	0	0	0
LOWER MISSISSIPPI	8	371	817	2376	206	406	667	15	67	404
SOURIS-RED-RAINY	9	9	3	0	6	2	0	0	0	0
MISSOURI	10	435	1166	2804	190	291	200	0	0	0
ARKANSAS-WHITE-RED	11	462	1055	2587	13	27	12	0	0	0
TEXAS-GULF	12	843	1813	5332	13	15	25	158	189	403
RIO GRANDE	13	81	38	175	0	0	0	0	0	0
UPPER COLORADO	14	155	367	558	2	2	0	0	0	0
LOWER COLORADO	15	174	381	611	0	0	0	0	0	0
GREAT BASIN	16	24	163	806	1	0	0	0	0	0
PACIFIC NORTHWEST	17	66	370	1655	23	2	2	0	0	421
CALIFORNIA	18	556	1330	2062	0	0	0	364	803	970
ALASKA	19	9	17	48	2	1	1	3	2	17
HAWAII	20	36	70	163	0	0	0	29	55	128
CARIBBEAN	21	75	207	606	0	0	0	60	108	96
NATIONAL TOTAL REGIONS 1-18		10923	23967	56274	3923	4017	2835	1699	3419	4361
NATIONAL TOTAL REGIONS 1-21		11043	24261	57091	3925	4018	2836	1791	3584	4602

TABLE I-10 WATER QUALITY INDICATORS (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION		DISCHARGES OF HEAT, BOD, AND TSS TO WATER - "1975": HEAT: DISCHARGED BY MFG PLANTS TRILLION BTU/YR	BIOCHEMICAL OXYGEN DEMAND (BOD): TOTAL DISCHARGED MILLION LBS/YR	BOD: IF UNDER B A T * MILLION LBS/YR	TOTAL SUSPENDED SOLIDS (TSS): TOTAL DISCHARGED MILLION LBS/YR	TSS: IF UNDER B A T * MILLION LBS/YR
NEW ENGLAND	1	128	710	127	7355	5077
MID-ATLANTIC	2	412	1900	325	22861	12436
SOUTH ATLANTIC-GULF	3	225	1348	268	30118	26581
GREAT LAKES	4	630	1173	262	46998	20913
OHIO	5	566	1502	836	157162	152206
TENNESSEE	6	116	469	244	50605	41159
UPPER MISSISSIPPI	7	86	1539	1067	182764	176427
LOWER MISSISSIPPI	8	287	947	611	184549	183094
SOURIS-RED-RAINY	9	5	54	34	3680	3557
MISSOURI	10	22	1935	1742	717481	328357
ARKANSAS-WHITE-RED	11	21	500	277	84714	79096
TEXAS-GULF	12	371	835	96	28279	25622
RIO GRANDE	13	17	39	14	21975	5702
UPPER COLORADO	14	<1	725	717	131321	127633
LOWER COLORADO	15	1	135	72	119700	25785
GREAT BASIN	16	3	43	20	92696	6654
PACIFIC NORTHWEST	17	115	950	456	115563	76368
CALIFORNIA	18	43	1999	696	104812	88445
ALASKA	19	7	N/A	N/A	N/A	N/A
HAWAII	20	N/A	N/A	N/A	N/A	N/A
CARIBBEAN	21	N/A	N/A	N/A	N/A	N/A
NATIONAL TOTAL REGIONS 1-18		3048	16803	7864	2102633	1385112
NATIONAL TOTAL REGIONS 1-21		N/A	N/A	N/A	N/A	N/A

* B A T - BEST AVAILABLE TECHNOLOGY SEE EXPLANATORY NOTES

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TABLE I–11 COMMERCIAL NAVIGATION

(REGIONS 1–21) MISSISSIPPI AND GULF INTRACOASTAL WATERWAYS NATIONAL SUMMARY

REGION		COMMODITY ORIGINS (MILLION TONS) PETROLEUM AND PRODUCTS	COAL AND COKE	STEEL IRON + IRON ORE	SAND GRAVEL STONE	GRAINS	LOGS AND LUMBER	CHEMICALS	SHELLS	OTHER	TOTAL COMMODITY MOVED	CHANGES IN TOTAL COMMODITY MOVED FROM "1975"	
1	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
2	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
3	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
4	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
5	"1975"	11	90	2	13	2	<1	3	0	6	128	–	–
	1985	12	112	3	15	2	<1	5	0	9	159	31	24%
	2000	15	156	3	18	4	<1	8	0	13	219	91	71%
6	"1975"	<1	3	<1	2	<1	<1	<1	0	1	7	–	–
	1985	<1	4	<1	2	<1	<1	1	0	1	9	2	29%
	2000	<1	21	1	2	<1	<1	1	0	2	30	23	329%
7	"1975"	6	18	<1	4	21	<1	<1	0	11	63	–	–
	1985	8	57	<1	5	26	<1	<1	0	15	110	47	75%
	2000	10	67	<1	7	34	<1	3	0	23	141	78	124%
8	"1975"	93	4	2	2	2	<1	16	9	26	155	–	–
	1985	108	5	3	2	2	<1	25	11	35	190	35	23%
	2000	135	6	3	3	3	<1	43	13	52	260	105	68%
9	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
10	"1975"	0	<1	<1	<1	<1	0	<1	0	<1	2	–	–
	1985	0	<1	<1	<1	<1	0	<1	0	<1	2	0	0%
	2000	0	<1	<1	<1	1	0	<1	0	2	2	0	0%
11	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
12	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
13	"1975"	<1	<1	<1	0	<1	0	<1	0	<1	1	–	–
	1985	<1	<1	<1	0	<1	0	<1	0	1	1	0	0%
	2000	<1	<1	<1	0	<1	0	1	0	1	2	1	100%
14	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
15	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
16	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
17	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
18	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
19	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
20	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
21	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
NATION (1–18)	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		

DATA WERE LIMITED TO THE MISSISSIPPI RIVER AND GULF INTRACOASTAL WATERWAY SYSTEM
SUFFICIENT COMMODITY DATA AND ASSOCIATED PROJECTION FACTORS FOR OTHER WATERWAY SYSTEMS WERE NOT AVAILABLE BY SUBREGION
REGIONAL TOTALS INCOMPLETE DATA NOT SUPPLIED FOR SOME SUBREGIONS

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TABLE I-11 COMMERCIAL NAVIGATION (CONTINUED)

(REGIONS 1-21) MISSISSIPPI AND GULF INTRACOASTAL WATERWAYS NATIONAL SUMMARY

COMMODITY FLOWS PAST SELECTED LOCATIONS (MILLION TONS)

REGION		PETROLEUM AND PRODUCTS	COAL AND COKE	STEEL IRON + IRON ORE	SAND GRAVEL STONE	GRAINS	LOGS AND LUMBER	CHEM-ICALS	SHELLS	OTHER	TOTAL COMMODITY FLOW	CHANGES IN TOTAL COMMODITY FLOW FROM "1975"	
1	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
2	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
3	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
4	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
5	"1975"	12	10	2	1	3	<1	6	0	9	44	–	–
	1985	14	29	3	1	3	<1	9	0	12	72	28	64%
	2000	18	33	3	2	6	<1	16	<1	19	97	53	120%
6	"1975"	2	7	<1	<1	1	0	1	0	2	14	–	–
	1985	2	8	<1	<1	1	0	2	0	3	17	3	21%
	2000	3	21	1	1	3	0	6	<1	5	40	26	186%
7	"1975"	37	6	3	<1	22	<1	10	<1	15	94	–	–
	1985	43	41	3	<1	26	<1	16	<1	19	149	55	59%
	2000	55	47	4	<1	36	<1	28	<1	30	199	105	112%
8	"1975"	61	1	1	2	2	<1	13	2	4	87	–	–
	1985	71	2	2	3	2	<1	20	2	6	106	19	22%
	2000	89	2	2	3	2	<1	34	2	8	142	55	63%
9	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
10	"1975"	<1	<1	<1	0	1	0	<1	0	1	2	–	–
	1985	<1	<1	<1	0	1	0	1	0	1	3	1	50%
	2000	<1	<1	<1	0	1	0	1	0	1	4	2	100%
11	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
12	"1975"	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	N/A•	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
13	"1975"	4	<1	<1	<1	<1	0	<1	0	<1	5	–	–
	1985	5	<1	<1	<1	<1	0	1	0	1	6	1	20%
	2000	7	<1	<1	<1	<1	0	1	0	1	9	4	80%
14	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
15	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
16	"1975"	0	0	0	0	0	0	0	0	0	0	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
17	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
18	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
19	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
20	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
21	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		
NATION (1-18)	"1975"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–
	1985	"	"	"	"	"	"	"	"	"	"		
	2000	"	"	"	"	"	"	"	"	"	"		

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TABLE 11-1 ANNUAL WATER SUPPLY DATA - "1975"

(REGIONS 1-21) NATIONAL SUMMARY

	SURFACE WATER RESOURCES								GROUND WATER RESOURCES			
	ANNUAL STREAMFLOW FREQUENCY ANALYSIS					EXISTING SURFACE STORAGE			STORAGE		WITHDRAWALS	
	PERCENTAGE EXCEEDANCE											
REGION	MEAN (MGD)	5% (MGD)	50% (MGD)	80% (MGD)	95% (MGD)	MAXIMUM STORAGE (BIL GAL)	NORMAL STORAGE (BIL GAL)	SURFACE AREA (1000 AC)	TOTAL STORAGE (TRIL GAL)	AVAILABLE STORAGE (TRIL GAL)	TOTAL (MGD)	OVRDRFT (MGD)
1	78180	107700	77440	62730	48290	6310	4722	412	N/A	N/A	635	0
2	79190	115100	77830	61230	48430	7853	6271	142	1161	414	2661	32
3	228010	356600	219290	164140	121820	19799	13382	1766	N/A	4460	5449	339
4	72710	103890	71670	57280	44925	4199	3292	182	N/A	261	1215	27
5	178000	254000	178000	141000	105000	14098	5161	681	1399	383	1843	0
6	40800	57900	40800	35900	31400	7724	3600	466	N/A	530	271	0
7	121000	189000	121000	91800	65300	7574	4231	469	4638	2243	2366	0
8	433000	757000	433000	282000	202000	6398	2034	542	2596	1272	4838	412
9	6010	11400	5620	3360	1810	2429	1430	18	703	172	86	0
10	44100	74300	43200	29900	17600	38488	27161	2087	1118	445	10407	2557
11	62600	120700	59100	37400	21560	22761	9853	1515	664	499	8846	5457
12	28270	62430	22920	12266	6305	17912	7660	930	2803	1434	7222	5578
13	1230	4370	585	270	158	4410	2534	173	16033	1874	2335	657
14	10000	15600	10000	7020	3900	3691	3328	318	1054	78	126	0
15	1550	1680	1550	1360	1230	23491	19962	251	571	N/A	5008	2415
16	2562	4663	2353	1646	1173	1368	1239	130	944	171	1424	591
17	255270	344720	254270	213333	179668	21257	17839	1280	1377	180	7348	627
18	47375	87391	44337	29767	19506	14416	12697	413	327	82	19160	2197
19	905000	1030000	898000	795000	705000	283	267	12	N/A	1122	44	0
20	6747	10333	6318	4910	3824	17	13	1	N/A	N/A	790	0
21	4851	7130	4460	3300	1620	132	92	7	N/A	16	254	13
NATION (1-18)	1233357	1956944	1210865	889382	675315	224179	146397	11774	N/A	N/A	81240	20889
NATION (1-21)	2149955	3004407	2119643	1692592	1385759	224612	146769	11793	N/A	N/A	82328	20902

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TABLE II-2 ANNUAL IMPORTS, EXPORTS, AND NET EVAPORATION

(REGIONS 1-21) NATIONAL SUMMARY

(MILLION GALLONS PER DAY)

REGION	IMPORTS			EXPORTS			NET EVAPORATION: RESERVOIRS			NET EVAPORATION: FARM/STOCK PONDS		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
1	179	251	319	179	251	319	0	0	0	0	0	0
2	2070	2070	2070	1591	1591	1591	0	0	0	0	0	0
3	125	125	125	131	131	131	0	0	0	0	0	0
4	19	19	19	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	2064	2064	2064	0	0	0	37	37	37	6	8	9
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	58	641	0	0	0	11	11	11	5	7	8
10	411	551	1106	0	118	1243	3954	3954	3954	970	1370	1641
11	158	207	230	30	30	30	1898	1898	1898	717	1012	1213
12	401	401	401	371	371	371	1289	1289	1289	416	586	703
13	234	199	199	0	0	0	653	653	653	77	111	132
14	0	0	0	805	985	1095	688	688	688	23	33	40
15	35	45	136	4498	4129	4032	1153	1153	1153	49	69	83
16	103	179	253	2	2	2	317	317	317	10	14	16
17	47	47	47	0	0	0	1915	1915	1915	99	140	168
18	10426	11932	13130	5988	7863	9249	646	646	646	23	33	40
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	1	1	1	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
NATION (1-18)	16272	18148	20740	13595	15471	18063	12561	12561	12561	2395	3383	4053
NATION (1-21)	16272	18148	20740	13595	15471	18063	12562	12562	12562	2395	3383	4053

TABLE II-3 ANNUAL INSTREAM FLOW USES

(REGIONS 1-21) NATIONAL SUMMARY

(MILLION GALLONS PER DAY)

REGION		FISH AND WILDLIFE (IFA)*			NAVIGATION*			TREATIES AND COMPACTS		
		"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
NEW ENGLAND	1	69001	69001	69001	N/A	N/A	N/A	0	0	0
MID-ATLANTIC	2	68840	68840	68840	N/A	N/A	N/A	1131	1131	1131
SOUTH ATLANTIC-GULF	3	188655	188655	188655	N/A	N/A	N/A	0	0	0
GREAT LAKES	4	63951	63951	63951	N/A	N/A	N/A	0	0	0
OHIO	5	160520	160520	160520	410	530	645	0	0	0
TENNESSEE	6	38480	38480	38480	16100	16100	16100	0	0	0
UPPER MISSISSIPPI	7	110750	110750	110750	34880	34880	34880	0	0	0
LOWER MISSISSIPPI	8	359033	359033	359033	119500	119500	119500	0	0	0
SOURIS-RED-RAINY	9	3673	3673	3673	0	0	0	0	0	0
MISSOURI	10	33958	33958	33958	25840	25840	25840	0	0	0
ARKANSAS-WHITE-RED	11	46169	46169	46169	N/A	N/A	N/A	0	0	0
TEXAS-GULF	12	22917	22917	22917	N/A	N/A	N/A	0	0	0
RIO GRANDE	13	2287	2287	2287	N/A	N/A	N/A	0	0	0
UPPER COLORADO	14	7947	7947	7947	0	0	0	6700	6700	6700
LOWER COLORADO	15	6864	6864	6864	0	0	0	1340	1340	1340
GREAT BASIN	16	3389	3389	3389	0	0	0	0	0	0
PACIFIC NORTHWEST	17	214004	214004	214004	N/A	N/A	N/A	0	0	0
CALIFORNIA	18	32607	32607	32607	N/A	N/A	N/A	0	0	0
ALASKA	19	859000	859000	859000	N/A	N/A	N/A	0	0	0
HAWAII	20	4590	4590	4590	0	0	0	0	0	0
CARIBBEAN	21	3706	3706	3706	0	0	0	0	0	0
NATIONAL TOTAL REGIONS 1-18		1035221	1035221	1035221	N/A	N/A	N/A	2471	2471	2471
NATIONAL TOTAL REGIONS 1-21		1902517	1902517	1902517	N/A	N/A	N/A	2471	2471	2471

* (IFA) INSTREAM FLOW APPROXIMATIONS AS DEFINED IN EXPLANATORY NOTES. FOR USE ONLY IN SECOND NATIONAL WATER ASSESSMENT
* NAVIGATION INSTREAM FLOW DATA WERE LIMITED TO THE MISSISSIPPI RIVER AND GULF INTRACOASTAL WATERWAY SYSTEM

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

(REGIONS 1-21) — BASE CONDITIONS — NATIONAL SUMMARY

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
AGRICULTURE	160655	168485	156397	88303	95053	95057
IRRIGATION	158743	166252	153846	86391	92820	92506
LIVESTOCK	1912	2233	2551	1912	2233	2551
STEAM ELECT	88916	94858	79492	1419	4062	10541
MANUFACT	51222	23687	19669	6059	8903	14699
PRIM METALS	17571	5714	3451	1951	2305	2732
CHEMICALS	13458	5719	5231	1316	2208	4089
PAPER	8438	5995	5376	1058	2020	4256
FOOD	2579	1486	1169	388	525	792
PETROLEUM	2528	1499	1225	551	662	976
TRANSPORT	1333	595	479	161	249	366
TEXTILES	561	266	212	66	94	145
ALL OTHER	4754	2413	2526	568	840	1343
DOMESTIC	23256	26303	30318	6268	7073	8074
CENTRAL	21164	23983	27918	4976	5665	6638
NONCENTRAL	2092	2320	2400	1292	1408	1436
COMMERCIAL	5530	6048	6732	1109	1216	1369
MINERALS	7055	8832	11328	2196	2777	3609
NONMETALS	3686	4560	6123	543	686	1021
FUELS	2552	3219	3844	1359	1688	2075
METALS	817	1053	1361	294	403	513
PUBLIC LANDS	1239	1466	1737	1236	1461	1731
BLM LANDS	1050	1130	1231	1050	1130	1231
NAT FORESTS	177	319	483	177	319	483
NAT PARKS	12	17	23	9	12	17
FISH HATCH	627	696	724	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	338500	330375	306397	106590	120545	135080
TOT SALINE	59737	91236	118815			
FRESH (BASE) + SALINE	398237	421611	425212			

(REGIONS 1-18) — CONTIGUOUS U S

AGRICULTURE	158681	166754	155108	87543	94269	94371
IRRIGATION	156776	164532	152572	85638	92047	91835
LIVESTOCK	1905	2222	2536	1905	2222	2536
STEAM ELECT	88880	94838	79481	1419	4060	10536
MANUFACT	50836	23413	19444	5959	8774	14519
PRIM METALS	17571	5714	3451	1951	2305	2732
CHEMICALS	13454	5715	5226	1314	2205	4085
PAPER	8314	5909	5298	1034	1983	4194
FOOD	2333	1312	1037	318	442	686
PETROLEUM	2522	1492	1218	548	658	970
TRANSPORT	1333	595	479	161	249	366
TEXTILES	561	266	212	66	94	145
ALL OTHER	4748	2410	2523	567	838	1341
DOMESTIC	22713	25650	29518	6169	6952	7926
CENTRAL	20641	23358	27156	4889	5562	6512
NONCENTRAL	2072	2292	2362	1280	1390	1414
COMMERCIAL	5450	5951	6616	1088	1191	1339
MINERALS	6993	8602	10805	2180	2631	3253
NONMETALS	3651	4517	6069	539	681	1015
FUELS	2540	3086	3502	1348	1568	1767
METALS	802	999	1234	293	382	471
PUBLIC LANDS	1229	1456	1717	1226	1451	1711
BLM LANDS	1050	1130	1231	1050	1130	1231
NAT FORESTS	167	309	463	167	309	463
NAT PARKS	12	17	23	9	12	17
FISH HATCH	627	696	724	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	335409	327360	303413	105584	119328	133655
TOT SALINE	57417	86853	112470			
FRESH (BASE) + SALINE	392826	414213	415883			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION			
	"1975"	1985	2000	"1975"	1985	2000	
NEW ENGLAND REGION							REGION 1
AGRICULTURE	53	60	65	43	48	52	
IRRIGATION	35	41	46	25	29	33	
LIVESTOCK	18	19	19	18	19	19	
STEAM ELECT	1263	1069	375	21	18	167	
MANUFACT	2170	1022	781	192	332	567	
PRIM METALS	132	36	20	4	8	14	
CHEMICALS	109	66	55	15	27	42	
PAPER	962	520	395	86	158	313	
FOOD	56	30	23	9	11	15	
PETROLEUM	16	8	5	3	4	4	
TRANSPORT	341	97	61	26	37	48	
TEXTILES	45	12	5	2	4	4	
ALL OTHER	509	253	217	47	83	127	
DOMESTIC	1122	1223	1356	164	179	196	
CENTRAL	1011	1097	1222	96	103	114	
NONCENTRAL	111	126	134	68	76	82	
COMMERCIAL	361	393	442	48	52	58	
MINERALS	90	115	153	11	16	20	
NONMETALS	87	112	149	11	16	20	
FUELS	0	0	0	0	0	0	
METALS	3	3	4	<1	<1	<1	
PUBLIC LANDS	2	2	3	2	2	3	
BLM LANDS	0	0	0	0	0	0	
NAT FORESTS	2	2	3	2	2	3	
NAT PARKS	0	0	0	0	0	0	
FISH HATCH	37	55	55	0	0	0	
MISC OTHER	0	0	0	0	0	0	
TOTAL (BASE) FRESHWATER	5098	3939	3230	481	647	1063	
TOT SALINE	5216	14604	10161				
FRESH (BASE) + SALINE	10314	18543	13391				
MID-ATLANTIC REGION							REGION 2
AGRICULTURE	333	435	552	264	338	425	
IRRIGATION	265	366	481	196	269	354	
LIVESTOCK	68	69	71	68	69	71	
STEAM ELECT	7463	7130	4657	103	224	644	
MANUFACT	5416	2526	1942	607	934	1361	
PRIM METALS	1124	616	365	173	239	288	
CHEMICALS	1850	686	568	179	301	429	
PAPER	745	460	389	76	146	305	
FOOD	271	172	130	45	61	78	
PETROLEUM	562	228	137	71	87	109	
TRANSPORT	67	46	32	6	15	24	
TEXTILES	37	17	12	3	5	7	
ALL OTHER	760	301	309	54	80	121	
DOMESTIC	3954	4467	5168	705	790	896	
CENTRAL	3627	4095	4758	505	565	650	
NONCENTRAL	327	372	410	200	225	246	
COMMERCIAL	650	726	826	91	101	114	
MINERALS	459	548	700	70	82	102	
NONMETALS	424	514	662	56	69	88	
FUELS	21	19	22	12	11	12	
METALS	14	15	16	2	2	2	
PUBLIC LANDS	4	4	7	3	3	6	
BLM LANDS	0	0	0	0	0	0	
NAT FORESTS	2	2	4	2	2	4	
NAT PARKS	2	2	3	1	1	2	
FISH HATCH	21	21	21	0	0	0	
MISC OTHER	0	0	0	0	0	0	
TOTAL (BASE) FRESHWATER	18300	15857	13873	1843	2472	3548	
TOT SALINE	19625	28634	26208				
FRESH (BASE) + SALINE	37925	44491	40081				

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
SOUTH ATLANTIC–GULF REGION						REGION 3
AGRICULTURE	3598	4174	4711	2886	3350	3799
IRRIGATION	3464	4008	4509	2752	3184	3597
LIVESTOCK	134	166	202	134	166	202
STEAM ELECT	12768	12912	13952	153	722	1857
MANUFACT	4103	3377	3318	611	1203	2532
PRIM METALS	270	189	145	51	73	115
CHEMICALS	870	668	748	165	317	589
PAPER	2111	1974	1875	262	614	1492
FOOD	142	99	91	15	28	59
PETROLEUM	28	32	25	12	15	20
TRANSPORT	19	14	34	4	17	26
TEXTILES	427	200	157	50	68	107
ALL OTHER	236	201	243	52	71	124
DOMESTIC	2288	2801	3486	880	1079	1345
CENTRAL	1931	2369	3005	657	816	1057
NONCENTRAL	357	432	481	223	263	288
COMMERCIAL	553	632	769	118	138	161
MINERALS	1178	1538	2077	214	274	349
NONMETALS	1105	1446	1983	158	207	284
FUELS	68	85	86	55	66	64
METALS	5	7	8	1	1	1
PUBLIC LANDS	5	6	10	5	6	10
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	5	6	10	5	6	10
NAT PARKS	0	0	0	0	0	0
FISH HATCH	17	17	17	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	24510	25457	28340	4867	6772	10053
TOT SALINE	7460	14976	20239			
FRESH (BASE) + SALINE	31970	40433	48579			
GREAT LAKES REGION						REGION 4
AGRICULTURE	230	296	369	199	254	319
IRRIGATION	145	211	282	114	169	232
LIVESTOCK	85	85	87	85	85	87
STEAM ELECT	24362	22689	16061	175	497	1384
MANUFACT	13220	4106	2821	1474	1719	2059
PRIM METALS	7545	2212	1282	1030	1069	1017
CHEMICALS	1939	425	335	71	131	255
PAPER	982	534	427	143	213	334
FOOD	354	153	116	38	48	68
PETROLEUM	687	141	95	51	56	74
TRANSPORT	657	273	204	80	111	155
TEXTILES	0	0	0	0	0	0
ALL OTHER	1056	368	362	61	91	156
DOMESTIC	3267	3614	4077	476	519	563
CENTRAL	2946	3264	3717	280	308	349
NONCENTRAL	321	350	360	196	211	214
COMMERCIAL	1010	1091	1206	113	123	140
MINERALS	696	831	1044	155	175	211
NONMETALS	451	563	734	62	74	99
FUELS	14	18	21	8	10	11
METALS	231	250	289	85	91	101
PUBLIC LANDS	6	13	17	6	13	17
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	6	13	17	6	13	17
NAT PARKS	0	0	0	0	0	0
FISH HATCH	22	26	28	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	42813	32666	25623	2598	3300	4693
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	42813	32666	25623			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
OHIO REGION						REGION 5
AGRICULTURE	160	195	230	150	180	213
IRRIGATION	47	68	91	37	53	74
LIVESTOCK	113	127	139	113	127	139
STEAM ELECT	21022	21008	10574	324	656	1692
MANUFACT	10881	3323	2341	817	1095	1757
PRIM METALS	6346	1833	1050	467	607	834
CHEMICALS	3261	745	593	168	215	464
PAPER	224	151	133	23	46	101
FOOD	124	71	56	17	24	34
PETROLEUM	114	52	48	23	27	38
TRANSPORT	89	75	70	21	32	55
TEXTILES	7	4	3	1	1	2
ALL OTHER	716	392	388	97	143	229
DOMESTIC	1842	2068	2343	349	389	424
CENTRAL	1561	1751	2013	175	196	227
NONCENTRAL	281	317	330	174	193	197
COMMERCIAL	495	529	571	62	67	74
MINERALS	493	662	808	91	132	160
NONMETALS	308	372	471	34	50	64
FUELS	183	288	334	57	82	96
METALS	2	2	3	<1	<1	<1
PUBLIC LANDS	5	8	12	5	8	12
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	5	8	12	5	8	12
NAT PARKS	0	0	0	0	0	0
FISH HATCH	36	45	46	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	34934	27838	16925	1798	2527	4332
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	34934	27838	16925			
TENNESSEE REGION						REGION 6
AGRICULTURE	41	50	58	38	46	54
IRRIGATION	14	18	21	11	14	17
LIVESTOCK	27	32	37	27	32	37
STEAM ELECT	4799	5738	4581	42	231	417
MANUFACT	2093	765	671	147	266	514
PRIM METALS	77	43	33	12	16	25
CHEMICALS	1520	396	336	81	145	262
PAPER	381	268	246	41	85	196
FOOD	19	10	8	1	2	5
PETROLEUM	0	0	0	0	0	0
TRANSPORT	0	0	0	0	0	0
TEXTILES	31	21	19	8	11	14
ALL OTHER	65	27	29	4	7	12
DOMESTIC	263	319	383	59	69	76
CENTRAL	210	259	323	26	32	39
NONCENTRAL	53	60	60	33	37	37
COMMERCIAL	90	102	116	11	12	14
MINERALS	110	140	186	15	21	27
NONMETALS	86	108	144	12	15	20
FUELS	8	14	21	1	3	4
METALS	16	18	21	2	3	3
PUBLIC LANDS	1	2	3	1	2	3
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	1	2	3	1	2	3
NAT PARKS	0	0	0	0	0	0
FISH HATCH	15	15	15	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	7412	7131	6013	313	647	1105
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	7412	7131	6013			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
UPPER MISSISSIPPI REGION						REGION 7
AGRICULTURE	422	566	691	383	513	627
IRRIGATION	192	283	387	153	230	323
LIVESTOCK	230	283	304	230	283	304
STEAM ELECT	7644	6347	3537	129	352	1079
MANUFACT	2030	886	728	240	309	506
PRIM METALS	315	135	95	41	41	75
CHEMICALS	384	143	131	54	61	99
PAPER	348	140	104	20	38	80
FOOD	506	234	169	62	81	118
PETROLEUM	50	36	33	18	19	26
TRANSPORT	26	23	22	5	9	16
TEXTILES	0	0	0	0	0	0
ALL OTHER	401	175	174	40	60	92
DOMESTIC	1450	1609	1808	282	302	324
CENTRAL	1280	1440	1653	178	200	231
NONCENTRAL	170	169	155	104	102	93
COMMERCIAL	515	552	603	63	67	74
MINERALS	333	417	533	46	58	74
NONMETALS	268	334	427	35	45	57
FUELS	20	33	48	4	6	9
METALS	45	50	58	7	7	8
PUBLIC LANDS	2	3	4	2	3	4
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	2	3	4	2	3	4
NAT PARKS	0	0	0	0	0	0
FISH HATCH	5	6	6	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	12401	10386	7910	1145	1604	2688
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	12401	10386	7910			
LOWER MISSISSIPPI REGION						REGION 8
AGRICULTURE	4624	4613	4507	3109	3258	3335
IRRIGATION	4580	4559	4444	3065	3204	3272
LIVESTOCK	44	54	63	44	54	63
STEAM ELECT	4175	9313	16687	54	118	291
MANUFACT	4163	1634	1365	314	552	1067
PRIM METALS	535	101	58	29	36	46
CHEMICALS	2251	734	635	141	264	504
PAPER	517	403	381	46	119	304
FOOD	209	104	71	17	29	52
PETROLEUM	441	220	150	66	80	119
TRANSPORT	3	3	3	1	1	2
TEXTILES	13	10	11	1	4	8
ALL OTHER	194	59	56	13	19	32
DOMESTIC	655	721	790	294	319	344
CENTRAL	595	657	729	255	279	307
NONCENTRAL	60	64	61	39	40	37
COMMERCIAL	150	159	170	49	51	54
MINERALS	799	1010	1318	206	253	416
NONMETALS	141	157	242	36	38	114
FUELS	644	841	1065	167	212	299
METALS	14	12	11	3	3	3
PUBLIC LANDS	1	3	4	1	3	4
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	1	3	4	1	3	4
NAT PARKS	0	0	0	0	0	0
FISH HATCH	<1	<1	<1	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	14567	17453	24841	4027	4554	5511
TOT SALINE	1253	1590	10181			
FRESH (BASE) + SALINE	15820	19043	35022			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
SOURIS-RED-RAINY REGION						REGION 9
AGRICULTURE	72	177	471	63	149	387
IRRIGATION	46	144	434	37	116	350
LIVESTOCK	26	33	37	26	33	37
STEAM ELECT	82	23	0	1	0	0
MANUFACT	102	44	31	13	19	23
PRIM METALS	0	0	0	0	0	0
CHEMICALS	0	0	0	0	0	0
PAPER	86	33	22	9	13	17
FOOD	15	10	8	4	5	5
PETROLEUM	0	0	0	0	0	0
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	1	1	1	0	1	1
DOMESTIC	53	56	56	25	25	25
CENTRAL	41	44	47	17	18	19
NONCENTRAL	12	12	9	8	7	6
COMMERCIAL	15	15	14	6	6	6
MINERALS	8	9	10	3	3	3
NONMETALS	4	5	6	1	1	1
FUELS	4	4	4	2	2	2
METALS	0	0	0	0	0	0
PUBLIC LANDS	1	2	2	1	2	2
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	1	2	2	1	2	2
NAT PARKS	0	0	0	0	0	0
FISH HATCH	3	3	3	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	336	329	587	112	204	446
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	336	329	587			
MISSOURI REGION						REGION 10
AGRICULTURE	32086	39935	36894	14664	18156	18265
IRRIGATION	31636	39376	36236	14214	17597	17607
LIVESTOCK	450	559	658	450	559	658
STEAM ELECT	3540	5834	4938	68	239	637
MANUFACT	669	315	292	136	122	202
PRIM METALS	89	23	14	8	10	11
CHEMICALS	188	83	88	68	35	69
PAPER	2	3	5	0	1	4
FOOD	187	113	92	23	36	65
PETROLEUM	91	36	29	20	19	24
TRANSPORT	7	8	9	3	4	7
TEXTILES	0	0	0	0	0	0
ALL OTHER	105	49	55	14	17	22
DOMESTIC	961	1045	1161	262	280	302
CENTRAL	872	959	1083	207	227	256
NONCENTRAL	89	86	78	55	53	46
COMMERCIAL	285	306	336	69	72	78
MINERALS	269	356	424	111	139	163
NONMETALS	91	116	143	10	12	14
FUELS	144	198	236	96	122	142
METALS	34	42	45	5	5	7
PUBLIC LANDS	159	198	266	159	198	266
BLM LANDS	107	121	140	107	121	140
NAT FORESTS	50	75	123	50	75	123
NAT PARKS	2	2	3	2	2	3
FISH HATCH	47	48	48	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	38016	48037	44359	15469	19206	19913
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	38016	48037	44359			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
ARKANSAS-WHITE-RED REGION						REGION 11
AGRICULTURE	10195	10721	10055	7263	7706	7404
IRRIGATION	9980	10483	9776	7048	7468	7125
LIVESTOCK	215	238	279	215	238	279
STEAM ELECT	498	1026	1012	89	237	457
MANUFACT	713	476	480	165	232	360
PRIM METALS	137	84	62	18	29	49
CHEMICALS	162	94	102	43	63	81
PAPER	200	125	110	30	50	86
FOOD	54	28	25	7	9	15
PETROLEUM	74	75	94	44	51	75
TRANSPORT	0	0	0	0	0	0
TEXTILES	1	2	5	1	1	3
ALL OTHER	85	68	82	22	29	51
DOMESTIC	735	807	894	279	305	331
CENTRAL	667	737	830	236	262	293
NONCENTRAL	68	70	64	43	43	38
COMMERCIAL	210	221	238	69	72	78
MINERALS	448	469	571	173	184	218
NONMETALS	222	209	289	52	46	73
FUELS	172	190	185	114	128	130
METALS	54	70	97	7	10	15
PUBLIC LANDS	26	33	39	26	33	39
BLM LANDS	20	21	21	20	21	21
NAT FORESTS	6	12	18	6	12	18
NAT PARKS	0	0	0	0	0	0
FISH HATCH	43	46	48	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	12868	13799	13337	8064	8769	8887
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	12868	13799	13337			
TEXAS-GULF REGION						REGION 12
AGRICULTURE	11718	9530	7655	9527	7794	6328
IRRIGATION	11538	9333	7427	9347	7597	6100
LIVESTOCK	180	197	228	180	197	228
STEAM ELECT	724	1000	1713	99	270	991
MANUFACT	1932	2559	2444	571	1003	1917
PRIM METALS	588	242	162	60	99	129
CHEMICALS	586	1490	1448	271	549	1151
PAPER	245	200	218	38	79	174
FOOD	66	55	54	11	21	38
PETROLEUM	312	496	479	170	224	382
TRANSPORT	89	24	15	6	9	12
TEXTILES	0	0	0	0	0	0
ALL OTHER	46	52	68	15	22	31
DOMESTIC	1207	1380	1621	413	467	541
CENTRAL	1152	1320	1565	379	431	508
NONCENTRAL	55	60	56	34	36	33
COMMERCIAL	283	317	300	94	103	118
MINERALS	1044	1133	1245	555	588	632
NONMETALS	187	198	275	20	20	29
FUELS	837	902	930	532	564	598
METALS	20	33	40	3	4	5
PUBLIC LANDS	<1	2	2	<1	2	2
BLM LANDS	<1	<1	<1	<1	<1	<1
NAT FORESTS	<1	2	2	<1	2	2
NAT PARKS	0	0	0	0	0	0
FISH HATCH	17	11	11	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	16925	15932	14991	11259	10227	10529
TOT SALINE	9163	4950	10371			
FRESH (BASE) + SALINE	26088	20882	25362			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
RIO GRANDE REGION						REGION 13
AGRICULTURE	5722	5537	4917	3924	3959	3614
IRRIGATION	5684	5498	4873	3886	3920	3570
LIVESTOCK	38	39	44	38	39	44
STEAM ELECT	34	16	10	18	9	5
MANUFACT	19	42	32	5	15	24
PRIM METALS	10	6	4	1	2	3
CHEMICALS	1	31	22	0	10	17
PAPER	0	0	0	0	0	0
FOOD	0	0	0	0	0	0
PETROLEUM	0	0	0	0	0	0
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	8	5	6	4	3	4
DOMESTIC	265	287	312	138	150	163
CENTRAL	254	276	301	132	144	158
NONCENTRAL	11	11	11	6	6	5
COMMERCIAL	62	65	68	30	31	32
MINERALS	190	221	255	103	129	150
NONMETALS	28	46	64	14	29	43
FUELS	153	151	147	86	90	88
METALS	9	24	44	3	10	19
PUBLIC LANDS	22	27	28	22	27	28
BLM LANDS	22	25	26	22	25	26
NAT FORESTS	<1	<1	<1	<1	<1	<1
NAT PARKS	<1	2	2	<1	2	2
FISH HATCH	7	9	11	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	6321	6204	5633	4240	4320	4016
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	6321	6204	5633			
UPPER COLORADO REGION						REGION 14
AGRICULTURE	6427	7254	6706	2221	2688	2775
IRRIGATION	6400	7223	6672	2194	2657	2741
LIVESTOCK	27	31	34	27	31	34
STEAM ELECT	103	157	201	39	106	151
MANUFACT	4	2	2	2	1	2
PRIM METALS	0	0	0	0	0	0
CHEMICALS	0	0	0	0	0	0
PAPER	0	0	0	0	0	0
FOOD	0	0	0	0	0	0
PETROLEUM	4	1	1	2	0	1
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	0	1	1	0	1	1
DOMESTIC	70	76	83	25	27	29
CENTRAL	67	73	80	22	24	27
NONCENTRAL	3	3	3	3	3	2
COMMERCIAL	10	10	11	3	4	4
MINERALS	132	195	355	47	72	144
NONMETALS	45	68	127	6	10	20
FUELS	68	97	171	38	56	111
METALS	19	30	57	3	6	13
PUBLIC LANDS	103	120	127	103	120	127
BLM LANDS	98	110	113	98	110	113
NAT FORESTS	3	7	11	3	7	11
NAT PARKS	2	3	3	2	3	3
FISH HATCH	20	27	34	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	6869	7841	7519	2440	3018	3232
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	6869	7841	7519			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
LOWER COLORADO REGION						REGION 15
AGRICULTURE	8036	7351	6403	4073	4014	3780
IRRIGATION	7989	7299	6343	4026	3962	3720
LIVESTOCK	47	52	60	47	52	60
STEAM ELECT	68	150	154	63	134	126
MANUFACT	89	92	138	55	54	104
PRIM METALS	13	8	6	12	3	5
CHEMICALS	8	7	13	5	5	9
PAPER	15	18	26	3	8	22
FOOD	19	10	8	14	4	6
PETROLEUM	1	1	0	1	0	0
TRANSPORT	10	8	7	5	6	5
TEXTILES	0	0	0	0	0	0
ALL OTHER	23	40	78	15	28	57
DOMESTIC	423	520	658	199	245	310
CENTRAL	416	512	649	195	240	304
NONCENTRAL	7	8	9	4	5	6
COMMERCIAL	75	92	114	35	43	54
MINERALS	184	252	311	151	217	280
NONMETALS	27	40	53	8	19	44
FUELS	7	6	8	5	4	5
METALS	150	206	250	138	194	231
PUBLIC LANDS	20	49	56	19	47	54
BLM LANDS	17	30	34	17	30	34
NAT FORESTS	<1	15	17	<1	15	17
NAT PARKS	3	4	5	2	2	3
FISH HATCH	22	22	23	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	8917	8528	7857	4595	4754	4708
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	8917	8528	7857			
GREAT BASIN REGION						REGION 16
AGRICULTURE	7002	6154	5861	3258	3116	3232
IRRIGATION	6969	6120	5825	3225	3082	3196
LIVESTOCK	33	34	36	33	34	36
STEAM ELECT	33	65	82	3	42	52
MANUFACT	112	93	98	24	42	77
PRIM METALS	75	65	68	12	26	54
CHEMICALS	14	5	5	2	3	4
PAPER	0	0	0	0	0	0
FOOD	10	9	8	3	5	6
PETROLEUM	8	7	7	4	4	6
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	5	7	10	3	4	7
DOMESTIC	340	399	475	130	151	178
CENTRAL	333	391	468	126	146	174
NONCENTRAL	7	8	7	4	5	4
COMMERCIAL	38	45	55	17	19	22
MINERALS	145	206	273	28	44	64
NONMETALS	22	36	58	3	7	12
FUELS	1	1	1	<1	<1	<1
METALS	122	169	214	25	37	52
PUBLIC LANDS	319	351	411	319	351	411
BLM LANDS	310	330	377	310	330	377
NAT FORESTS	9	21	34	9	21	34
NAT PARKS	0	0	0	0	0	0
FISH HATCH	2	3	3	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	7991	7316	7258	3779	3765	4036
TOT SALINE	0	0	0			
FRESH (BASE) + SALINE	7991	7316	7258			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
PACIFIC NORTHWEST REGION						REGION 17
AGRICULTURE	33253	34725	30063	11098	13448	13315
IRRIGATION	33181	34639	29961	11026	13362	13213
LIVESTOCK	72	86	102	72	86	102
STEAM ELECT	260	203	580	13	104	344
MANUFACT	2324	1321	1132	329	501	880
PRIM METALS	281	89	55	20	29	43
CHEMICALS	260	73	65	30	42	49
PAPER	1326	868	739	197	312	588
FOOD	112	68	56	11	19	41
PETROLEUM	11	12	15	6	8	13
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	334	211	202	65	91	146
DOMESTIC	804	863	957	210	220	238
CENTRAL	720	776	874	157	168	188
NONCENTRAL	84	87	83	53	52	50
COMMERCIAL	274	282	307	55	56	60
MINERALS	118	141	167	18	19	27
NONMETALS	57	75	91	8	9	14
FUELS	3	4	6	2	2	4
METALS	58	62	70	8	8	9
PUBLIC LANDS	190	262	332	190	262	332
BLM LANDS	156	163	165	156	163	165
NAT FORESTS	33	98	164	33	98	164
NAT PARKS	1	1	3	1	1	3
FISH HATCH	272	301	314	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	37495	38098	33852	11913	14610	15196
TOT SALINE	131	9	10652			
FRESH (BASE) + SALINE	37626	38107	44504			
CALIFORNIA REGION						REGION 18
AGRICULTURE	34709	34981	34900	24380	25252	26447
IRRIGATION	34611	34863	34764	24282	25134	26311
LIVESTOCK	98	118	136	98	118	136
STEAM ELECT	42	158	367	25	101	242
MANUFACT	796	830	828	257	375	567
PRIM METALS	34	32	32	13	18	24
CHEMICALS	51	69	82	21	37	61
PAPER	170	212	228	60	101	178
FOOD	189	146	122	41	59	81
PETROLEUM	123	147	100	57	64	79
TRANSPORT	25	24	22	4	8	16
TEXTILES	0	0	0	0	0	0
ALL OTHER	204	200	242	61	88	128
DOMESTIC	3014	3395	3890	1279	1436	1641
CENTRAL	2958	3338	3839	1246	1403	1611
NONCENTRAL	56	57	51	33	33	30
COMMERCIAL	374	414	470	155	174	198
MINERALS	297	359	375	183	225	213
NONMETALS	98	118	151	13	14	19
FUELS	193	235	217	169	210	192
METALS	6	6	7	1	1	2
PUBLIC LANDS	363	371	394	362	369	391
BLM LANDS	320	330	355	320	330	355
NAT FORESTS	41	38	35	41	38	35
NAT PARKS	2	3	4	1	1	1
FISH HATCH	41	41	41	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	39636	40549	41265	26641	27932	29699
TOT SALINE	14569	22090	24658			
FRESH (BASE) + SALINE	54205	62639	65923			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
ALASKA REGION						REGION 19
AGRICULTURE	4	4	5	3	3	4
IRRIGATION	4	4	4	3	3	3
LIVESTOCK	<1	<1	1	<1	<1	1
STEAM ELECT	36	20	11	0	2	5
MANUFACT	134	93	86	26	41	68
PRIM METALS	0	0	0	0	0	0
CHEMICALS	4	4	5	2	3	4
PAPER	124	86	78	24	37	62
FOOD	0	0	0	0	0	0
PETROLEUM	1	1	1	0	0	1
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	5	2	2	0	1	1
DOMESTIC	84	105	137	6	8	10
CENTRAL	80	101	132	4	5	7
NONCENTRAL	4	4	5	2	3	3
COMMERCIAL	7	9	10	1	2	2
MINERALS	30	192	476	12	141	350
NONMETALS	3	5	7	0	0	0
FUELS	12	133	342	11	120	308
METALS	15	54	127	1	21	42
PUBLIC LANDS	10	10	20	10	10	20
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	10	10	20	10	10	20
NAT PARKS	0	0	0	0	0	0
FISH HATCH	0	0	0	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	305	433	745	58	207	459
TOT SALINE	57	41	420			
FRESH (BASE) + SALINE	362	474	1165			
HAWAII REGION						REGION 20
AGRICULTURE	1449	1229	954	476	484	476
IRRIGATION	1447	1226	951	474	481	473
LIVESTOCK	2	3	3	2	3	3
STEAM ELECT	0	0	0	0	0	0
MANUFACT	252	181	139	74	88	112
PRIM METALS	0	0	0	0	0	0
CHEMICALS	0	0	0	0	0	0
PAPER	0	0	0	0	0	0
FOOD	246	174	132	70	83	106
PETROLEUM	5	6	6	3	4	5
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	1	1	1	1	1	1
DOMESTIC	148	172	209	44	52	63
CENTRAL	148	172	209	44	52	63
NONCENTRAL	<1	<1	<1	<1	<1	<1
COMMERCIAL	29	36	46	11	12	15
MINERALS	1	1	1	0	0	0
NONMETALS	1	1	1	0	0	0
FUELS	0	0	0	0	0	0
METALS	0	0	0	0	0	0
PUBLIC LANDS	0	0	0	0	0	0
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	0	0	0	0	0	0
NAT PARKS	0	0	0	0	0	0
FISH HATCH	0	0	0	0	0	0
MISC. OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	1879	1619	1349	605	636	666
TOT SALINE	1139	2005	3637			
FRESH (BASE) + SALINE	3018	3624	4986			

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TABLE II-4 ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES

BASE CONDITIONS

(MILLION GALLONS PER DAY)

	TOTAL WITHDRAWALS			TOTAL CONSUMPTION		
	"1975"	1985	2000	"1975"	1985	2000
CARIBBEAN REGION						REGION 21
AGRICULTURE	521	498	330	281	297	206
IRRIGATION	516	490	319	276	289	195
LIVESTOCK	5	8	11	5	8	11
STEAM ELECT	0	0	0	0	0	0
MANUFACT	0	0	0	0	0	0
PRIM METALS	0	0	0	0	0	0
CHEMICALS	0	0	0	0	0	0
PAPER	0	0	0	0	0	0
FOOD	0	0	0	0	0	0
PETROLEUM	0	0	0	0	0	0
TRANSPORT	0	0	0	0	0	0
TEXTILES	0	0	0	0	0	0
ALL OTHER	0	0	0	0	0	0
DOMESTIC	311	376	454	49	61	75
CENTRAL	295	352	421	39	46	56
NONCENTRAL	16	24	33	10	15	19
COMMERCIAL	44	52	60	9	11	13
MINERALS	31	37	46	4	5	6
NONMETALS	31	37	46	4	5	6
FUELS	0	0	0	0	0	0
METALS	0	0	0	0	0	0
PUBLIC LANDS	0	0	0	0	0	0
BLM LANDS	0	0	0	0	0	0
NAT FORESTS	0	0	0	0	0	0
NAT PARKS	0	0	0	0	0	0
FISH HATCH	0	0	0	0	0	0
MISC OTHER	0	0	0	0	0	0
TOTAL (BASE) FRESHWATER	907	963	890	343	374	300
TOT SALINE	1124	2337	2288			
FRESH (BASE) + SALINE	2031	3300	3178			

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TABLE II-5 ANNUAL WATER ADEQUACY ANALYSIS

(REGIONS 1-21) BASE CONDITIONS NATIONAL SUMMARY

REGION		INSTREAM (01)* FISH + WILDLIFE (MGD)	INSTREAM (02) NAVIGATION (MGD)	(03) CONSUMPTION ABOVE INFLOW POINTS	(04) CONSUMPTION WITHIN HYDRO UNIT	OFFSTREAM (MILLION GALLONS PER DAY) (05) NET EXPORTS (EXPORTS - IMPORTS) ABOVE INFLOW POINTS	(06) NET EXPORTS (EXPORTS - IMPORTS) WITHIN HYDRO UNIT	(07)* CHANGE OF (05+06) FROM 1975	(08)* INCREASE OF (05+06) FROM 1975	(09) NET EVAPORATION ABOVE INFLOW POINTS	(10) NET EVAPORATION WITHIN HYDRO UNIT	(11) NET EVAPORATION CHANGE OF (09+10) FROM 1975	(12) OFFSTREAM USE (03+04 +08+11)
1	"1975"	69001	N/A	0	481	0	0	0	0	0	0	0	481
	1985	69001	N/A	0	647	0	0	0	0	0	0	0	647
	2000	69001	N/A	0	1063	0	0	0	0	0	0	0	1063
2	"1975"	68840	N/A	0	1843	0	-479	0	0	0	0	0	1843
	1985	68840	N/A	0	2472	0	-479	0	0	0	0	0	2472
	2000	68840	N/A	0	3548	0	-479	0	0	0	0	0	3548
3	"1975"	188655	N/A	0	4867	0	6	0	0	0	0	0	4867
	1985	188655	N/A	0	6772	0	6	0	0	0	0	0	6772
	2000	188655	N/A	0	10053	0	6	0	0	0	0	0	10053
4	"1975"	63951	N/A	0	2598	0	-19	0	0	0	0	0	2598
	1985	63951	N/A	0	3300	0	-19	0	0	0	0	0	3300
	2000	63951	N/A	0	4693	0	-19	0	0	0	0	0	4693
5	"1975"	160520	410	313	1798	0	0	0	0	0	0	0	2111
	1985	160520	530	647	2527	0	0	0	0	0	0	0	3174
	2000	160520	645	1105	4332	0	0	0	0	0	0	0	5437
6	"1975"	38480	16100	0	313	0	0	0	0	0	0	0	313
	1985	38480	16100	0	647	0	0	0	0	0	0	0	647
	2000	38480	16100	0	1105	0	0	0	0	0	0	0	1105
7	"1975"	110750	34880	15469	1145	-411	-2064	0	0	4924	43	0	16614
	1985	110750	34880	19206	1604	-433	-2064	-22	0	5324	45	402	21212
	2000	110750	34880	19913	2688	137	-2064	548	548	5595	46	674	23823
8	"1975"	359033	119500	26789	4027	-2603	0	0	0	7582	0	0	30816
	1985	359033	119500	32753	4554	-2674	0	-71	0	8279	0	697	38004
	2000	359033	119500	36925	5511	-2127	0	476	476	8752	0	1170	44082
9	"1975"	3673	0	0	112	0	0	0	0	0	16	0	112
	1985	3673	0	0	204	0	-58	-58	0	0	18	2	206
	2000	3673	0	0	446	0	-641	-641	0	0	19	3	449
10	"1975"	33958	25840	0	15469	0	-411	0	0	0	4924	0	15469
	1985	33958	25840	0	19206	0	-433	-22	0	0	5324	400	19606
	2000	33958	25840	0	19913	0	137	548	548	0	5595	671	21132
11	"1975"	46169	N/A	0	8064	0	-128	0	0	0	2615	0	8064
	1985	46169	N/A	0	8769	0	-177	-49	0	0	2910	295	9064
	2000	46169	N/A	0	8887	0	-200	-72	0	0	3111	496	9383
12	"1975"	22917	N/A	0	11259	0	-30	0	0	0	1705	0	11259
	1985	22917	N/A	0	10227	0	-30	0	0	0	1875	170	10397
	2000	22917	N/A	0	10529	0	-30	0	0	0	1992	287	10816
13	"1975"	2287	N/A	0	4240	0	-234	0	0	0	730	0	4240
	1985	2287	N/A	0	4320	0	-199	35	35	0	764	34	4389
	2000	2287	N/A	0	4016	0	-199	35	35	0	785	55	4106
14	"1975"	7947	0	0	2440	0	805	0	0	0	711	0	2440
	1985	7947	0	0	3018	0	985	180	180	0	721	10	3208
	2000	7947	0	0	3232	0	1095	290	290	0	728	17	3539
15	"1975"	6864	0	2440	4595	805	4463	0	0	711	1202	0	7035
	1985	6864	0	3018	4754	985	4084	-199	0	721	1222	30	7802
	2000	6864	0	3232	4708	1095	3896	-277	0	728	1236	51	7991
16	"1975"	3389	0	0	3779	0	-101	0	0	0	327	0	3779
	1985	3389	0	0	3765	0	-177	-76	0	0	331	4	3769
	2000	3389	0	0	4036	0	-251	-150	0	0	333	6	4042
17	"1975"	214004	N/A	0	11913	0	-47	0	0	0	2014	0	11913
	1985	214004	N/A	0	14610	0	-47	0	0	0	2055	41	14651
	2000	214004	N/A	0	15196	0	-47	0	0	0	2083	69	15265
18	"1975"	32607	N/A	0	26641	0	-4438	0	0	0	669	0	26641
	1985	32607	N/A	0	27932	0	-4069	369	369	0	679	10	28311
	2000	32607	N/A	0	29699	0	-3881	557	557	0	686	17	30273
19	"1975"	859000	N/A	0	58	0	0	0	0	0	0	0	58
	1985	859000	N/A	0	207	0	0	0	0	0	0	0	207
	2000	859000	N/A	0	459	0	0	0	0	0	0	0	459
20	"1975"	4590	0	0	605	0	0	0	0	0	1	0	605
	1985	4590	0	0	636	0	0	0	0	0	1	0	636
	2000	4590	0	0	666	0	0	0	0	0	1	0	666
21	"1975"	3706	0	0	343	0	0	0	0	0	0	0	343
	1985	3706	0	0	374	0	0	0	0	0	0	0	374
	2000	3706	0	0	300	0	0	0	0	0	0	0	300
NATION (1-18)	"1975"	1035221	N/A	0	105584	0	-2677	0	0	0	14956	0	105584
	1985	1035221	N/A	0	119328	0	-2677	0	0	0	15944	988	120316
	2000	1035221	N/A	0	133655	0	-2677	0	0	0	16614	1658	135313

* (01) INSTREAM FLOW APPROXIMATIONS AS DEFINED IN EXPLANATORY NOTES FOR USE ONLY IN SECOND NATIONAL WATER ASSESSMENT
* (07) CHANGES IN NET EXPORTS ARE NEGATIVE WHEN THERE IS AN INCREASE IN IMPORTS OR A DECREASE IN EXPORTS
* (08) ONLY POSITIVE VALUES OF (07) ARE CONSIDERED OFFSTREAM USES NEGATIVE VALUES OF (07) ARE TREATED AS ZERO

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TABLE II-5 ANNUAL WATER ADEQUACY ANALYSIS (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

BASE CONDITIONS

REGION		(13) CURRENT STRMFLW AT OUTFLW PT (MGD)	STREAMFLOW AS SUPPLY (14)• "1975" CONSUMP-TION (03+04) (MGD)	(15) CURRENT STRMFLW SUPPLY (13+14) (MGD)	(16) GRND WTR OVERDRAFT ABOVE OUTFLW PT (MGD)	(17)• ASSESSED TOTAL STRMFLW (15-16) (MGD)	INSTREAM FLOW (18) MAXIMUM INSTREAM USE (01 OR 02) (MGD)	(19)• ASSESSED STRMFLW AT OUTFLW PT (MGD)	(20) ASSESSED SURPLUS STRMFLW (19-18) (MGD)	WATER ADEQUACY INDICATORS (21) CURRENT STRMFLW DEPLETION (12)/(15)	(22)• OFFSTREAM USE TO TOTAL STRMFLW (12)/(17)	(23) INSTREAM USE TO TOTAL STRMFLW (18)/(17)	(24) TOTAL USE TO TOTAL STRMFLW (22+23)
1	"1975"	78180	481	78661	0	78661	69001	78180	9179	1%	1%	88%	89%
	1985	–	–	–	0		69001	78014	9013	–	1%	88%	89%
	2000	–	–	–	0		69001	77598	8597	–	1%	88%	89%
2	"1975"	79190	1843	81033	32	81001	68840	79158	10318	2%	2%	85%	87%
	1985	–	–	–	0		68840	78529	9689	–	3%	85%	88%
	2000	–	–	–	0		68840	77453	8613	–	4%	85%	89%
3	"1975"	228010	4867	232877	339	232538	188655	227671	39016	2%	2%	81%	83%
	1985	–	–	–	0		188655	225766	37111	–	3%	81%	84%
	2000	–	–	–	0		188655	222485	33830	–	4%	81%	85%
4	"1975"	72710	2598	75308	27	75281	63951	72683	8732	3%	3%	85%	88%
	1985	–	–	–	0		63951	71981	8030	–	4%	85%	89%
	2000	–	–	–	0		63951	70588	6637	–	6%	85%	91%
5	"1975"	178000	2111	180111	0	180111	160520	178000	17480	1%	1%	89%	90%
	1985	–	–	–	0		160520	176937	16417	–	2%	89%	91%
	2000	–	–	–	0		160520	174674	14154	–	3%	89%	92%
6	"1975"	40800	313	41113	0	41113	38480	40800	2320	1%	1%	94%	95%
	1985	–	–	–	0		38480	40466	1986	–	2%	94%	96%
	2000	–	–	–	0		38480	40008	1528	–	3%	94%	97%
7	"1975"	121000	16614	137614	2557	135057	110750	118443	7693	12%	12%	82%	94%
	1985	–	–	–	0		110750	113867	3117	–	16%	82%	98%
	2000	–	–	–	0		110750	111234	484	–	18%	82%	100%
8	"1975"	433000	30816	463816	8426	455390	359033	424574	65541	7%	7%	79%	86%
	1985	–	–	–	0		359033	417457	58424	–	8%	79%	87%
	2000	–	–	–	0		359033	411308	52275	–	10%	79%	89%
9	"1975"	6010	112	6122	0	6122	3673	6010	2337	2%	2%	60%	62%
	1985	–	–	–	0		3673	5974	2301	–	3%	60%	63%
	2000	–	–	–	0		3673	6314	2641	–	7%	60%	67%
10	"1975"	44100	15469	59569	2557	57012	33958	41543	7585	26%	27%	60%	87%
	1985	–	–	–	0		33958	37428	3470	–	34%	60%	94%
	2000	–	–	–	0		33958	35880	1922	–	37%	60%	97%
11	"1975"	62600	8064	70664	5457	65207	46169	57143	10974	11%	12%	71%	83%
	1985	–	–	–	0		46169	56192	10023	–	14%	71%	85%
	2000	–	–	–	0		46169	55896	9727	–	14%	71%	85%
12	"1975"	28270	11259	39529	5578	33951	22917	22692	-225	28%	33%	68%	101%
	1985	–	–	–	0		22917	23554	637	–	31%	68%	99%
	2000	–	–	–	0		22917	23135	218	–	32%	68%	100%
13	"1975"	1230	4240	5470	657	4813	2287	573	-1714	78%	88%	48%	136%
	1985	–	–	–	0		2287	424	-1863	–	91%	48%	139%
	2000	–	–	–	0		2287	707	-1580	–	85%	48%	133%
14	"1975"	10000	2440	12440	0	12440	7947	10000	2053	20%	20%	64%	84%
	1985	–	–	–	0		7947	9232	1285	–	26%	64%	90%
	2000	–	–	–	0		7947	8901	954	–	28%	64%	92%
15	"1975"	1550	7035	8585	2415	6170	6864	-865	-7729	82%	114%	111%	225%
	1985	–	–	–	0		6864	-1433	-8297	–	126%	111%	237%
	2000	–	–	–	0		6864	-1544	-8408	–	130%	111%	241%
16	"1975"	2562	3779	6341	591	5750	3389	1971	-1418	60%	66%	59%	125%
	1985	–	–	–	0		3389	2057	-1332	–	66%	59%	125%
	2000	–	–	–	0		3389	1858	-1531	–	70%	59%	129%
17	"1975"	255270	11913	267183	627	266556	214004	254643	40639	4%	4%	80%	84%
	1985	–	–	–	0		214004	251905	37901	–	5%	80%	85%
	2000	–	–	–	0		214004	251291	37287	–	6%	80%	86%
18	"1975"	47375	26641	74016	2197	71819	32607	45178	12571	36%	37%	45%	82%
	1985	–	–	–	0		32607	43508	10901	–	39%	45%	84%
	2000	–	–	–	0		32607	41546	8939	–	42%	45%	87%
19	"1975"	905000	58	905058	0	905058	859000	905000	46000	<1%	<1%	95%	95%
	1985	–	–	–	0		859000	904851	45851	–	<1%	95%	95%
	2000	–	–	–	0		859000	904599	45599	–	<1%	95%	95%
20	"1975"	6747	605	7352	0	7352	4590	6747	2157	8%	8%	62%	70%
	1985	–	–	–	0		4590	6716	2126	–	9%	62%	71%
	2000	–	–	–	0		4590	6686	2096	–	9%	62%	71%
21	"1975"	4851	343	5194	13	5181	3706	4838	1132	7%	7%	72%	79%
	1985	–	–	–	0		3706	4807	1101	–	7%	72%	79%
	2000	–	–	–	0		3706	4881	1175	–	6%	72%	78%
NATION (1-18)	"1975"	1233357	105584	1338941	20889	1318052	1035221	1212468	177247	8%	8%	79%	87%
	1985	–	–	–	0		1035221	1197736	162515	–	9%	79%	88%
	2000	–	–	–	0		1035221	1182739	147518	–	10%	79%	89%

• (14) "1975" BASE-CONDITIONS CONSUMPTION IS ADDED TO STREAMFLOW TO DETERMINE AVAILABLE FRESHWATER SUPPLY
• (17),(19) TOTAL STREAMFLOW AND ASSESSED STREAMFLOW EXCLUDE CONTRIBUTIONS FROM GROUND-WATER OVERDRAFT
• (19) = (17) – (03) – (04) – (07) – (11)
• (22) ALSO CALLED ASSESSED STREAMFLOW DEPLETION

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TABLE II-6 NATURAL WATER SUPPLY ANALYSIS

(REGIONS 1-21) NATIONAL SUMMARY

REGION		(01) CONSUMPTION ABOVE INFLOW POINTS (MGD)	(02) CONSUMPTION WITHIN HYDRO UNIT (MGD)	(03) NET EVAPORATION ABOVE INFLOW POINTS (MGD)	(04) NET EVAPORATION WITHIN HYDRO UNIT (MGD)	(05) NET EXPORTS ABOVE INFLOW POINTS (MGD)	(06) NET EXPORTS WITHIN HYDRO UNIT (MGD)	(07) NET IMPORTS ABOVE INFLOW POINTS (MGD)	(08) NET IMPORTS WITHIN HYDRO UNIT (MGD)	(09) G W OVERDRAFT ABOVE INFLOW POINTS (MGD)	(10) G W OVERDRAFT WITHIN HYDRO UNIT (MGD)	(11)* TOTAL DEPLETIONS ABOVE INFLOW POINTS (MGD)	(12)* TOTAL DEPLETIONS WITHIN HYDRO UNIT (MGD)
1	"1975"	0	481	0	0	0	0	0	0	0	0	0	481
	1985	0	647	0	0	0	0	0	0	0	0	0	647
	2000	0	1063	0	0	0	0	0	0	0	0	0	1063
2	"1975"	0	1843	0	0	0	0	0	479	0	32	0	1843
	1985	0	2472	0	0	0	0	0	479	0	0	0	2472
	2000	0	3548	0	0	0	0	0	479	0	0	0	3548
3	"1975"	0	4867	0	0	0	6	0	0	0	339	0	4873
	1985	0	6772	0	0	0	6	0	0	0	0	0	6778
	2000	0	10053	0	0	0	6	0	0	0	0	0	10059
4	"1975"	0	2598	0	0	0	0	0	19	0	27	0	2598
	1985	0	3300	0	0	0	0	0	19	0	0	0	3300
	2000	0	4693	0	0	0	0	0	19	0	0	0	4693
5	"1975"	313	1798	0	0	0	0	0	0	0	0	313	1798
	1985	647	2527	0	0	0	0	0	0	0	0	647	2527
	2000	1105	4332	0	0	0	0	0	0	0	0	1105	4332
6	"1975"	0	313	0	0	0	0	0	0	0	0	0	313
	1985	0	647	0	0	0	0	0	0	0	0	0	647
	2000	0	1105	0	0	0	0	0	0	0	0	0	1105
7	"1975"	15469	1145	4924	43	0	0	411	2064	2557	0	20393	1188
	1985	19206	1604	5324	45	0	0	433	2064	0	0	24530	1649
	2000	19913	2688	5595	46	137	0	0	2064	0	0	25645	2734
8	"1975"	26789	4027	7582	0	0	0	2603	0	8014	412	34371	4027
	1985	32753	4554	8279	0	0	0	2674	0	0	0	41032	4554
	2000	36925	5511	8752	0	0	0	2127	0	0	0	45677	5511
9	"1975"	0	112	0	16	0	0	0	0	0	0	0	128
	1985	0	204	0	18	0	0	0	58	0	0	0	222
	2000	0	446	0	19	0	0	0	641	0	0	0	465
10	"1975"	0	15469	0	4924	0	0	0	411	0	2557	0	20393
	1985	0	19206	0	5324	0	0	0	433	0	0	0	24530
	2000	0	19913	0	5595	0	137	0	0	0	0	0	25645
11	"1975"	0	8064	0	2615	0	0	0	128	0	5457	0	10679
	1985	0	8769	0	2910	0	0	0	177	0	0	0	11679
	2000	0	8887	0	3111	0	0	0	200	0	0	0	11998
12	"1975"	0	11259	0	1705	0	0	0	30	0	5578	0	12964
	1985	0	10227	0	1875	0	0	0	30	0	0	0	12102
	2000	0	10529	0	1992	0	0	0	30	0	0	0	12521
13	"1975"	0	4240	0	730	0	0	0	234	0	657	0	4970
	1985	0	4320	0	764	0	0	0	199	0	0	0	5084
	2000	0	4016	0	785	0	0	0	199	0	0	0	4801
14	"1975"	0	2440	0	711	0	805	0	0	0	0	0	3956
	1985	0	3018	0	721	0	985	0	0	0	0	0	4724
	2000	0	3232	0	728	0	1095	0	0	0	0	0	5055
15	"1975"	2440	4595	711	1202	805	4463	0	0	0	2415	3956	10260
	1985	3018	4754	721	1222	985	4084	0	0	0	0	4724	10060
	2000	3232	4708	728	1236	1095	3896	0	0	0	0	5055	9840
16	"1975"	0	3779	0	327	0	0	0	101	0	591	0	4106
	1985	0	3765	0	331	0	0	0	177	0	0	0	4096
	2000	0	4036	0	333	0	0	0	251	0	0	0	4369
17	"1975"	0	11913	0	2014	0	0	0	47	0	627	0	13927
	1985	0	14610	0	2055	0	0	0	47	0	0	0	16665
	2000	0	15196	0	2083	0	0	0	47	0	0	0	17279
18	"1975"	0	26641	0	669	0	0	0	4438	0	2197	0	27310
	1985	0	27932	0	679	0	0	0	4069	0	0	0	28611
	2000	0	29699	0	686	0	0	0	3881	0	0	0	30385
19	"1975"	0	58	0	0	0	0	0	0	0	0	0	58
	1985	0	207	0	0	0	0	0	0	0	0	0	207
	2000	0	459	0	0	0	0	0	0	0	0	0	459
20	"1975"	0	605	0	1	0	0	0	0	0	0	0	606
	1985	0	636	0	1	0	0	0	0	0	0	0	637
	2000	0	666	0	1	0	0	0	0	0	0	0	667
21	"1975"	0	343	0	0	0	0	0	0	0	13	0	343
	1985	0	374	0	0	0	0	0	0	0	0	0	374
	2000	0	300	0	0	0	0	0	0	0	0	0	300
NATION (1-18)	"1975"	0	105584	0	14956	0	0	0	2677	0	20889	0	120540
	1985	0	119328	0	15944	0	0	0	2677	0	0	0	135272
	2000	0	133655	0	16614	0	0	0	2677	0	0	0	150269

* (11)=(01)+(03)+(05) * (12)=(02)+(04)+(06)

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TABLE II-6 NATURAL WATER SUPPLY ANALYSIS (CONTINUED)

(REGIONS 1-21) NATIONAL SUMMARY

REGION		(13) INFLOWS ENTERING HYDRO. UNIT (MGD)	(14) CURRENT STRMFLW AT OUTFLW PT (MGD)	(15)• TOTAL DEPLETIONS ABOVE INFLOW POINTS (MGD)	(16)• TOTAL DEPLETIONS WITHIN HYDRO UNIT (MGD)	(17)• NATURAL OUTFLOW AT OUTFLW PT (MGD)	(18)• NATURAL OUTFLOW WITHIN HYDRO. UNIT (MGD)	(19) NAT FLOW DEPLETN ABOVE OUTFLW PT (15)+(16) /(17)	(20) NAT FLOW DEPLETN WITHIN HYDRO. UNIT (16)/(18)	(21) DRAINAGE AREA ABOVE OUTFLW PT (SQ MI)	(22) DRAINAGE AREA WITHIN HYDRO. UNIT (SQ MI)	(23) ESTIMATED RUNOFF ABOVE OUTFLW PT (17)/(21) (INCHES)	(24) ESTIMATED RUNOFF IN HYDRO UNIT (18)/(22) (INCHES)
1	"1975"	0	78180	0	481	78661	78661	1%	1%	71990	71990	23"	23"
	1985			0	647			1%	1%				
	2000			0	1063			1%	1%				
2	"1975"	0	79190	0	1843	80522	80522	2%	2%	104910	104910	16"	16"
	1985			0	2472			3%	3%				
	2000			0	3548			4%	4%				
3	"1975"	0	228010	0	4873	232544	232544	2%	2%	277200	277200	18"	18"
	1985			0	6778			3%	3%				
	2000			0	10059			4%	4%				
4	"1975"	0	72710	0	2598	75262	75262	3%	3%	113760	113760	14"	14"
	1985			0	3300			4%	4%				
	2000			0	4693			6%	6%				
5	"1975"	40800	178000	313	1798	180111	138998	1%	1%	203470	162660	19"	18"
	1985			647	2527			2%	2%				
	2000			1105	4332			3%	3%				
6	"1975"	0	40800	0	313	41113	41113	1%	1%	40810	40810	21"	21"
	1985			0	647			2%	2%				
	2000			0	1105			3%	3%				
7	"1975"	44100	121000	20393	1188	137549	76024	16%	2%	701360	190170	4"	8"
	1985			24530	1649			19%	2%				
	2000			25645	2734			21%	4%				
8	"1975"	361600	433000	34371	4027	460369	75015	8%	5%	1255890	103520	8"	15"
	1985			41032	4554			10%	6%				
	2000			45677	5511			11%	7%				
9	"1975"	0	6010	0	128	6138	6138	2%	2%	59370	59370	2"	2"
	1985			0	222			4%	4%				
	2000			0	465			8%	8%				
10	"1975"	0	44100	0	20393	61525	61525	33%	33%	511190	511190	3"	3"
	1985			0	24530			40%	40%				
	2000			0	25645			42%	42%				
11	"1975"	0	62600	0	10679	67694	67694	16%	16%	247540	247540	6"	6"
	1985			0	11679			17%	17%				
	2000			0	11998			18%	18%				
12	"1975"	0	28270	0	12964	35626	35626	36%	36%	181440	181440	4"	4"
	1985			0	12102			34%	34%				
	2000			0	12521			35%	35%				
13	"1975"	0	1230	0	4970	5309	5309	94%	94%	132790	132790	1"	1"
	1985			0	5084			96%	96%				
	2000			0	4801			90%	90%				
14	"1975"	0	10000	0	3956	13956	13956	28%	28%	113330	113330	3"	3"
	1985			0	4724			34%	34%				
	2000			0	5055			36%	36%				
15	"1975"	10000	1550	3956	10260	13351	-605••	106%	N/C	253890	140560	1"	0"
	1985			4724	10060			111%	N/C				
	2000			5055	9840			112%	N/C				
16	"1975"	0	2562	0	4106	5976	5976	69%	69%	142070	142070	1"	1"
	1985			0	4096			69%	69%				
	2000			0	4369			73%	73%				
17	"1975"	0	255270	0	13927	268523	268523	5%	5%	277340	277340	20"	20"
	1985			0	16665			6%	6%				
	2000			0	17279			6%	6%				
18	"1975"	0	47375	0	27310	68050	68050	40%	40%	176510	176510	8"	8"
	1985			0	28611			42%	42%				
	2000			0	30385			45%	45%				
19	"1975"	0	905000	0	58	905058	905058	<1%	<1%	586402	586402	32"	32"
	1985			0	207			<1%	<1%				
	2000			0	459			<1%	<1%				
20	"1975"	0	6747	0	606	7353	7353	8%	8%	6447	6447	24"	24"
	1985			0	637			9%	9%				
	2000			0	667			9%	9%				
21	"1975"	0	4851	0	343	5181	5181	7%	7%	3567	3567	31"	31"
	1985			0	374			7%	7%				
	2000			0	300			6%	6%				
NATION (1-18)	"1975"	0	1233357	0	120540	1330331	1330331	9%	9%	3047160	3047160	9"	9"
	1985			0	135272			10%	10%				
	2000			0	150269			11%	11%				

• (15)=(11)+(01)+(03)+(05) • (16)=(12)+(02)+(04)+(06)
• (17)=(14)+(01)+(02)+(03)+(04)+(05)+(06)-(07)-(08)-(09)-(10) • (18)=(14)-(13)+(02)+(04)+(06)-(08)-(10)
•• A NEGATIVE VALUE OF NATURAL OUTFLOW INDICATES THAT EVAPORATION AND PLANT TRANSPIRATION EXCEED RAINFALL IN THE REGION.

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY

BASE CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (01)* TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(02)* ASSESSED SURPLUS STRMFLW (MGD)	(03)* CURRENT STRMFLW DEPLETN	(TABLE III-5) (04)* ASSESSED STRMFLW DEPLETN	(05) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (06) NO. OF MONTHS WHERE (02) < 0 0	(07) NO. OF MONTHS WHERE (04) > 40/70/90%	ANNUAL INFORMATION (08)* ASSESSED TOTAL STRMFLW (MGD)	(09)* ASSESSED SURPLUS STRMFLW	(10)* CURRENT STRMFLW DEPLETN	(TABLE II-5) (11)* ASSESSED STRMFLW DEPLETN	(12) INSTREAM USE TO TOTAL STRMFLW
NEW ENGLAND REGION												REGION 1
101 "1975"	20499	1700	<1%	<1%	91%	0	0/ 0/ 0	37988	4550	<1%	<1%	88%
/ 1985		1639	–	1%	91%	0	0/ 0/ 0		4494	–	<1%	88%
ATLANT 2000	JUL 2000	1515	–	1%	91%	0	0/ 0/ 0		4376	–	1%	88%
102 "1975"	3403	390	1%	1%	87%	0	0/ 0/ 0	9925	1080	<1%	<1%	89%
/ 1985		378	–	2%	87%	0	0/ 0/ 0		1075	–	<1%	89%
ATLANT 2000	AUG 2000	360	–	2%	87%	0	0/ 0/ 0		1063	–	1%	89%
103 "1975"	9698	461	1%	1%	94%	0	0/ 0/ 0	4726	587	3%	3%	85%
/ 1985		414	–	2%	94%	0	0/ 0/ 0		605	–	4%	85%
ATLANT 2000	MAR 2000	353	–	3%	94%	0	0/ 0/ 0		607	–	5%	85%
104 "1975"	2170	390	5%	5%	77%	0	0/ 0/ 0	4858	562	2%	2%	87%
/ 1985		361	–	6%	77%	0	0/ 0/ 0		533	–	2%	87%
ATLANT 2000	JUL 2000	320	–	8%	77%	0	0/ 0/ 0		495	–	3%	87%
105 "1975"	4564	519	2%	2%	86%	0	0/ 0/ 0	12520	1420	1%	1%	88%
/ 1985		362	–	6%	86%	0	0/ 0/ 0		1330	–	2%	88%
ATLANT 2000	SEP 2000	60	–	12%	86%	0	0/ 0/ 0		1086	–	4%	88%
106 "1975"	5843	459	<1%	<1%	92%	0	0/ 0/ 0	8644	980	<1%	<1%	88%
/ 1985		456	–	<1%	92%	0	0/ 0/ 0		976	–	<1%	88%
CANADA 2000	FEB 2000	449	–	1%	92%	0	0/ 0/ 0		970	–	<1%	88%
MID-ATLANTIC REGION												REGION 2
201 "1975"	29322	389	<1%	<1%	98%	0	0/ 0/ 0	12331	1190	1%	1%	89%
/ 1985		381	–	1%	98%	0	0/ 0/ 0		1163	–	1%	89%
202 2000	APR 2000	253	–	1%	98%	0	0/ 0/ 0		1046	–	2%	89%
202 "1975"	29262	886	2%	2%	95%	0	0/ 0/ 0	16217	1723	4%	4%	86%
/ 1985		778	–	2%	95%	0	0/ 0/ 0		1600	–	5%	86%
ATLANT 2000	MAR 2000	569	–	3%	95%	0	0/ 0/ 0		1350	–	6%	86%
203 "1975"	19180	1001	3%	3%	92%	0	0/ 0/ 0	16289	1865	4%	4%	85%
/ 1985		865	–	3%	92%	0	0/ 0/ 0		1694	–	5%	85%
ATLANT 2000	FEB 2000	685	–	4%	92%	0	0/ 0/ 0		1470	–	6%	85%
204 "1975"	6974	971	4%	4%	82%	0	0/ 0/ 0	24760	3110	1%	1%	86%
/ 1985		891	–	5%	82%	0	0/ 0/ 0		3029	–	1%	86%
ATLANT 2000	SEP 2000	693	–	8%	82%	0	0/ 0/ 0		2833	–	2%	86%
205 "1975"	8504	311	2%	2%	94%	0	0/ 0/ 0	14812	2250	2%	2%	83%
/ 1985		135	–	4%	94%	0	0/ 0/ 0		2050	–	3%	83%
ATLANT 2000	NOV 2000	-69	–	7%	94%	1	0/ 0/ 0		1822	–	4%	83%
206 "1975"	3096	451	4%	4%	81%	0	0/ 0/ 0	8923	1370	1%	1%	83%
/ 1985		398	–	6%	81%	0	0/ 0/ 0		1316	–	2%	83%
ATLANT 2000	SEP 2000	227	–	11%	81%	0	0/ 0/ 0		1138	–	4%	83%
SOUTH ATLANTIC-GULF REGION												REGION 3
301 "1975"	20241	4504	2%	2%	76%	0	0/ 0/ 0	26210	7333	1%	1%	71%
/ 1985		4278	–	3%	76%	0	0/ 0/ 0		7118	–	2%	71%
ATLANT 2000	MAY 2000	3843	–	5%	76%	0	0/ 0/ 0		6689	–	4%	71%
302 "1975"	19866	2820	2%	2%	84%	0	0/ 0/ 0	28286	5401	1%	1%	80%
/ 1985		2510	–	3%	84%	0	0/ 0/ 0		5110	–	2%	80%
ATLANT 2000	JUN 2000	1896	–	7%	84%	0	0/ 0/ 0		4517	–	4%	80%
303 "1975"	12980	2740	1%	1%	78%	0	0/ 0/ 0	25605	5947	1%	1%	76%
/ 1985		2516	–	3%	78%	0	0/ 0/ 0		5707	–	2%	76%
ATLANT 2000	NOV 2000	2206	–	5%	78%	0	0/ 0/ 0		5380	–	3%	76%
304 "1975"	12955	1750	13%	13%	73%	0	0/ 0/ 0	19614	3424	6%	6%	77%
/ 1985		1289	–	17%	73%	0	0/ 0/ 0		3103	–	7%	77%
ATLANT 2000	MAY 2000	837	–	20%	73%	0	0/ 0/ 0		2751	–	9%	77%
305 "1975"	16858	-4104	14%	14%	110%	3	5/ 1/ 0	9434	646	23%	23%	70%
/ 1985		-4465	–	16%	110%	4	6/ 2/ 0		299	–	27%	70%
GULF 2000	OCT 2000	-5046	–	20%	110%	6	6/ 3/ 2		-268	–	33%	70%
306 "1975"	12331	1126	1%	1%	90%	0	0/ 0/ 0	22004	2743	1%	1%	86%
/ 1985		1026	–	2%	90%	0	0/ 0/ 0		2605	–	2%	86%
GULF 2000	NOV 2000	801	–	4%	90%	0	0/ 0/ 0		2324	–	3%	86%
307 "1975"	21958	1557	1%	1%	92%	0	0/ 0/ 0	40258	4277	<1%	<1%	89%
/ 1985		1373	–	2%	92%	0	0/ 0/ 0		4093	–	1%	89%
GULF 2000	OCT 2000	843	–	4%	92%	0	0/ 0/ 0		3566	–	2%	89%
308 "1975"	14901	1839	1%	1%	86%	0	0/ 0/ 0	42000	5690	<1%	<1%	86%
/ 1985		1729	–	2%	86%	0	0/ 0/ 0		5580	–	1%	86%
GULF 2000	SEP 2000	1598	–	3%	86%	0	0/ 0/ 0		5448	–	1%	86%
309 "1975"	6913	1416	2%	2%	78%	0	0/ 0/ 0	19127	3555	1%	1%	81%
/ 1985		1360	–	3%	78%	0	0/ 0/ 0		3496	–	1%	81%
GULF 2000	OCT 2000	1288	–	4%	78%	0	0/ 0/ 0		3423	–	1%	81%

* (01) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
*
* (01),(08) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION – "1975" GROUND-WATER OVERDRAFT
* (02),(09) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW – TOTAL DEPLETIONS – INSTREAM USE
* (03),(10) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
* (04),(11) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (CONTINUED)

DRY CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL (13)* TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	MONTH INFORMATION (14)* ASSESSED SURPLUS STRMFLW (MGD)	(15)* CURRENT STRMFLW DEPLETN	(TABLE IV-4) (16)* ASSESSED STRMFLW DEPLETN	(17) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (18) NO OF MONTHS WHERE (14) < 0 0	(19) NO OF MONTHS WHERE (16) > 40/70/90%	ANNUAL INFORMATION (20)* ASSESSED TOTAL STRMFLW (MGD)	(21)* ASSESSED SURPLUS STRMFLW	(22)* CURRENT STRMFLW DEPLETN	(TABLE IV-2) (23)* ASSESSED STRMFLW DEPLETN	(24) INSTREAM USE TO TOTAL STRMFLW
NEW ENGLAND REGION												REGION 1
101 "1975"	13699	-5101	1%	1%	137%	12	0/ 0/ 0	31088	-2351	<1%	<1%	107%
/ 1985		-5164	-	1%	137%	12	0/ 0/ 0		-2406	-	<1%	107%
ATLANT 2000 JUL 2000		-5289	-	2%	137%	12	0/ 0/ 0		-2525	-	1%	107%
102 "1975"	2113	-903	2%	2%	141%	12	0/ 0/ 0	7855	-991	<1%	<1%	112%
/ 1985		-918	-	3%	141%	12	0/ 0/ 0		-996	-	1%	112%
ATLANT 2000 AUG 2000		-934	-	4%	141%	12	0/ 0/ 0		-1008	-	1%	112%
103 "1975"	7048	-2189	2%	2%	129%	12	0/ 0/ 0	3946	-196	4%	4%	101%
/ 1985		-2236	-	3%	129%	12	0/ 0/ 0		-178	-	5%	101%
ATLANT 2000 MAR 2000		-2297	-	4%	129%	12	0/ 0/ 0		-176	-	7%	101%
104 "1975"	1130	-652	9%	9%	149%	12	0/ 0/ 0	3698	-599	2%	2%	114%
/ 1985		-682	-	12%	149%	12	0/ 0/ 0		-628	-	3%	114%
ATLANT 2000 JUL 2000		-722	-	15%	149%	12	0/ 0/ 0		-665	-	4%	114%
105 "1975"	2814	-1232	4%	4%	140%	12	0/ 0/ 0	9880	-1222	1%	1%	111%
/ 1985		-1389	-	9%	140%	12	0/ 0/ 0		-1311	-	2%	111%
ATLANT 2000 SEP 2000		-1691	-	20%	140%	12	0/ 0/ 0		-1556	-	5%	111%
106 "1975"	3833	-1551	1%	1%	140%	12	0/ 0/ 0	6744	-920	<1%	<1%	113%
/ 1985		-1554	-	1%	140%	12	0/ 0/ 0		-924	-	<1%	113%
CANADA 2000 FEB 2000		-1561	-	1%	140%	12	0/ 0/ 0		-930	-	1%	113%
MID-ATLANTIC REGION												REGION 2
201 "1975"	22122	-6811	1%	1%	130%	12	0/ 0/ 0	9311	-1832	1%	1%	118%
/ 1985		-6839	-	1%	130%	12	0/ 0/ 0		-1859	-	2%	118%
202 2000 APR 2000		-6947	-	1%	130%	12	0/ 0/ 0		-1976	-	3%	118%
202 "1975"	21662	-6714	3%	3%	128%	12	0/ 0/ 0	12017	-2486	5%	5%	115%
/ 1985		-6822	-	3%	128%	12	0/ 0/ 0		-2611	-	6%	115%
ATLANT 2000 MAR 2000		-7031	-	4%	128%	12	0/ 0/ 0		-2864	-	8%	115%
203 "1975"	13680	-4499	4%	4%	129%	12	0/ 0/ 0	12789	-1656	5%	5%	108%
/ 1985		-4635	-	5%	129%	12	0/ 0/ 0		-1835	-	6%	108%
ATLANT 2000 FEB 2000		-4815	-	6%	129%	12	0/ 0/ 0		-2067	-	8%	108%
204 "1975"	4584	-1421	6%	6%	125%	12	0/ 0/ 0	20260	-1392	1%	1%	106%
/ 1985		-1503	-	7%	125%	12	0/ 0/ 0		-1474	-	2%	106%
ATLANT 2000 SEP 2000		-1700	-	12%	125%	12	0/ 0/ 0		-1671	-	3%	106%
205 "1975"	6114	-2079	3%	3%	131%	12	0/ 0/ 0	11312	-1262	2%	2%	109%
/ 1985		-2255	-	6%	131%	12	0/ 0/ 0		-1467	-	4%	109%
ATLANT 2000 NOV 2000		-2459	-	9%	131%	12	0/ 0/ 0		-1702	-	6%	109%
206 "1975"	1876	-772	7%	7%	134%	12	0/ 0/ 0	6663	-892	2%	2%	111%
/ 1985		-826	-	10%	134%	12	0/ 0/ 0		-948	-	3%	111%
ATLANT 2000 SEP 2000		-997	-	19%	134%	12	0/ 0/ 0		-1127	-	6%	111%
SOUTH ATLANTIC-GULF REGION												REGION 3
301 "1975"	9841	-5937	4%	4%	156%	12	0/ 0/ 0	19110	213	2%	2%	97%
/ 1985		-6180	-	7%	156%	12	0/ 0/ 0		-11	-	3%	97%
ATLANT 2000 MAY 2000		-6638	-	11%	156%	12	0/ 0/ 0		-451	-	5%	97%
302 "1975"	12566	-4495	3%	3%	133%	12	0/ 0/ 0	19886	-3004	1%	1%	114%
/ 1985		-4810	-	6%	133%	12	0/ 0/ 0		-3297	-	3%	114%
ATLANT 2000 JUN 2000		-5431	-	11%	133%	12	0/ 0/ 0		-3892	-	6%	114%
303 "1975"	7190	-3050	2%	2%	140%	12	0/ 0/ 0	17605	-2057	1%	1%	111%
/ 1985		-3274	-	5%	140%	12	0/ 0/ 0		-2300	-	2%	111%
ATLANT 2000 NOV 2000		-3584	-	10%	140%	12	0/ 0/ 0		-2629	-	4%	111%
304 "1975"	5565	-5846	33%	34%	171%	12	0/ 0/ 0	11514	-4880	11%	12%	131%
/ 1985		-6352	-	43%	171%	12	1/ 0/ 0		-5239	-	15%	131%
ATLANT 2000 MAY 2000		-6840	-	52%	171%	12	2/ 0/ 0		-5616	-	18%	131%
305 "1975"	8978	-12503	32%	32%	207%	12	10/ 7/ 7	6264	-3074	43%	44%	105%
/ 1985		-12925	-	37%	207%	12	10/ 8/ 7		-3481	-	50%	105%
GULF 2000 OCT 2000		-13572	-	44%	207%	12	11/ 9/ 8		-4109	-	60%	105%
306 "1975"	8211	-3002	2%	2%	135%	12	0/ 0/ 0	16804	-2475	1%	1%	113%
/ 1985		-3102	-	3%	135%	12	0/ 0/ 0		-2622	-	2%	113%
GULF 2000 NOV 2000		-3327	-	6%	135%	12	0/ 0/ 0		-2912	-	4%	113%
307 "1975"	14958	-5443	1%	1%	135%	12	0/ 0/ 0	31858	-4124	1%	1%	112%
/ 1985		-5627	-	2%	135%	12	0/ 0/ 0		-4309	-	1%	112%
GULF 2000 OCT 2000		-6157	-	6%	135%	12	0/ 0/ 0		-4836	-	3%	112%
308 "1975"	8991	-4071	2%	2%	143%	12	0/ 0/ 0	32300	-4011	1%	1%	112%
/ 1985		-4181	-	3%	143%	12	0/ 0/ 0		-4121	-	1%	112%
GULF 2000 SEP 2000		-4312	-	5%	143%	12	0/ 0/ 0		-4252	-	1%	112%
309 "1975"	3423	-2075	4%	4%	157%	12	0/ 0/ 0	13327	-2246	1%	1%	116%
/ 1985		-2133	-	6%	157%	12	0/ 0/ 0		-2304	-	1%	116%
GULF 2000 OCT 2000		-2206	-	8%	157%	12	0/ 0/ 0		-2378	-	2%	116%

* (13) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
*
* (13),(20) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION - "1975" GROUND-WATER OVERDRAFT
* (14),(21) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW - TOTAL DEPLETIONS - INSTREAM USE
* (15),(22) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
* (16),(23) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY

BASE CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL (01)* TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	MONTH INFORMATION (02)* ASSESSED SURPLUS STRMFLW (MGD)	(03)* CURRENT STRMFLW DEPLETN	(TABLE III-5) (04)* ASSESSED STRMFLW DEPLETN	(05) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (06) NO OF MONTHS WHERE (02) < 0 0	(07) NO OF MONTHS WHERE (04) > 40/70/90%	ANNUAL INFORMATION (08)* ASSESSED TOTAL STRMFLW (MGD)	(09)* ASSESSED SURPLUS STRMFLW	(10)* CURRENT STRMFLW DEPLETN	(TABLE II-5) (11)* ASSESSED STRMFLW DEPLETN	(12) INSTREAM USE TO TOTAL STRMFLW
GREAT LAKES REGION												**REGION 4**
401	"1975" 4069	321	3%	3%	89%	0	0/ 0/ 0	9892	1122	1%	1%	87%
/	1985	302	–	4%	89%	0	0/ 0/ 0		1098	–	2%	87%
GT LKS	2000 JAN 2000	206	–	6%	89%	0	0/ 0/ 0		1005	–	3%	87%
402	"1975" 6786	262	2%	2%	94%	0	0/ 0/ 0	9655	770	2%	2%	90%
/	1985	222	–	2%	94%	0	0/ 0/ 0		717	–	2%	90%
GT LKS	2000 FEB 2000	96	–	4%	94%	0	0/ 0/ 0		573	–	4%	90%
403	"1975" 1119	149	54%	54%	33%	0	4/ 0/ 0	1784	355	31%	31%	49%
/	1985	–82	–	74%	33%	3	8/ 1/ 0		146	–	43%	49%
GT LKS	2000 AUG 2000	–473	–	109%	33%	12	10/ 8/ 3		–212	–	63%	49%
404	"1975" 10374	191	4%	4%	94%	0	0/ 0/ 0	14934	708	2%	2%	94%
/	1985	–20	–	6%	94%	1	0/ 0/ 0		592	–	2%	94%
GT LKS	2000 AUG 2000	–274	–	9%	94%	2	0/ 0/ 0		446	–	3%	94%
405	"1975" 4022	225	3%	3%	92%	0	0/ 0/ 0	7293	803	1%	1%	88%
/	1985	178	–	4%	92%	0	0/ 0/ 0		767	–	2%	88%
GT LKS	2000 AUG 2000	35	–	8%	92%	0	0/ 0/ 0		644	–	3%	88%
406	"1975" 2254	451	31%	31%	49%	0	0/ 0/ 0	7890	2377	8%	8%	62%
/	1985	248	–	40%	49%	0	2/ 0/ 0		2191	–	11%	62%
GT LKS	2000 AUG 2000	–43	–	53%	49%	1	3/ 0/ 0		1921	–	14%	62%
407	"1975" 1869	320	38%	38%	45%	0	0/ 0/ 0	5714	1012	12%	12%	70%
/	1985	278	–	40%	45%	0	1/ 0/ 0		983	–	12%	70%
GT LKS	2000 AUG 2000	206	–	44%	45%	0	1/ 0/ 0		923	–	13%	70%
408	"1975" 7325	513	2%	2%	91%	0	0/ 0/ 0	18119	1585	1%	1%	91%
/	1985	452	–	3%	91%	0	0/ 0/ 0		1536	–	1%	91%
GT LKS	2000 AUG 2000	231	–	6%	91%	0	0/ 0/ 0		1337	–	2%	91%
OHIO REGION												**REGION 5**
501	"1975" 7180	1228	3%	3%	80%	0	0/ 0/ 0	19880	2445	1%	1%	87%
/	1985	1185	–	3%	80%	0	0/ 0/ 0		2404	–	1%	87%
502	2000 AUG 2000	1108	–	4%	80%	0	0/ 0/ 0		2335	–	1%	87%
502	"1975" 17222	2687	7%	7%	77%	0	0/ 0/ 0	64918	8406	2%	2%	85%
/	1985	2222	–	10%	77%	0	0/ 0/ 0		7941	–	3%	85%
505	2000 SEP 2000	1158	–	16%	77%	0	0/ 0/ 0		6868	–	4%	85%
503	"1975" 3037	389	8%	8%	79%	0	0/ 0/ 0	12762	2887	2%	2%	75%
/	1985	290	–	12%	79%	0	0/ 0/ 0		2785	–	3%	75%
502	2000 OCT 2000	77	–	19%	79%	0	0/ 0/ 0		2562	–	5%	75%
504	"1975" 3084	450	4%	4%	82%	0	0/ 0/ 0	10811	1491	1%	1%	85%
/	1985	393	–	6%	82%	0	0/ 0/ 0		1434	–	2%	85%
502	2000 SEP 2000	230	–	11%	82%	0	0/ 0/ 0		1276	–	3%	85%
505	"1975" 56952	4104	4%	4%	89%	0	0/ 0/ 0	180111	17480	1%	1%	89%
/	1985	3058	–	5%	89%	0	0/ 0/ 0		16417	–	2%	89%
801	2000 OCT 2000	837	–	9%	89%	0	0/ 0/ 0		14154	–	3%	89%
506	"1975" 5318	839	5%	5%	79%	0	0/ 0/ 0	19965	5083	1%	1%	73%
/	1985	777	–	6%	79%	0	0/ 0/ 0		5022	–	2%	73%
505	2000 SEP 2000	499	–	12%	79%	0	0/ 0/ 0		4742	–	3%	73%
507	"1975" 14778	417	1%	1%	97%	0	0/ 0/ 0	21665	2632	<1%	<1%	88%
/	1985	333	–	1%	97%	0	0/ 0/ 0		2549	–	1%	88%
505	2000 JUN 2000	215	–	2%	97%	0	0/ 0/ 0		2429	–	1%	88%
TENNESSEE REGION												**REGION 6**
601	"1975" 19840	341	1%	1%	97%	0	0/ 0/ 0	23316	1353	1%	1%	93%
/	1985	152	–	2%	97%	0	0/ 0/ 0		1175	–	2%	93%
602	2000 AUG 2000	–88	–	3%	97%	2	0/ 0/ 0		941	–	3%	93%
602	"1975" 25702	2	1%	1%	99%	0	0/ 0/ 0	41113	2320	1%	1%	94%
/	1985	–331	–	2%	99%	2	0/ 0/ 0		1986	–	2%	94%
505	2000 OCT 2000	–769	–	4%	99%	3	0/ 0/ 0		1528	–	3%	94%
UPPER MISSISSIPPI REGION												**REGION 7**
701	"1975" 4735	320	3%	3%	90%	0	0/ 0/ 0	10506	1600	2%	2%	83%
/	1985	268	–	4%	90%	0	0/ 0/ 0		1519	–	3%	83%
702	2000 JAN 2000	213	–	5%	90%	0	0/ 0/ 0		1432	–	4%	83%
702	"1975" 14574	400	2%	2%	95%	0	0/ 0/ 0	27285	2292	1%	1%	90%
/	1985	331	–	2%	95%	0	0/ 0/ 0		2172	–	2%	90%
703	2000 JAN 2000	161	–	4%	95%	0	0/ 0/ 0		1947	–	3%	90%
703	"1975" 23538	1900	2%	2%	90%	0	0/ 0/ 0	43974	5050	2%	2%	87%
/	1985	1688	–	3%	90%	0	0/ 0/ 0		4781	–	2%	87%
704	2000 DEC 2000	1127	–	6%	90%	0	0/ 0/ 0		4187	–	3%	87%
704	"1975" 37766	0	3%	3%	97%	0	0/ 0/ 0	63928	5750	1%	1%	90%
/	1985	–431	–	4%	97%	1	0/ 0/ 0		5328	–	2%	90%
705	2000 SEP 2000	–1422	–	6%	97%	1	0/ 0/ 0		4359	–	4%	90%
705	"1975" 135294	–6141	37%	40%	65%	1	0/ 0/ 0	135057	7693	12%	12%	82%
/	1985	–19650	–	50%	65%	4	1/ 0/ 0		3117	–	16%	82%
801	2000 AUG 2000	–29571	–	57%	65%	3	2/ 0/ 0		484	–	18%	82%
LOWER MISSISSIPPI REGION												**REGION 8**
801	"1975" 178767	–79693	17%	18%	126%	4	0/ 0/ 0	363852	53297	7%	7%	78%
/	1985	–90756	–	24%	126%	5	0/ 0/ 0		46746	–	9%	78%
802	2000 SEP 2000	–95407	–	27%	126%	5	1/ 0/ 0		41339	–	10%	78%
802	"1975" 206712	–81031	17%	18%	122%	4	0/ 0/ 0	407702	59184	7%	7%	78%
/	1985	–93908	–	24%	122%	4	0/ 0/ 0		52165	–	9%	78%
803	2000 SEP 2000	–98168	–	26%	122%	6	1/ 0/ 0		46526	–	10%	78%
803	"1975" 219314	–100173	16%	17%	129%	5	0/ 0/ 0	455390	65541	7%	7%	79%
/	1985	–113308	–	23%	129%	6	0/ 0/ 0		58424	–	8%	79%
GULF	2000 SEP 2000	–118174	–	25%	129%	6	0/ 0/ 0		52275	–	10%	79%

* (01) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW

* (01),(08) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION + "1975" GROUND-WATER OVERDRAFT
* (02),(09) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW – TOTAL DEPLETIONS – INSTREAM USE
* (03),(10) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
* (04),(11) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7. SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (CONTINUED)

DRY CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (13)• TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(14)• ASSESSED SURPLUS STRMFLW (MGD)	(15)• CURRENT STRMFLW DEPLETN	(TABLE IV-4) (16)• ASSESSED STRMFLW DEPLETN	(17) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (18) NO. OF MONTHS WHERE (14) < 0.0	(19) NO. OF MONTHS WHERE (16) > 40/70/90%	ANNUAL INFORMATION (20)• ASSESSED TOTAL STRMFLW (MGD)	(21)• ASSESSED SURPLUS STRMFLW	(22)• CURRENT STRMFLW DEPLETN	(TABLE IV-2) (23)• ASSESSED STRMFLW DEPLETN	(24) INSTREAM USE TO TOTAL STRMFLW
GREAT LAKES REGION												**REGION 4**
401 "1975"	2779	−969	5%	5%	130%	12	0/ 0/ 0	8022	−748	2%	2%	108%
/ 1985		−988	–	5%	130%	12	0/ 0/ 0		−772	–	2%	108%
GT.LKS. 2000	JAN 2000	−1084	–	9%	130%	12	0/ 0/ 0		−866	–	3%	108%
402 "1975"	5166	−1358	2%	2%	124%	12	0/ 0/ 0	7455	−1435	2%	2%	117%
/ 1985		−1398	–	3%	124%	12	0/ 0/ 0		−1491	–	3%	117%
GT.LKS. 2000	FEB 2000	−1524	–	6%	124%	12	0/ 0/ 0		−1638	–	5%	117%
403 "1975"	789	−187	77%	77%	47%	12	10/ 4/ 0	1394	−37	40%	40%	63%
/ 1985		−420	–	107%	47%	12	12/ 9/ 5		−247	–	55%	63%
GT.LKS. 2000	AUG 2000	−814	–	157%	47%	12	12/10/10		−606	–	81%	63%
404 "1975"	8824	−1389	5%	5%	111%	12	0/ 0/ 0	12634	−1601	2%	2%	111%
/ 1985		−1612	–	8%	111%	12	0/ 0/ 0		−1722	–	3%	111%
GT.LKS. 2000	AUG 2000	−1883	–	11%	111%	12	0/ 0/ 0		−1873	–	4%	111%
405 "1975"	2922	−879	4%	4%	126%	12	0/ 0/ 0	5613	−878	1%	1%	114%
/ 1985		−930	–	6%	126%	12	0/ 0/ 0		−915	–	2%	114%
GT.LKS. 2000	AUG 2000	−1076	–	11%	126%	12	0/ 0/ 0		−1039	–	4%	114%
406 "1975"	1305	−505	54%	54%	84%	12	5/ 0/ 0	5370	−145	12%	12%	91%
/ 1985		−708	–	70%	84%	12	6/ 2/ 0		−331	–	16%	91%
GT.LKS. 2000	AUG 2000	−1003	–	93%	84%	12	8/ 5/ 3		−602	–	21%	91%
407 "1975"	1233	−323	58%	58%	68%	12	4/ 0/ 0	4744	40	14%	14%	85%
/ 1985		−367	–	62%	68%	12	4/ 0/ 0		10	–	15%	85%
GT.LKS. 2000	AUG 2000	−442	–	68%	68%	12	5/ 0/ 0		−50	–	16%	85%
408 "1975"	5005	−1818	3%	3%	133%	12	0/ 0/ 0	14619	−1917	1%	1%	112%
/ 1985		−1883	–	5%	133%	12	0/ 0/ 0		−1968	–	1%	112%
GT.LKS. 2000	AUG 2000	−2107	–	9%	133%	12	0/ 0/ 0		−2167	–	3%	112%
OHIO REGION												**REGION 5**
501 "1975"	3560	−2393	6%	6%	162%	12	0/ 0/ 0	17080	−355	1%	1%	101%
/ 1985		−2437	–	7%	162%	12	0/ 0/ 0		−396	–	1%	101%
502 2000	AUG 2000	−2514	–	9%	162%	12	0/ 0/ 0		−466	–	2%	101%
502 "1975"	9302	−5238	13%	13%	143%	12	0/ 0/ 0	53318	−3198	2%	2%	104%
/ 1985		−5700	–	18%	143%	12	0/ 0/ 0		−3664	–	3%	104%
505 2000	SEP 2000	−6767	–	30%	143%	12	0/ 0/ 0		−4740	–	5%	104%
503 "1975"	1807	−841	14%	14%	132%	12	0/ 0/ 0	9702	−176	3%	3%	99%
/ 1985		−940	–	20%	132%	12	0/ 0/ 0		−279	–	4%	99%
502 2000	OCT 2000	−1153	–	31%	132%	12	0/ 0/ 0		−503	–	6%	99%
504 "1975"	1794	−840	6%	6%	140%	12	0/ 0/ 0	8901	−420	1%	1%	103%
/ 1985		−897	–	10%	140%	12	0/ 0/ 0		−477	–	2%	103%
502 2000	SEP 2000	−1060	–	19%	140%	12	0/ 0/ 0		−636	–	4%	103%
505 "1975"	38552	−14297	5%	5%	132%	12	0/ 0/ 0	143111	−19530	1%	1%	112%
/ 1985		−15342	–	8%	132%	12	0/ 0/ 0		−20599	–	2%	112%
801 2000	OCT 2000	−17563	–	14%	132%	12	0/ 0/ 0		−22866	–	4%	112%
506 "1975"	2988	−1493	9%	9%	141%	12	0/ 0/ 0	13465	−1418	2%	2%	109%
/ 1985		−1558	–	12%	141%	12	0/ 0/ 0		−1481	–	2%	109%
505 2000	SEP 2000	−1838	–	21%	141%	12	0/ 0/ 0		−1761	–	5%	109%
507 "1975"	11478	−2886	1%	1%	124%	12	0/ 0/ 0	16465	−2569	<1%	<1%	115%
/ 1985		−2970	–	1%	124%	12	0/ 0/ 0		−2653	–	1%	115%
505 2000	JUN 2000	−3089	–	2%	124%	12	0/ 0/ 0		−2773	–	2%	115%
TENNESSEE REGION												**REGION 6**
601 "1975"	16140	−3360	1%	1%	119%	12	0/ 0/ 0	19516	−2447	1%	1%	111%
/ 1985		−3553	–	3%	119%	12	0/ 0/ 0		−2626	–	2%	111%
602 2000	AUG 2000	−3794	–	4%	119%	12	0/ 0/ 0		−2860	–	3%	111%
602 "1975"	23202	−2498	1%	1%	109%	12	0/ 0/ 0	36213	−2581	1%	1%	106%
/ 1985		−2831	–	3%	109%	12	0/ 0/ 0		−2916	–	2%	106%
505 2000	OCT 2000	−3269	–	5%	109%	12	0/ 0/ 0		−3374	–	3%	106%
UPPER MISSISSIPPI REGION												**REGION 7**
701 "1975"	3245	−1170	4%	4%	132%	12	0/ 0/ 0	6606	−2313	3%	3%	132%
/ 1985		−1222	–	6%	132%	12	0/ 0/ 0		−2400	–	5%	132%
702 2000	JAN 2000	−1277	–	8%	132%	12	0/ 0/ 0		−2495	–	6%	132%
702 "1975"	11174	−3000	2%	2%	124%	12	0/ 0/ 0	21485	−3534	2%	2%	115%
/ 1985		−3069	–	3%	124%	12	0/ 0/ 0		−3667	–	3%	115%
703 2000	JAN 2000	−3239	–	5%	124%	12	0/ 0/ 0		−3907	–	4%	115%
703 "1975"	15638	−6000	3%	3%	135%	12	0/ 0/ 0	31974	−6981	2%	2%	120%
/ 1985		−6212	–	5%	135%	12	0/ 0/ 0		−7265	–	3%	120%
704 2000	DEC 2000	−6773	–	8%	135%	12	0/ 0/ 0		−7877	–	5%	120%
704 "1975"	26866	−10947	4%	4%	137%	12	0/ 0/ 0	48728	−9489	2%	2%	117%
/ 1985		−11396	–	5%	137%	12	0/ 0/ 0		−9930	–	3%	117%
705 2000	SEP 2000	−12414	–	9%	137%	12	0/ 0/ 0		−10922	–	5%	117%
705 "1975"	110694	−39680	52%	56%	79%	12	2/ 0/ 0	105857	−23501	17%	18%	105%
/ 1985		−53233	–	69%	79%	12	3/ 0/ 0		−28661	–	22%	105%
801 2000	AUG 2000	−63723	–	78%	79%	12	3/ 1/ 0		−31352	–	25%	105%
LOWER MISSISSIPPI REGION												**REGION 8**
801 "1975"	138767	−128240	28%	30%	163%	10	1/ 0/ 0	243852	−69858	12%	12%	117%
/ 1985		−136038	–	35%	163%	10	2/ 0/ 0		−77055	–	15%	117%
802 2000	SEP 2000	−140492	–	38%	163%	11	2/ 0/ 0		−82512	–	17%	117%
802 "1975"	160712	−136122	26%	28%	156%	10	1/ 0/ 0	274702	−77317	11%	12%	116%
/ 1985		−145791	–	34%	156%	10	2/ 0/ 0		−85007	–	15%	116%
803 2000	SEP 2000	−149747	–	37%	156%	12	2/ 0/ 0		−90671	–	17%	116%
803 "1975"	171314	−157264	25%	27%	165%	11	1/ 0/ 0	304390	−88993	11%	11%	118%
/ 1985		−167191	–	33%	165%	11	2/ 0/ 0		−96776	–	14%	118%
GULF 2000	SEP 2000	−171753	–	35%	165%	11	2/ 0/ 0		−102948	–	16%	118%

• (13) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW.
•
• (13),(20) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION − "1975" GROUND-WATER OVERDRAFT.
• (14),(21) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW − TOTAL DEPLETIONS − INSTREAM USE.
• (15),(22) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT).
• (16),(23) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT).

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY

BASE CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (01)• TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(02)• ASSESSED SURPLUS STRMFLW (MGD)	(03)• CURRENT STRMFLW DEPLETN	(TABLE III-5) (04)• ASSESSED STRMFLW DEPLETN	(05) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (06) NO OF MONTHS WHERE (02) < 0 0	(07) NO OF MONTHS WHERE (04) > 40/70/90%	ANNUAL INFORMATION (08)• ASSESSED TOTAL STRMFLW (MGD)	(09)• ASSESSED SURPLUS STRMFLW	(10)• CURRENT STRMFLW DEPLETN	(TABLE II-5) (11)• ASSESSED STRMFLW DEPLETN	(12) INSTREAM USE TO TOTAL STRMFLW
SOURIS-RED-RAINY REGION												REGION 9
901 "1975"	1083	-1419	5%	5%	226%	6	0/ 0/ 0	6122	2337	2%	2%	60%
/ 1985		-1429	–	6%	226%	6	0/ 0/ 0		2301	–	3%	60%
CANADA 2000	FEB 2000	-1435	–	6%	226%	4	0/ 0/ 0		2641	–	7%	60%
MISSOURI REGION												REGION 10
1001 "1975"	13874	-1778	58%	58%	55%	3	2/ 0/ 0	7691	1366	23%	23%	59%
/ 1985		-6348	–	91%	55%	6	4/ 2/ 2		-50	–	42%	59%
1005 2000	JUL 2000	-6433	–	92%	55%	6	4/ 2/ 2		-131	–	43%	59%
1002 "1975"	7181	-410	55%	55%	51%	3	2/ 0/ 0	6085	1120	22%	22%	60%
/ 1985		-4055	–	106%	51%	4	3/ 3/ 1		71	–	39%	60%
1003 2000	AUG 2000	-4278	–	109%	51%	4	3/ 3/ 1		38	–	39%	60%
1003 "1975"	11901	-1901	57%	57%	59%	3	2/ 0/ 0	6994	1337	21%	21%	60%
/ 1985		-5893	–	91%	59%	6	4/ 2/ 1		163	–	38%	60%
1001 2000	JUL 2000	-5901	–	91%	59%	6	4/ 2/ 2		111	–	38%	60%
1004 "1975"	30510	-971	17%	17%	86%	4	1/ 0/ 0	9839	393	21%	21%	75%
/ 1985		-3626	–	26%	86%		3/ 1/ 0		-730	–	33%	75%
1005 2000	JUN 1985	-2987	–	24%	86%	9	3/ 1/ 0		-658	–	32%	75%
1005 "1975"	26603	-2173	39%	39%	69%	5	1/ 0/ 0	18562	3118	24%	24%	60%
/ 1985		-7047	–	57%	69%	6	4/ 1/ 0		221	–	39%	60%
1006 2000	JUN 2000	-8356	–	62%	69%	8	4/ 2/ 0		-1167	–	47%	60%
1006 "1975"	30800	-864	35%	35%	68%	5	1/ 0/ 0	21029	3925	22%	22%	60%
/ 1985		-6084	–	52%	68%	7	4/ 0/ 0		841	–	36%	60%
1009 2000	JUN 2000	-7440	–	56%	68%	7	4/ 2/ 0		-287	–	42%	60%
1007 "1975"	9685	-3168	96%	110%	22%	12	5/ 4/ 4	3899	-1574	76%	85%	55%
/ 1985		-3168	–	111%	22%	12	5/ 4/ 3		-1380	–	82%	55%
1008 2000	AUG 2000	-5146	–	132%	22%	12	5/ 4/ 3		-1747	–	92%	55%
1008 "1975"	22388	-2603	91%	104%	8%	4	5/ 4/ 3	9695	-250	63%	69%	34%
/ 1985		-5141	–	115%	8%	5	5/ 4/ 3		-876	–	76%	34%
1009 2000	AUG 2000	-6775	–	123%	8%	5	5/ 4/ 3		-1134	–	79%	34%
1009 "1975"	58229	1607	58%	61%	36%	6	3/ 0/ 0	35260	2947	32%	32%	59%
/ 1985		-11112	–	83%	36%	9	4/ 2/ 0		-810	–	43%	59%
1011 2000	AUG 2000	-17696	–	94%	36%	9	4/ 2/ 2		-2265	–	47%	59%
1010 "1975"	12673	-6900	82%	125%	29%	10	4/ 3/ 2	6176	-1396	50%	63%	60%
/ 1985		-6876	–	125%	29%	10	4/ 3/ 2		-1654	–	67%	60%
1011 2000	AUG 2000	-8569	–	136%	29%	9	3/ 3/ 2		-1597	–	66%	60%
1011 "1975"	77211	-8600	59%	67%	44%	4	2/ 0/ 0	57012	7585	26%	27%	60%
/ 1985		-21436	–	84%	44%	4	3/ 1/ 0		3470	–	34%	60%
705 2000	AUG 2000	-29950	–	95%	44%	5	3/ 2/ 1		1922	–	37%	60%
ARKANSAS-WHITE-RED REGION												REGION 11
1101 "1975"	6640	578	1%	1%	91%	0	0/ 0/ 0	15994	2699	1%	1%	83%
/ 1985		567	–	1%	91%	0	0/ 0/ 0		2681	–	1%	83%
801 2000	SEP 2000	540	–	1%	91%	0	0/ 0/ 0		2658	–	1%	83%
1102 "1975"	2988	-338	94%	97%	14%	12	11/ 5/ 1	877	-297	83%	85%	49%
/ 1985		-668	–	112%	14%	10	11/ 7/ 2		-223	–	82%	49%
1103 2000	JUL 1985	-170	–	98%	14%	10	11/ 9/ 2		-129	–	74%	49%
1103 "1975"	3779	-8513	75%	249%	76%	5	4/ 2/ 2	4935	-706	39%	56%	58%
/ 1985		-13857	–	392%	76%	4	3/ 2/ 2		-1223	–	68%	58%
1104 2000	AUG 2000	-13917	–	394%	76%	5	3/ 2/ 2		-1246	–	69%	58%
1104 "1975"	16197	-8985	57%	104%	51%	3	3/ 1/ 1	28319	4626	17%	19%	64%
/ 1985		-15021	–	142%	51%	3	3/ 2/ 1		3982	–	22%	64%
801 2000	AUG 1985	-14986	–	142%	51%	3	3/ 2/ 1		3665	–	23%	64%
1105 "1975"	4552	-5498	68%	135%	86%	5	6/ 4/ 3	3911	-876	41%	62%	60%
/ 1985		-6317	–	153%	86%	5	4/ 4/ 3		-875	–	62%	60%
1104 2000	JUL 2000	-6679	–	161%	86%	5	5/ 4/ 4		-958	–	64%	60%
1106 "1975"	4681	-4716	74%	129%	72%	7	7/ 3/ 3	3337	-959	50%	68%	61%
/ 1985		-6565	–	168%	72%	5	5/ 4/ 3		-1201	–	75%	61%
1107 2000	JUL 1985	-5770	–	151%	72%	5	5/ 4/ 4		-1101	–	72%	61%
1107 "1975"	9954	-1985	50%	70%	50%	2	3/ 0/ 0	20894	3649	11%	12%	71%
/ 1985		-3932	–	90%	50%	3	3/ 1/ 0		3380	–	13%	71%
802 2000	AUG 1985	-1777	–	68%	50%	4	3/ 0/ 0		3404	–	13%	71%
TEXAS-GULF REGION												REGION 12
1201 "1975"	6274	56	12%	12%	87%	0	0/ 0/ 0	10763	1701	5%	5%	80%
/ 1985		26	–	13%	87%	0	0/ 0/ 0		1644	–	5%	80%
GULF 2000	JUL 2000	-588	–	22%	87%	3	0/ 0/ 0		1177	–	10%	80%
1202 "1975"	3406	-358	57%	62%	48%	2	3/ 0/ 0	8804	993	18%	18%	71%
/ 1985		-726	–	73%	48%	4	3/ 1/ 0		720	–	21%	71%
GULF 2000	AUG 2000	-1849	–	106%	48%	7	5/ 2/ 1		-128	–	31%	71%
1203 "1975"	5715	-17529	95%	395%	12%	6	6/ 3/ 3	5803	-2407	51%	84%	58%
/ 1985		-16367	–	375%	12%	4	4/ 3/ 3		-1480	–	68%	58%
GULF 2000	AUG 1975	-8570	–	238%	12%	4	4/ 3/ 3		-780	–	56%	58%
1204 "1975"	6378	-3975	93%	151%	11%	5	6/ 4/ 4	3714	-704	63%	82%	37%
/ 1985		-2768	–	132%	11%	3	6/ 4/ 3		-343	–	73%	37%
GULF 2000	AUG 1975	-572	–	98%	11%	7	7/ 4/ 2		-201	–	69%	37%
1205 "1975"	6034	-1132	42%	47%	72%	8	1/ 0/ 0	4867	192	24%	26%	70%
/ 1985		-1727	–	57%	72%	8	1/ 0/ 0		96	–	28%	70%
GULF 2000	JUN 1985	-1496	–	53%	72%	8	1/ 0/ 0		150	–	26%	70%

• (01) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW.
•
• (01),(08) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION – "1975" GROUND-WATER OVERDRAFT
• (02),(09) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW – TOTAL DEPLETIONS – INSTREAM USE.
• (03),(10) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
• (04),(11) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7. SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (CONTINUED)

DRY CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION		CRITICAL MONTH INFORMATION...(TABLE IV-4) (13)* TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(14)* ASSESSED SURPLUS STRMFLW (MGD)	(15)* CURRENT STRMFLW DEPLETN	(16)* ASSESSED STRMFLW DEPLETN	(17) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (18) NO. OF MONTHS WHERE (14) < 0.0	(19) NO. OF MONTHS WHERE (16) > 40/70/90%	ANNUAL INFORMATION...(TABLE IV-2) (20)* ASSESSED TOTAL STRMFLW (MGD)	(21)* ASSESSED SURPLUS STRMFLW	(22)* CURRENT STRMFLW DEPLETN	(23)* ASSESSED STRMFLW DEPLETN	(24) INSTREAM USE TO TOTAL STRMFLW
SOURIS–RED–RAINY REGION													REGION 9
901	"1975"	512	−1990	10%	10%	478%	10	0/ 0/ 0	3472	−323	4%	4%	106%
/	1985		−2000	–	12%	478%	10	1/ 0/ 0		−380	–	7%	106%
CANADA	2000	FEB 2000	−2006	–	13%	478%	10	3/ 2/ 1		−103	–	16%	106%
MISSOURI REGION													REGION 10
1001	"1975"	12174	−3994	71%	71%	62%	6	4/ 2/ 0	6431	−275	34%	34%	71%
/	1985		−10844	–	127%	62%	6	6/ 4/ 4		−1992	–	60%	71%
1005	2000	JUL 2000	−10914	–	127%	62%	6	6/ 4/ 3		−2073	–	62%	71%
1002	"1975"	6331	−2263	78%	78%	58%	7	3/ 1/ 0	5005	−184	31%	31%	73%
/	1985		−6234	–	141%	58%	7	5/ 3/ 3		−1416	–	55%	73%
1003	2000	AUG 2000	−6477	–	145%	58%	7	5/ 3/ 3		−1448	–	56%	73%
1003	"1975"	9961	−4222	72%	72%	70%	6	4/ 2/ 0	5834	−108	30%	30%	72%
/	1985		−10028	–	131%	70%	6	6/ 4/ 3		−1510	–	54%	72%
1001	2000	JUL 2000	−10015	–	130%	70%	6	6/ 4/ 3		−1562	–	55%	72%
1004	"1975"	22710	−9015	24%	25%	115%	12	3/ 0/ 0	8159	−1398	27%	27%	90%
/	1985		−11864	–	37%	115%	12	3/ 3/ 2		−2583	–	41%	90%
1005	2000	JUN 1985	−11187	–	34%	115%	12	3/ 3/ 2		−2507	–	41%	90%
1005	"1975"	21203	−8070	51%	51%	87%	7	3/ 0/ 0	14962	−1126	34%	34%	74%
/	1985		−14518	–	82%	87%	10	5/ 3/ 1		−4403	–	55%	74%
1006	2000	JUN 2000	−15804	–	88%	87%	10	5/ 4/ 2		−5803	–	65%	74%
1006	"1975"	26600	−5656	43%	43%	79%	7	3/ 0/ 0	17529	−243	30%	30%	72%
/	1985		−12503	–	68%	79%	10	5/ 2/ 0		−3748	–	50%	72%
1009	2000	JUN 2000	−13953	–	74%	79%	10	5/ 4/ 2		−4939	–	57%	72%
1007	"1975"	9447	−5401	117%	134%	23%	12	6/ 5/ 4	3616	−2169	90%	100%	60%
/	1985		−4461	–	125%	23%	12	5/ 5/ 5		−1956	–	97%	60%
1008	2000	AUG 2000	−6618	–	148%	23%	12	11/ 4/ 4		−2344	–	108%	60%
1008	"1975"	21338	−8194	113%	130%	8%	12	6/ 4/ 4	8925	−1903	77%	85%	37%
/	1985		−9890	–	139%	8%	12	6/ 5/ 5		−2657	–	94%	37%
1009	2000	AUG 2000	−11625	–	147%	8%	12	6/ 5/ 4		−2904	–	97%	37%
1009	"1975"	54329	−9829	75%	80%	38%	11	4/ 2/ 0	31560	−2315	40%	41%	66%
/	1985		−22154	–	102%	38%	11	5/ 4/ 2		−6621	–	55%	66%
1011	2000	AUG 2000	−29061	–	115%	38%	11	5/ 4/ 2		−8129	–	60%	66%
1010	"1975"	10363	−10496	100%	166%	36%	12	5/ 5/ 5	4166	−3797	74%	102%	89%
/	1985		−10803	–	168%	36%	12	7/ 6/ 4		−4070	–	109%	89%
1011	2000	AUG 2000	−12653	–	186%	36%	12	5/ 4/ 3		−3995	–	107%	89%
1011	"1975"	65211	−29422	81%	93%	52%	11	4/ 3/ 1	42812	−8569	38%	41%	79%
/	1985		−42197	–	113%	52%	11	4/ 3/ 2		−13248	–	52%	79%
705	2000	AUG 2000	−51191	–	126%	52%	11	4/ 3/ 3		−14831	–	55%	79%
ARKANSAS–WHITE–RED REGION													REGION 11
1101	"1975"	4250	−1827	2%	2%	141%	12	0/ 0/ 0	10594	−2707	1%	1%	125%
/	1985		−1824	–	1%	141%	12	0/ 0/ 0		−2726	–	1%	125%
801	2000	SEP 2000	−1851	–	2%	141%	12	0/ 0/ 0		−2749	–	1%	125%
1102	"1975"	2872	−1291	126%	130%	15%	12	12/ 6/ 5	813	−610	119%	122%	53%
/	1985		−1984	–	159%	15%	12	12/11/11		−510	–	116%	53%
1103	2000	JUL 1985	−1309	–	138%	15%	10	12/11/10		−377	–	102%	53%
1103	"1975"	1428	−12617	110%	783%	201%	12	8/ 7/ 7	2515	−3605	70%	129%	114%
/	1985		−18443	–	1193%	201%	12	8/ 5/ 3		−4155	–	153%	114%
1104	2000	AUG 2000	−18359	–	1189%	201%	12	11/ 5/ 3		−4138	–	153%	114%
1104	"1975"	7167	−20856	95%	275%	116%	12	5/ 4/ 3	16219	−8368	31%	40%	112%
/	1985		−27581	–	370%	116%	12	5/ 3/ 3		−9025	–	44%	112%
801	2000	AUG 1985	−27319	–	366%	116%	12	5/ 3/ 3		−9305	–	46%	112%
1105	"1975"	2752	−8184	97%	255%	142%	12	12/12/11	1991	−3194	70%	143%	118%
/	1985		−9269	–	295%	142%	12	12/11/10		−3176	–	142%	118%
1104	2000	JUL 2000	−9671	–	309%	142%	12	12/11/11		−3260	–	146%	118%
1106	"1975"	4251	−5788	86%	157%	79%	12	10/ 7/ 7	2537	−2019	67%	100%	80%
/	1985		−7907	–	207%	79%	12	7/ 6/ 5		−2275	–	110%	80%
1107	2000	JUL 1985	−6985	–	185%	79%	12	7/ 6/ 5		−2144	–	105%	80%
1107	"1975"	5684	−6832	79%	133%	88%	12	3/ 3/ 3	13194	−4319	19%	21%	112%
/	1985		−9232	–	175%	88%	12	5/ 3/ 3		−4623	–	23%	112%
802	2000	AUG 1985	−6781	–	132%	88%	12	5/ 3/ 3		−4550	–	22%	112%
TEXAS–GULF REGION													REGION 12
1201	"1975"	3064	−3218	27%	27%	178%	12	0/ 0/ 0	5613	−3483	9%	10%	153%
/	1985		−3234	–	28%	178%	12	0/ 0/ 0		−3533	–	10%	153%
GULF	2000	JUL 2000	−3839	–	47%	178%	12	5/ 1/ 0		−3995	–	19%	153%
1202	"1975"	2251	−1631	87%	99%	73%	12	8/ 5/ 3	4474	−3400	35%	37%	139%
/	1985		−1970	–	114%	73%	12	10/ 6/ 4		−3665	–	43%	139%
GULF	2000	AUG 2000	−3108	–	165%	73%	12	12/ 8/ 7		−4516	–	62%	139%
1203	"1975"	4580	−22156	115%	569%	15%	12	11/10/ 8	2703	−6139	85%	203%	124%
/	1985		−20349	–	530%	15%	12	12/ 8/ 8		−5058	–	163%	124%
GULF	2000	AUG 1975	−11434	–	335%	15%	12	12/ 9/ 8		−4237	–	132%	124%
1204	"1975"	5900	−5938	113%	188%	12%	12	12/ 8/ 6	2550	−2258	93%	135%	53%
/	1985		−4372	–	162%	12%	12	12/ 8/ 8		−1831	–	119%	53%
GULF	2000	AUG 1975	−1806	–	118%	12%	12	12/12/11		−1627	–	111%	53%
1205	"1975"	3384	−3889	71%	87%	128%	12	10/ 6/ 0	2607	−2152	45%	51%	132%
/	1985		−4645	–	110%	128%	12	11/ 6/ 3		−2247	–	55%	132%
GULF	2000	JUN 1985	−4382	–	102%	128%	12	11/ 5/ 2		−2180	–	52%	132%

* (13) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW

* (13),(20) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION − "1975" GROUND-WATER OVERDRAFT.
* (14),(21) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW − TOTAL DEPLETIONS − INSTREAM USE.
* (15),(22) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT).
* (16),(23) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT).

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY

BASE CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (01)• TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(02)• ASSESSED SURPLUS STRMFLW (MGD)	(03)• CURRENT STRMFLW DEPLETN	(TABLE III-5) (04)• ASSESSED STRMFLW DEPLETN	(05) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (06) NO OF MONTHS WHERE (02) < 0.0	(07) NO OF MONTHS WHERE (04) > 40/70/90%	ANNUAL INFORMATION (08)• ASSESSED TOTAL STRMFLW (MGD)	(09)• ASSESSED SURPLUS STRMFLW	(10)• CURRENT STRMFLW DEPLETN	(TABLE II-5) (11)• ASSESSED STRMFLW DEPLETN	(12) INSTREAM USE TO TOTAL STRMFLW
RIO GRANDE REGION												REGION 13
1301 "1975"	1469	-305	92%	92%	28%	10	4/ 4/ 2	848	-80	69%	69%	41%
/ 1985		-686	-	133%	28%	12	5/ 4/ 4		-253	-	89%	41%
1302 2000	AUG 2000	-693	-	133%	28%	12	5/ 4/ 4		-238	-	87%	41%
1302 "1975"	2050	-724	75%	87%	49%	12	12/10/ 5	1906	-755	84%	96%	44%
/ 1985		-1866	-	142%	49%	12	12/12/12		-1012	-	109%	44%
1303 2000	MAY 1985	-1813	-	140%	49%	12	12/12/11		-990	-	108%	44%
1303 "1975"	3184	-1804	84%	105%	51%	12	12/ 9/ 7	2958	-1422	84%	102%	46%
/ 1985		-2781	-	136%	51%	12	12/12/ 9		-1519	-	105%	46%
1305 2000	MAY 1985	-2428	-	125%	51%	12	12/11/ 7		-1335	-	99%	46%
1304 "1975"	1490	-546	95%	113%	24%	12	8/ 6/ 5	595	-265	82%	94%	50%
/ 1985		-43	-	79%	24%	10	8/ 3/ 0		-107	-	68%	50%
1303 2000	JUL 1975	-133	-	85%	24%	10	12/ 4/ 1		-147	-	75%	50%
1305 "1975"	6993	-2465	86%	96%	39%	12	12/ 6/ 6	4813	-1714	78%	88%	48%
/ 1985		-3743	-	114%	39%	11	12/ 7/ 6		-1863	-	91%	48%
GULF 2000	MAY 1985	-3228	-	107%	39%	11	11/ 7/ 5		-1580	-	85%	48%
UPPER COLORADO REGION												REGION 14
1401 "1975"	4006	-866	45%	45%	76%	4	2/ 0/ 0	4699	624	22%	22%	65%
/ 1985		-2237	-	80%	76%	7	3/ 1/ 0		329	-	28%	65%
1403 2000	AUG 2000	-2614	-	89%	76%	7	3/ 1/ 0		179	-	31%	65%
1402 "1975"	3283	-1343	31%	31%	110%	9	1/ 0/ 0	5727	1117	17%	17%	63%
/ 1985		-2044	-	52%	110%	8	2/ 0/ 0		1073	-	18%	63%
1403 2000	SEP 1985	-2022	-	52%	110%	9	2/ 0/ 0		1001	-	19%	63%
1403 "1975"	21486	355	37%	37%	62%	0	1/ 0/ 0	12440	2053	20%	20%	64%
/ 1985		-841	-	42%	62%	5	3/ 0/ 0		1285	-	26%	64%
1502 2000	JUN 2000	-1728	-	46%	62%	5	3/ 0/ 0		954	-	28%	64%
LOWER COLORADO REGION												REGION 15
1501 "1975"	314	-180	50%	51%	106%	2	3/ 0/ 0	340	67	21%	21%	59%
/ 1985		-251	-	78%	106%	3	4/ 1/ 0		28	-	36%	59%
1502 2000	JUN 2000	-283	-	89%	106%	3	5/ 2/ 0		3	-	43%	59%
1502 "1975"	12747	-13498	90%	116%	90%	12	12/10/ 8	6170	-7729	82%	114%	111%
/ 1985		-14539	-	124%	90%	12	12/11/10		-8297	-	126%	111%
MEXICO 2000	JUN 2000	-15157	-	129%	90%	12	12/12/10		-8408	-	130%	111%
1503 "1975"	2487	-5200	100%	276%	33%	12	12/12/12	1363	-2776	99%	254%	50%
/ 1985		-4446	-	246%	33%	12	12/12/12		-2867	-	261%	50%
1502 2000	AUG 1975	-4468	-	251%	33%	12	12/12/12		-2682	-	254%	50%
GREAT BASIN REGION												REGION 16
1601 "1975"	1457	-1069	58%	60%	114%	5	4/ 2/ 2	2852	-59	43%	44%	58%
/ 1985		-1688	-	110%	114%	3	5/ 2/ 2		105	-	41%	58%
CLS BSN 2000	SEP 1985	-1511	-	105%	114%	3	5/ 2/ 2		91	-	44%	58%
1602 "1975"	1461	-1003	89%	150%	19%	12	12/10/ 4	473	-404	84%	127%	59%
/ 1985		-449	-	112%	19%	12	12/12/ 6		-347	-	115%	59%
CLS BSN 2000	JUL 1975	-545	-	118%	19%	12	12/11/ 7		-357	-	117%	59%
1603 "1975"	666	-664	91%	117%	83%	12	12/12/ 9	923	-708	89%	117%	60%
/ 1985		-1644	-	264%	83%	12	12/12/11		-856	-	133%	60%
CLS BSN 2000	SEP 2000	-1819	-	290%	83%	12	12/12/12		-959	-	144%	60%
1604 "1975"	1688	-762	90%	92%	53%	7	7/ 3/ 1	1502	-247	56%	56%	60%
/ 1985		-1013	-	107%	53%	7	8/ 3/ 3		-234	-	56%	60%
CLS BSN 2000	AUG 2000	-1110	-	112%	53%	9	9/ 4/ 3		-306	-	60%	60%
PACIFIC NORTHWEST REGION												REGION 17
1701 "1975"	13977	-6428	9%	9%	137%	2	0/ 0/ 0	32016	12181	2%	2%	60%
/ 1985		-7808	-	18%	137%	2	0/ 0/ 0		11892	-	3%	60%
1702 2000	AUG 2000	-7909	-	19%	137%	2	0/ 0/ 0		11847	-	3%	60%
1702 "1975"	176497	692	8%	8%	92%	1	0/ 0/ 0	124619	25309	8%	8%	71%
/ 1985		-3174	-	10%	92%	2	0/ 0/ 0		23300	-	10%	71%
1705 2000	MAY 2000	-3508	-	10%	92%	2	0/ 0/ 0		22942	-	10%	71%
1703 "1975"	24836	-5272	82%	84%	37%	4	3/ 1/ 0	15503	1327	33%	33%	58%
/ 1985		-5700	-	86%	37%	4	5/ 2/ 0		571	-	38%	58%
1704 2000	JUL 1985	-5273	-	84%	37%	4	5/ 2/ 0		690	-	37%	58%
1704 "1975"	25449	-1416	54%	55%	51%	2	2/ 0/ 0	35012	7912	16%	16%	62%
/ 1985		-4272	-	66%	51%	4	2/ 0/ 0		6988	-	19%	62%
1702 2000	AUG 1985	-4261	-	66%	51%	4	2/ 0/ 0		6970	-	19%	62%
1705 "1975"	131155	7838	20%	20%	74%	0	0/ 0/ 0	222359	32714	5%	5%	80%
/ 1985		1403	-	25%	74%	0	0/ 0/ 0		30374	-	6%	80%
PACIFIC 2000	AUG 2000	859	-	25%	74%	0	0/ 0/ 0		29890	-	6%	80%
1706 "1975"	16518	3122	1%	1%	80%	0	0/ 0/ 0	42394	7951	<1%	<1%	81%
/ 1985		2960	-	2%	80%	0	0/ 0/ 0		7834	-	1%	81%
PACIFIC 2000	SEP 2000	2804	-	3%	80%	0	0/ 0/ 0		7656	-	1%	81%
1707 "1975"	1489	-703	73%	75%	73%	8	4/ 2/ 0	1803	-26	41%	41%	60%
/ 1985		-2987	-	228%	73%	7	4/ 3/ 3		-307	-	57%	60%
CLS BSN 2000	JUL 1985	-2836	-	218%	73%	7	4/ 3/ 3		-259	-	54%	60%

• (01) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
•
• (01),(08) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION - "1975" GROUND-WATER OVERDRAFT
• (02),(09) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW - TOTAL DEPLETIONS - INSTREAM USE
• (03),(10) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
• (04),(11) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (CONTINUED)

DRY CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION		CRITICAL MONTH INFORMATION (13)• TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(14)• ASSESSED SURPLUS STRMFLW (MGD)	(15)• CURRENT STRMFLW DEPLETN	(TABLE IV-4) (16)• ASSESSED STRMFLW DEPLETN	(17) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (18) NO OF MONTHS WHERE (14) < 0 0	(19) NO OF MONTHS WHERE (16) > 40/70/90%	(20)• ASSESSED TOTAL STRMFLW (MGD)	ANNUAL INFORMATION (21)• ASSESSED SURPLUS STRMFLW	(22)• CURRENT STRMFLW DEPLETN	(TABLE IV-2) (23)• ASSESSED STRMFLW DEPLETN	(24) INSTREAM USE TO TOTAL STRMFLW
RIO GRANDE REGION													REGION 13
1301	"1975"	1372	-1034	145%	145%	30%	12	5/ 4/ 4	687	-400	108%	108%	51%
/	1985		-1325	–	181%	30%	12	6/ 5/ 5		-605	–	138%	51%
1302	2000	AUG 2000	-1334	–	182%	30%	12	6/ 5/ 5		-586	–	135%	51%
1302	"1975"	1607	-1210	94%	113%	62%	12	12/12/10	1750	-1130	102%	117%	48%
/	1985		-2490	–	193%	62%	12	12/12/12		-1423	–	134%	48%
1303	2000	MAY 1985	-2431	–	189%	62%	12	12/12/12		-1394	–	132%	48%
1303	"1975"	2867	-2207	94%	120%	57%	12	12/12/10	2667	-2017	100%	125%	51%
/	1985		-3379	–	161%	57%	12	12/12/12		-2135	–	129%	51%
1305	2000	MAY 1985	-2995	–	148%	57%	12	12/12/11		-1931	–	121%	51%
1304	"1975"	1416	-652	101%	121%	25%	12	12/ 7/ 7	510	-395	101%	119%	58%
/	1985		-212	–	90%	25%	12	11/10/ 4		-222	–	85%	58%
1303	2000	JUL 1975	-308	–	96%	25%	12	12/10/ 9		-264	–	93%	58%
1305	"1975"	6080	-3796	103%	117%	45%	12	12/12/12	3853	-3103	104%	121%	59%
/	1985		-5321	–	142%	45%	12	12/12/12		-3277	–	126%	59%
GULF	2000	MAY 1985	-4757	–	133%	45%	12	12/12/11		-2962	–	118%	59%
UPPER COLORADO REGION													REGION 14
1401	"1975"	3186	-2962	97%	97%	96%	10	3/ 1/ 1	3699	-512	31%	31%	83%
/	1985		-3465	–	113%	96%	12	4/ 3/ 1		-830	–	40%	83%
1403	2000	AUG 2000	-3848	–	125%	96%	12	4/ 3/ 1		-971	–	44%	83%
1402	"1975"	3043	-2262	55%	55%	119%	9	3/ 0/ 0	4407	-273	24%	24%	82%
/	1985		-2408	–	60%	119%	9	3/ 0/ 0		-320	–	25%	82%
1403	2000	SEP 1985	-2382	–	60%	119%	9	3/ 0/ 0		-392	–	27%	82%
1403	"1975"	11136	-9605	67%	67%	119%	10	5/ 2/ 0	9460	-1164	28%	28%	84%
/	1985		-12051	–	89%	119%	11	5/ 4/ 2		-1987	–	37%	84%
1502	2000	JUN 2000	-12948	–	97%	119%	11	5/ 4/ 4		-2316	–	40%	84%
LOWER COLORADO REGION													REGION 15
1501	"1975"	294	-200	53%	55%	113%	6	4/ 0/ 0	268	-7	27%	28%	75%
/	1985		-278	–	86%	113%	9	7/ 3/ 0		-46	–	46%	75%
1502	2000	JUN 2000	-310	–	97%	113%	12	7/ 5/ 2		-72	–	56%	75%
1502	"1975"	12487	-13422	90%	116%	92%	12	12/10/ 9	5980	-8274	88%	124%	115%
/	1985		-15839	–	135%	92%	12	12/12/10		-8895	–	137%	115%
MEXICO	2000	JUN 2000	-16453	–	140%	92%	12	12/12/12		-8996	–	140%	115%
1503	"1975"	2483	-5493	104%	289%	33%	12	12/12/12	1344	-2896	103%	265%	50%
/	1985		-4627	–	254%	33%	12	12/12/12		-2985	–	272%	50%
1502	2000	AUG 1975	-4645	–	258%	33%	12	12/12/12		-2790	–	264%	50%
GREAT BASIN REGION													REGION 16
1601	"1975"	1094	-2363	160%	165%	151%	8	6/ 5/ 2	2452	-594	56%	57%	68%
/	1985		-2219	–	162%	151%	9	6/ 4/ 2		-412	–	52%	68%
CLS BSN	2000	SEP 1985	-2021	–	153%	151%	9	6/ 5/ 2		-425	–	56%	68%
1602	"1975"	1404	-866	83%	142%	20%	12	12/12/ 7	449	-468	93%	142%	62%
/	1985		-625	–	125%	20%	12	12/12/10		-405	–	128%	62%
CLS BSN	2000	JUL 1975	-728	–	132%	20%	12	12/12/11		-415	–	131%	62%
1603	"1975"	610	-1948	251%	329%	91%	12	12/12/12	848	-1037	117%	157%	65%
/	1985		-2131	–	359%	91%	12	12/12/12		-1214	–	178%	65%
CLS BSN	2000	SEP 2000	-2342	–	393%	91%	12	12/12/12		-1334	–	192%	65%
1604	"1975"	1566	-1204	117%	119%	58%	12	9/ 6/ 4	1085	-708	81%	82%	83%
/	1985		-1229	–	121%	58%	12	11/ 6/ 4		-691	–	81%	83%
CLS BSN	2000	AUG 2000	-1331	–	127%	58%	12	12/ 9/ 4		-766	–	88%	83%
PACIFIC NORTHWEST REGION													REGION 17
1701	"1975"	11477	-10024	20%	20%	167%	3	0/ 0/ 0	27316	7266	3%	3%	70%
/	1985		-11279	–	31%	167%	3	0/ 0/ 0		6863	–	5%	70%
1702	2000	AUG 2000	-11380	–	32%	167%	3	0/ 0/ 0		6818	–	5%	70%
1702	"1975"	139497	-41191	14%	14%	116%	4	0/ 0/ 0	108419	6398	12%	12%	82%
/	1985		-45076	–	17%	116%	6	2/ 0/ 0		3854	–	14%	82%
1705	2000	MAY 2000	-45430	–	17%	116%	6	2/ 0/ 0		3485	–	15%	82%
1703	"1975"	23376	-10039	100%	103%	40%	9	5/ 3/ 2	13033	-2589	50%	50%	69%
/	1985		-13239	–	117%	40%	9	5/ 5/ 3		-3545	–	58%	69%
1704	2000	JUL 1985	-12649	–	114%	40%	10	5/ 5/ 3		-3371	–	56%	69%
1704	"1975"	23649	-7214	74%	76%	55%	6	3/ 2/ 0	29712	1072	24%	24%	72%
/	1985		-10742	–	91%	55%	6	4/ 2/ 1		-86	–	28%	72%
1702	2000	AUG 1985	-10657	–	90%	55%	6	4/ 2/ 1		-72	–	28%	72%
1705	"1975"	116255	-14657	29%	29%	83%	11	0/ 0/ 0	187359	-5126	7%	7%	95%
/	1985		-22296	–	36%	83%	11	0/ 0/ 0		-8068	–	9%	95%
PACIFIC	2000	AUG 2000	-22782	–	36%	83%	11	0/ 0/ 0		-8535	–	9%	95%
1706	"1975"	13118	-291	2%	2%	100%	11	0/ 0/ 0	36094	1639	1%	1%	95%
/	1985		-466	–	3%	100%	11	0/ 0/ 0		1513	–	1%	95%
PACIFIC	2000	SEP 2000	-620	–	4%	100%	11	0/ 0/ 0		1335	–	1%	95%
1707	"1975"	1269	-2381	199%	202%	85%	10	4/ 3/ 3	1166	-706	67%	68%	93%
/	1985		-3421	–	284%	85%	11	6/ 3/ 3		-1004	–	93%	93%
CLS BSN	2000	JUL 1985	-3260	–	272%	85%	11	6/ 3/ 3		-953	–	89%	93%

• (13) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
•
• (13),(20) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION – "1975" GROUND-WATER OVERDRAFT
• (14),(21) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW – TOTAL DEPLETIONS – INSTREAM USE
• (15),(22) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
• (16),(23) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY

BASE CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (01)• TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(02)• ASSESSED SURPLUS STRMFLW (MGD)	(03)• CURRENT STRMFLW DEPLETN	(TABLE III-5) (04)• ASSESSED STRMFLW DEPLETN	(05) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (06) NO OF MONTHS WHERE (02) < 0 0	(07) NO OF MONTHS WHERE (04) > 40/70/90%	ANNUAL INFORMATION (08)• ASSESSED TOTAL STRMFLW (MGD)	(09)• ASSESSED SURPLUS STRMFLW	(10)• CURRENT STRMFLW DEPLETN	(TABLE II-5) (11)• ASSESSED STRMFLW DEPLETN	(12) INSTREAM USE TO TOTAL STRMFLW
CALIFORNIA REGION												REGION 18
1801 "1975"	3999	-8355	32%	32%	277%	4	0/ 0/ 0	26737	9403	3%	3%	62%
/ 1985		-9066	-	50%	277%	4	1/ 0/ 0		9201	-	4%	62%
PACIFIC 2000	AUG 2000	-9176	-	53%	277%	5	2/ 0/ 0		9125	-	4%	62%
1802 "1975"	8271	-10058	6%	6%	215%	4	5/ 1/ 0	19065	4590	28%	28%	48%
/ 1985		-12107	-	31%	215%	6	7/ 2/ 0		2271	-	40%	48%
PACIFIC 2000	NOV 2000	-13568	-	49%	215%	6	8/ 4/ 2		667	-	49%	48%
1803 "1975"	21843	-1837	78%	84%	24%	10	9/ 8/ 5	14229	-1261	82%	89%	20%
/ 1985		-6546	-	108%	24%	5	9/ 9/ 9		-1328	-	94%	20%
PACIFIC 2000	MAY 2000	-8017	-	116%	24%	7	9/ 8/ 8		-2066	-	103%	20%
1804 "1975"	4862	-476	8%	8%	102%	6	6/ 4/ 2	3379	320	24%	24%	67%
/ 1985		-256	-	9%	102%	2	6/ 5/ 4		433	-	29%	67%
PACIFIC 2000	MAR 1975	-288	-	12%	102%	3	7/ 6/ 5		406	-	33%	67%
1805 "1975"	2111	-146	72%	77%	29%	6	6/ 6/ 4	2240	377	36%	37%	46%
/ 1985		-863	-	113%	29%	5	6/ 5/ 4		235	-	45%	46%
PACIFIC 2000	MAY 2000	-995	-	124%	29%	4	6/ 5/ 4		254	-	48%	46%
1806 "1975"	10793	-853	100%	108%	<1%	8	12/10/ 8	5842	-388	93%	101%	6%
/ 1985		1204	-	92%	<1%	0	12/12/ 8		552	-	91%	6%
PACIFIC 2000	JUL 1975	2266	-	87%	<1%	0	12/12/ 6		1034	-	90%	6%
1807 "1975"	341	-825	75%	113%	229%	12	12/ 6/ 4	327	-470	70%	100%	143%
/ 1985		-826	-	113%	229%	12	12/ 7/ 6		-463	-	98%	143%
CLS BSN 2000	APR 2000	-861	-	123%	229%	12	12/ 7/ 6		-481	-	104%	143%
ALASKA REGION												REGION 19
1901 "1975"	246055	15090	<1%	<1%	94%	0	0/ 0/ 0	905058	46000	<1%	<1%	95%
/ 1985		14942	-	<1%	94%	0	0/ 0/ 0		45851	-	<1%	95%
PACIFIC 2000	APR 2000	14689	-	<1%	94%	0	0/ 0/ 0		45599	-	<1%	95%
HAWAII REGION												REGION 20
2001 "1975"	1209	191	4%	4%	80%	0	0/ 0/ 0	3521	1336	1%	1%	61%
/ 1985		184	-	5%	80%	0	0/ 0/ 0		1330	-	1%	61%
PACIFIC 2000	JUN 2000	176	-	5%	80%	0	0/ 0/ 0		1322	-	1%	61%
2002 "1975"	1054	72	33%	33%	61%	0	0/ 0/ 0	1482	304	17%	17%	62%
/ 1985		58	-	34%	61%	0	0/ 0/ 0		286	-	18%	62%
PACIFIC 2000	SEP 2000	50	-	35%	61%	0	0/ 0/ 0		276	-	19%	62%
2003 "1975"	513	13	48%	48%	49%	0	4/ 0/ 0	562	113	28%	28%	52%
/ 1985		11	-	49%	49%	0	4/ 0/ 0		102	-	30%	52%
PACIFIC 2000	JUL 2000	-8	-	52%	49%	1	5/ 0/ 0		82	-	33%	52%
2004 "1975"	960	110	26%	26%	63%	0	0/ 0/ 0	1787	404	9%	9%	68%
/ 1985		123	-	25%	63%	0	0/ 0/ 0		408	-	9%	68%
PACIFIC 2000	JUN 1975	134	-	23%	63%	0	0/ 0/ 0		416	-	9%	68%
CARIBBEAN REGION												REGION 21
2101 "1975"	3444	316	12%	12%	79%	0	0/ 0/ 0	5177	1131	7%	7%	72%
/ 1985		286	-	13%	79%	0	0/ 0/ 0		1102	-	7%	72%
ATLANT 2000	JAN 1985	397	-	10%	79%	0	0/ 0/ 0		1179	-	6%	72%
2102 "1975"	3	<1	100%	100%	0%	0	12/ 9/ 6	4	1	75%	75%	0%
/ 1985		-2	-	166%	0%	11	12/12/12		-1	-	125%	0%
ATLANT 2000	SEP 2000	-5	-	266%	0%	12	12/12/12		-4	-	200%	0%

• (01) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
•
• (01),(08) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION - "1975" GROUND-WATER OVERDRAFT
• (02),(09) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW - TOTAL DEPLETIONS - INSTREAM USE
• (03),(10) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
• (04),(11) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-7 SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (CONTINUED)

DRY CONDITIONS

SUBREGION / DOWNSTREAM SUBREGION	CRITICAL MONTH INFORMATION (13)* TOTAL STRMFLW —(MGD)— CRITICAL MONTH/YR	(14)* ASSESSED SURPLUS STRMFLW (MGD)	(15)* CURRENT STRMFLW DEPLETN	(TABLE IV-4) (16)* ASSESSED STRMFLW DEPLETN	(17) INSTREAM USE TO TOTAL STRMFLW	MONTHLY SUMMARY (18) NO OF MONTHS WHERE (14) < 0 0	(19) NO OF MONTHS WHERE (16) > 40/70/90%	ANNUAL INFORMATION (20)* ASSESSED TOTAL STRMFLW (MGD)	(21)* ASSESSED SURPLUS STRMFLW	(22)* CURRENT STRMFLW DEPLETN	(TABLE IV-2) (23)* ASSESSED STRMFLW DEPLETN	(24) INSTREAM USE TO TOTAL STRMFLW
CALIFORNIA REGION												REGION 18
1801 "1975"	3289	-9258	45%	45%	336%	9	2/ 0/ 0	18537	1072	5%	5%	90%
/ 1985		-10152	-	72%	336%	9	3/ 1/ 0		834	-	6%	90%
PACIFIC 2000	AUG 2000	-10274	-	76%	336%	9	3/ 1/ 0		752	-	6%	90%
1802 "1975"	5721	-12615	9%	9%	311%	9	7/ 3/ 0	14105	-853	41%	42%	64%
/ 1985		-14689	-	45%	311%	11	8/ 7/ 2		-3210	-	58%	64%
PACIFIC 2000	NOV 2000	-16150	-	71%	311%	11	10/ 8/ 6		-4832	-	70%	64%
1803 "1975"	17520	-9093	110%	122%	30%	12	9/ 9/ 9	12599	-3812	98%	108%	23%
/ 1985		-12602	-	145%	30%	12	10/ 9/ 9		-3932	-	114%	23%
PACIFIC 2000	MAY 2000	-14200	-	156%	30%	11	9/ 9/ 8		-4753	-	125%	23%
1804 "1975"	1972	-3366	19%	19%	252%	12	8/ 6/ 4	2049	-1064	42%	42%	110%
/ 1985		-3155	-	23%	252%	12	9/ 8/ 6		-961	-	51%	110%
PACIFIC 2000	MAR 1975	-3192	-	31%	252%	12	9/ 8/ 6		-991	-	58%	110%
1805 "1975"	1633	-1104	117%	130%	38%	12	7/ 7/ 7	1157	-793	74%	80%	89%
/ 1985		-1603	-	161%	38%	12	9/ 7/ 7		-952	-	95%	89%
PACIFIC 2000	MAY 2000	-1758	-	178%	38%	11	9/ 7/ 6		-939	-	103%	89%
1806 "1975"	10758	-1038	101%	109%	<1%	12	12/12/12	5487	-908	101%	110%	6%
/ 1985		881	-	95%	<1%	5	12/12/12		58	-	99%	6%
PACIFIC 2000	JUL 1975	1972	-	90%	<1%	4	12/12/ 9		548	-	99%	6%
1807 "1975"	281	-884	85%	136%	278%	12	12/12/ 6	277	-526	80%	121%	169%
/ 1985		-893	-	140%	278%	12	12/12/ 7		-518	-	118%	169%
CLS BSN 2000	APR 2000	-928	-	152%	278%	12	12/12/ 7		-536	-	124%	169%
ALASKA REGION												REGION 19
1901 "1975"	175055	-55910	<1%	<1%	132%	12	0/ 0/ 0	795058	-64001	<1%	<1%	108%
/ 1985		-56058	-	<1%	132%	12	0/ 0/ 0		-64150	-	<1%	108%
PACIFIC 2000	APR 2000	-56311	-	<1%	132%	12	0/ 0/ 0		-64402	-	<1%	108%
HAWAII REGION												REGION 20
2001 "1975"	644	-380	9%	9%	150%	12	0/ 0/ 0	2811	624	1%	1%	77%
/ 1985		-386	-	9%	150%	12	0/ 0/ 0		618	-	1%	77%
PACIFIC 2000	JUN 2000	-394	-	11%	150%	12	0/ 0/ 0		610	-	2%	77%
2002 "1975"	763	-221	45%	45%	84%	12	5/ 0/ 0	963	-225	27%	27%	96%
/ 1985		-247	-	49%	84%	12	5/ 0/ 0		-244	-	29%	96%
PACIFIC 2000	SEP 2000	-255	-	50%	84%	12	6/ 0/ 0		-253	-	30%	96%
2003 "1975"	345	-162	74%	74%	73%	12	9/ 4/ 0	414	-44	40%	40%	71%
/ 1985		-173	-	77%	73%	12	9/ 5/ 0		-55	-	42%	71%
PACIFIC 2000	JUL 2000	-192	-	83%	73%	12	11/ 5/ 0		-75	-	47%	71%
2004 "1975"	617	-239	41%	41%	97%	12	1/ 0/ 0	1327	-65	13%	13%	92%
/ 1985		-233	-	40%	97%	12	1/ 0/ 0		-61	-	13%	92%
PACIFIC 2000	JUN 1975	-222	-	39%	97%	12	0/ 0/ 0		-52	-	12%	92%
CARIBBEAN REGION												REGION 21
2101 "1975"	2214	-925	19%	19%	122%	12	0/ 0/ 0	3627	-453	10%	10%	102%
/ 1985		-955	-	21%	122%	12	0/ 0/ 0		-483	-	11%	102%
ATLANT 2000	JAN 1985	-986	-	22%	122%	12	0/ 0/ 0		-517	-	12%	102%
2102 "1975"	3	0	100%	100%	0%	12	12/12/12	3	0	100%	100%	0%
/ 1985		-2	-	167%	0%	12	12/12/12		-2	-	167%	0%
ATLANT 2000	SEP 2000	-5	-	267%	0%	12	12/12/12		-5	-	267%	0%

* (13) THE CRITICAL MONTH AND YEAR IS THAT MONTH AND YEAR WITH MINIMUM BASE-CONDITIONS ASSESSED SURPLUS STREAMFLOW
*
* (13),(20) ASSESSED TOTAL STREAMFLOW = "1975" STREAMFLOW + "1975" BASE-CONDITIONS CONSUMPTION - "1975" GROUND-WATER OVERDRAFT
* (14),(21) ASSESSED SURPLUS STREAMFLOW = ASSESSED TOTAL STREAMFLOW - TOTAL DEPLETIONS - INSTREAM USE
* (15),(22) CURRENT STREAMFLOW DEPLETION = TOTAL DEPLETIONS / CURRENT STREAMFLOW SUPPLY (INCLUDING GROUND-WATER OVERDRAFT)
* (16),(23) ASSESSED STREAMFLOW DEPLETION = TOTAL DEPLETIONS / ASSESSED TOTAL STREAMFLOW (EXCLUDING GROUND-WATER OVERDRAFT)

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TABLE II-8 WATER REQUIREMENTS FOR ENERGY

(REGIONS 1-21) NATIONAL SUMMARY

BASE CONDITIONS

WITHDRAWAL (MILLION GALLONS PER DAY)

REGION	FUELS PRODUCTION			PETROLEUM REFINING			ELECTRIC POWER GENERATION			TOTAL		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
1	0	0	0	16	8	5	1263	1069	375	1279	1077	380
2	21	19	22	562	228	137	7463	7130	4657	8046	7377	4816
3	68	85	86	28	32	25	12768	12912	13952	12864	13029	14063
4	14	18	21	687	141	95	24362	22689	18061	25063	22848	18177
5	183	288	334	114	52	48	21022	21008	10574	21319	21348	10956
6	8	14	21	0	0	0	4799	5738	4581	4807	5752	4602
7	20	33	48	50	36	33	7644	6347	3537	7714	6416	3618
8	644	841	1065	441	220	150	4175	9313	16687	5260	10374	17902
9	4	4	4	0	0	0	82	23	0	86	27	4
10	144	198	236	91	36	29	3540	5834	4938	3775	6068	5203
11	172	190	185	74	75	94	498	1026	1012	744	1291	1291
12	837	902	930	312	496	479	724	1000	1713	1873	2398	3122
13	153	151	147	0	0	0	34	16	10	187	167	157
14	88	97	171	4	1	1	103	157	201	175	255	373
15	7	6	8	1	1	0	68	150	154	76	157	162
16	1	1	1	8	7	7	33	65	82	42	73	90
17	3	4	6	11	12	15	260	203	580	274	219	601
18	193	235	217	123	147	100	42	158	367	358	540	684
19	12	133	342	1	1	1	36	20	11	49	154	354
20	0	0	0	5	6	6	0	0	0	5	6	6
21	0	0	0	0	0	0	0	0	0	0	0	0
NATION (1-18)	2540	3086	3502	2522	1492	1218	88880	94838	79481	93942	99416	84201
NATION (1-21)	2552	3219	3844	2528	1499	1225	88916	94858	79492	93996	99576	84561

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TABLE II-8. WATER REQUIREMENTS FOR ENERGY (CONTINUED)

(REGIONS 1-21) — BASE CONDITIONS — NATIONAL SUMMARY

CONSUMPTION (MILLION GALLONS PER DAY)

REGION	FUELS PRODUCTION			PETROLEUM REFINING			ELECTRIC POWER GENERATION			TOTAL		
	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000	"1975"	1985	2000
1	0	0	0	3	4	4	21	18	167	24	22	171
2	12	11	12	71	87	109	103	224	644	186	322	765
3	55	66	64	12	15	20	153	722	1857	220	803	1941
4	8	10	11	51	56	74	175	497	1384	234	563	1469
5	57	82	96	23	27	38	324	656	1692	404	765	1826
6	1	3	4	0	0	0	42	231	417	43	234	421
7	4	6	9	18	19	26	129	352	1079	151	377	1114
8	167	212	299	66	80	119	54	118	291	287	410	709
9	2	2	2	0	0	0	1	0	0	3	2	2
10	96	122	142	20	19	24	68	239	637	184	380	803
11	114	128	130	44	51	75	89	237	457	247	416	662
12	532	564	598	170	224	382	99	270	991	801	1058	1971
13	86	90	88	0	0	0	18	9	5	104	99	93
14	38	56	111	2	0	1	39	106	151	79	162	263
15	5	4	5	1	0	0	63	134	126	69	138	131
16	<1	<1	<1	4	4	6	3	42	52	7	46	58
17	2	2	4	6	8	13	13	104	344	21	114	361
18	169	210	192	57	64	79	25	101	242	251	375	513
19	11	120	308	0	0	1	0	2	5	11	122	314
20	0	0	0	3	4	5	0	0	0	3	4	5
21	0	0	0	0	0	0	0	0	0	0	0	0
NATION (1-18)	1348	1568	1767	548	658	970	1419	4060	10536	3315	6286	13273
NATION (1-21)	1359	1688	2075	551	662	976	1419	4062	10541	3329	6412	13592

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Figure 8. Industrial Groupings with Standard Industrial Classification (SIC) Codes

- All-industry total:
  - Agriculture, forestry and fisheries:
    - Agriculture ..... 01, 07.
    - Forestry and fisheries ..... 08, 09.
  - Mining:
    - Metal ..... 10.
    - Coal ..... 11, 12.
    - Crude petroleum and natural gas ..... 13.
    - Nonmetallic, except fuels ..... 14.
  - Contract construction ..... 15-17.
  - Manufacturing:
    - Food and kindred products ..... 20.
    - Textile mill products ..... 22.
    - Apparel and other fabric products ..... 23.
    - Lumber products and furniture ..... 24, 25.
    - Paper and allied products ..... 26.
    - Printing and publishing ..... 27.
    - Chemicals and allied products ..... 28.
    - Petroleum refining ..... 29.
    - Primary metals ..... 33.
    - Fabricated metals and ordnance ..... 34, 19.
    - Machinery, excluding electrical ..... 35.
    - Electrical machinery and supplies ..... 36.
    - Motor vehicles and equipment ..... 371.
    - Transportation equipment, excluding motor vehicles ..... 37 except 371.
    - Other manufacturing ..... 21, 30-32, 38, 39.
  - Transportation, communications, and public utilities:
    - Railroad transportation ..... 40.
    - Trucking and warehousing ..... 42.
    - Other transportation and services ..... 41, 44, 47.
    - Communications ..... 48.
    - Utilities (electric, gas, sanitary) ..... 49.
  - Wholesale and retail trade ..... 50, 52-57, 59.
  - Finance, insurance and real estate ..... 60-67.
  - Services:
    - Lodging places and personal services ..... 70, 72.
    - Business and repair services ..... 73, 75, 76.
    - Amusement and recreation services ..... 78, 79.
    - Private households ..... 88.
    - Professional services ..... 80, 81, 82, 84, 86, 89.
  - Government:
    - Civilian government:
      - Federal government ..... 91 except Fed. military.
      - State and local government ..... 92, 93.
    - Armed forces ..... Part of 91.

Source: Executive Office of the President, Bureau of the Budget, Standard Industrial Classification Manual, 1967.

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EXPLANATORY NOTES

Tables I-1 through I-11

Appendix I, Social, Economic, and Environmental Data, contains the socioeconomic baseline ("1975") and growth projections (1985 and 2000) on which the water supply and water use projections are based. This appendix presents two sets of data. One set, the National Future (NF), represents the Federal viewpoint; the other set, the State-Regional Future (SRF), represents the regional sponsor and/or State viewpoint. *Note:* Explanations for State-Regional Future information vary considerably. Where significant differences with the National Future exists, explanations are discussed in Volume 4, *Water Resources Regional Reports.*

TABLE I-1. POPULATION, EMPLOYMENT, AND INCOME

Population, employment, and income — Figures are based on the 1972 OBERS Projections (Series E) published by the Water Resources Council in June 1974.

Population density — Computed using land area as given in Table I-3.

Per capita income — Based on OBERS personal income, which is defined as the income received by persons from all sources. It is comprised of wage and salary disbursements, proprietor's income, other labor income, and transfer payments, less personal contributions for social insurance.

1975$ — Monetary figures shown in 1975 dollars. Source information was supplied in 1967 dollars and a factor of 1.533 applied to obtain 1975 dollars.

TABLE I-2. EARNINGS BY MAJOR SECTORS

Earnings — Figures are based on the 1972 OBERS Projections (Series E) published by the Water Resources Council in June 1974. Earnings is defined in OBERS as the sum of income accruing to persons from wage and salary disbursements, proprietor's income, and other labor income. Earnings are for Standard Industrial Classification (SIC) code groupings as shown (See Figure 8 for a listing of industries by SIC code).

Agriculture	01, 07-09
Manufacturing	19-39
Mining	10-14
Other	15-17, 40-42, 44, 47-50, 52,57, 59-67, 70, 72-73, 75-76, 78-82, 84, 86, 88-89, 91-93

1975$ — Monetary figures shown in 1975 dollars. Source information was supplied in 1967 dollars and a factor of 1.533 applied to obtain 1975 dollars.

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TABLE I-3. SURFACE AREA AND LAND USE — 1975

Water area — Based on Bureau of the Census information and includes inland bodies of water larger than 40 acres in size or streams more than 660 feet wide. However, other waters under the jurisdiction of the United States are included, such as Long Island Sound, Delaware Bay, Chesapeake Bay, New York Harbor, Puget Sound, Straits of Georgia, Straits of Juan De Fuca, Great Lakes, and some coastal waters.

Land area — Based on Bureau of Economic Analysis information and includes water areas smaller or narrower than water areas described above.

Cropland — Land used for agriculture but not in permanent pasture, native hayland, rangeland, or woodland. Cropland information is based on averages reported for the years 1971-1973.

Pasture and rangeland — Noncropland that produces valuable forage plants; includes Federal land used for grazing and range for reindeer and caribou.

Other agricultural land — Includes feedlots, farmsteads, farm roads, open land formerly cropped, etc.

Urban land — Residential, industrial, commercial, and institutional land uses in municipalities or metropolitan fringe areas with 2,500 inhabitants. Included are densely settled areas with less than 2,500 inhabitants within urbanized areas with more than 50,000 persons.

Other — Land not accounted for in other categories, e.g., rural residential, industrial, commercial and institutional land uses, highways and easements.

TABLE I-4. CROPLAND AND IRRIGATED FARMLAND

Cropland — Land used for agriculture but not in permanent pasture, native hayland, rangeland, or woodland. Cropland information is based on averages reported for the years 1971-1973.

Cropland harvested — Does not include nonrotational pasture and hayland harvested.

Irrigated farmland — Pasture and cropland to which water can be expected to be applied.

Forest cleared and drained and pasture drained — Land forecast to be converted to cropland by drainage based on current rates of conversion of private forest and pastureland that have wet soils.

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TABLE I-5. SHEET EROSION BY SOURCE

Sheet erosion — Estimates for sheet and rill erosion of the land surface caused by rainfall. Excluded are gully and streambank erosion, wind erosion, and gravity-caused movement of the soil mantle. Only part of the soil moved by sheet and rill erosion will actually enter stream channels, ponds, and lakes.

Cropland harvested — Estimates based upon the Soil Conservation Service's Conservation Needs Inventory of 1967, modified by their 1975 Potential Cropland Study.

Forest and rangeland — Estimates based upon information developed for the Forest and Range Land Environmental Study completed by the Forest Service in 1972. Woodland and pasture soil loss rates are assumed similar to forest and rangeland rates. In most areas, the rates are at or near geologic erosion rates.

Cropland erosion — Rates were estimated for several crops in a study by the Iowa State University. This information was extrapolated to obtain estimates for all cropland harvested. Regional erosion rates are weighted averages of subregional erosion rates.

TABLE I-6. FLOOD DAMAGES BY LAND USE

Flood damages, urban — Economic loss to urban areas caused by flood, including inundation, erosion, and sediment deposition. The loss may be evaluated in terms of cost of replacement, repair or rehabilitation, decrease in market or sales value, or decrease in income or production.

Flood damages, agriculture — Economic loss to agriculture caused by flood, including inundation, erosion, and sediment deposition. The loss may be evaluated in terms of cost of replacement, repair or rehabilitation, decrease in market or sales value, or decrease in income or production.

Flood damages, other — Economic loss to highways, bridges, and other social-overhead structures caused by flood, including inundation, erosion, and sediment deposition. The loss may be evaluated in terms of cost of replacement, repair or rehabilitation, decrease in market or sales value, or decrease in income or production.

1975$ — Monetary figures shown in 1975 dollars. Source information was supplied in 1967 dollars and a factor of 1.533 applied to obtain 1975 dollars.

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TABLE I-7. RECREATION REQUIREMENTS AND WILDERNESS AREAS

Water-dependent recreation activities — Beach swimming, canoeing, boating, sailing, water skiing, and sport fishing.

Water-enhanced recreation activities — Picnicking and camping.

Activity occasion — Participation by one person 12 or older in a recreation activity without relation to the duration of such participation.

Water surface area — Additional water surface needed to meet the demand for water-dependent recreation. In subregions where water and land areas available for recreation exceed local recreation demands, the needs are shown as zero. The regional and national totals do not show that a surplus in one subregion is available to meet a demand from another subregion.

Developed land area — Additional developed land needed to meet the demand for water-enhanced recreation activities. Also included is land requirements for parking areas and other necessary adjacent land uses for water-dependent activities. In subregions where water and land areas available for recreation exceed local recreation demands, the needs are shown as zero. The regional and national totals do not show that a surplus in one subregion is available to meet a demand from another subregion.

Designated wilderness areas — Federally designated areas as of September, 1976, under the Wilderness Act of September 3, 1964, defined as "areas where the earth and its community of life are untrampled by man, where man himself is a visitor who does not remain." *Note:* Several wilderness areas have portions in more than one subregion so are counted in each of those subregions. Regional and national totals have been reduced appropriately.

TABLE I-8. ELECTRIC POWER GENERATION BY FUEL SOURCE

Electric power generation — Excludes all electric powerplants with less than 25 megawatt installed capacity. In addition, information is not included for electric generation from gas, diesel, or oil-fired turbines, from solar or wind sources, or from pumped storage hydroelectric generation. These sources produce about 3 percent of the total U.S. electric generation, although this percentage varies considerably among subregions.

Steam electric power generation — Includes both fossil-fueled and nuclear-fueled powerplants with at least 25 megawatt installed capacity.

Conventional hydroelectric power generation — Electric energy produced in plants in which the turbine generators are driven by falling water. Excluded are powerplants with less than 25 megawatt installed capacity and pumped storage hydroelectric generation.

Fossil-fueled — Electric powerplants that use organic fuels (oil, coal, natural gas) to fire boilers.

Gigawatt hour (Gwh) — One million kilowatt hours. Equivalent to 3.4 million BTU (British thermal units) of heat energy.

Further information — Available in a supplementary report on *Water for Energy* published separately by the U.S. Water Resources Council in 1978 (GPO stock no. 052-045-00050-9).

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TABLE I-9. STEAM ELECTRIC GENERATING PLANTS

Steam electric generating plants — Excludes all powerplants with less than 25 megawatt installed capacity. See also "electric power generation" in explanatory notes for Table I-8.

Once-thru cooling — Method of cooling which allows the cooling water to flow through a condenser only once before being discharged back into the water source.

Further information — Available in a supplementary report on *Water for Energy* published separately by the U.S. Water Resources Council in 1978 (GPO stock no. 052-045-00050-9).

TABLE I-10. WATER QUALITY INDICATORS

Residual heat discharged from steam electric generating plants — Excludes plants with less than 25 megawatt installed capacity. See also "electric power generation" in explanatory notes for Table I-8.

Biochemical oxygen demand (BOD) — A measure of oxygen required for the oxidation of organic matter in water.

Total suspended solids (TSS) — Small particles of solid materials that contribute to turbidity and that resist separation by conventional means.

Best available technology economically achievable (BAT) — Estimates of the remaining BOD and TSS discharges in "1975" if BAT practices could have been installed in 1973. BAT is a standard to be applied to all water discharges by existing industries by July 1, 1983, to meet the requirements of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

TABLE I-11. COMMERCIAL NAVIGATION

Commercial navigation — Information is for domestic trade on the Mississippi River and Gulf Intracoastal Waterway systems. Foreign commodity exports and imports are excluded. Information for the Great Lakes and other domestic navigation systems was not developed by subregion for this assessment. The Corps of Engineers' National Waterways Study, when completed in 1981, will enable an update of the information for the Mississippi River - Gulf systems and will provide a basis for obtaining comparable information for the rest of the Nation.

Commodity origins — Includes all tonnage loaded to waterborne carriers at all points of embarkation in a subregion or region.

Commodity flows (commodity movement) — Subregional estimates of waterborne tonnage moving past locations selected to be at or near the downstream outflow point of the subregion. Both upstream and downstream movement is included. Commodities moved from one origin location through several subregions will be included in the totals for each of those subregions. Regional commodity flows are determined near the outflow point(s) of the regions. Note that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions flowing out of the region or Nation.

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EXPLANATORY NOTES

Tables II-1 through II-8

Appendix II, Annual Water Supply and Use Analysis, contains baseline water supply information and baseline and projected water withdrawal and water consumption information used for the assessment. Also included are a water adequacy analysis, a natural flow analysis, and a critical month analysis. Monthly details of Tables II-1 through II-5 are in Appendix III. Dry conditions information for Tables II-4, II-5, and II-8 are in Appendix IV.

TABLE II-1. ANNUAL WATER SUPPLY DATA — "1975"

Percentage exceedance /1/ — A statistical estimate of probability of flow. For example, a 5 percent exceedance flow will be exceeded only in about 5 years of a 100 year period. This represents a year with very high streamflows. A 95 percent exceedance flow will be exceeded about 95 years of a 100-year period and represents very low streamflows.

Existing surface storage — Estimated total storage capacity of ponds and reservoirs with over 50 acre-feet (16.3 million gallons) of capacity. Reservoirs with more than 15 acre-feet capacity are included if their dams are more than 25 feet high. Reservoirs with dams less than 6 feet high are excluded, regardless of capacity. Figures are given for both normal (design capacity) and maximum (spillway level) storage capacity. Surface area is for reservoir levels at normal capacity.

Total ground-water storage — Estimated volume of water underground when aquifers are filled.

Available ground-water storage — Portion of total ground-water storage that can be tapped with conventional wells, methods, and machinery.

Total ground-water withdrawals — Portion of total fresh-water withdrawals (Table II-4) obtained directly from ground water.

Ground-water overdraft — Portion of the average annual ground-water withdrawal rate that now exceeds the average annual ground-water recharge rate. These estimates are only for the second assessment; further studies are needed.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-2. ANNUAL IMPORTS, EXPORTS, AND NET EVAPORATION

Imports — Artificial transfers of fresh water to one subregion from another. Note that the regional and national totals shown are sums of the subregion information. Since only part of the transfers are between regions, these totals do not represent regional or national transfers. The regional and national totals shown only indicate subregional transfer activity.

Exports — Artificial transfers of fresh water from one subregion to another. Note that the regional and national totals shown are sums of the subregion information. Since only part of the transfers are between regions, these totals do not represent regional or national transfers. The regional and national totals shown only indicate subregional transfer activity.

Net evaporation — Limited to evaporation from manmade reservoirs that have more than 5,000 acre-feet storage capacity and from farm and stock ponds; if rainfall exceeds evaporation, zero is used.

TABLE II-3. ANNUAL INSTREAM FLOW USES

Fish and wildlife /1/ — Instream flow approximations (IFA) are based on estimates of streamflow required at subregional outflow points to maintain habitat for aquatic and riparian plants and animals. These estimates are only for the second assessment. Additional studies are needed to obtain better information for State, regional, and subregional planning. In 1979, the Water Resources Council will publish further information in *Instream Flows for Fish and Wildlife.*

Navigation /1/ — Water requirements have been estimated only for the Mississippi-Gulf Intracoastal Waterways system. The Corps of Engineers has started a three-year study to improve the estimates for the Mississippi-Gulf system and to obtain comparable information for other parts of the Nation.

Information was not available for all of regions 1, 2, 4, 12, 19, and for subregions 301, 302, 303, 304, 305, 309, 1010, 1101, 1702, 1704, 1705, 1706, 1802, 1803, and 1804.

Treaties and compacts /1/ — Streamflows for treaties and compacts are given for those subregions where a treaty or compact affects the flows to be discharged at the outflow point of a subregion.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-4. ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES (BASE CONDITIONS)

Base conditions — Based on conditions of fresh-water use compared to long-term fresh-water supply.

Irrigation — Irrigation withdrawals were estimated with efficiency ratios estimated according to irrigation practices in the subregions and limited by available water supply. This does not include water for soil salinity control, plant germination, frost protection, erosion protection, or for cooling crops. Consumption is the portion of withdrawals used through evapotranspiration. Incidental consumption associated with irrigation systems has been estimated.

Livestock — Consumption is the amount of water used in livestock watering.

Steam electric — Water use based on steam powered generation plants with 25 megawatts or more installed capacities. Most smaller plants operate for limited periods during the year so use relatively small quantities of water.

Manufacturing — Water use estimates are based on information for 9,300 large manufacturing plants obtained by the Department of Commerce and on OBERS Series E Projections. The 9,300 plants use about 98 percent of the manufacturing water in the United States. Manufacturing water use is shown for Standard Industrial Classification (SIC) code groupings as shown below. (See Figure 8 for a listing of industries by SIC code.)

Primary metals	33
Chemicals	28
Paper	26
Petroleum	29
Transportation	37
Textiles	22
All Other	19, 21, 23-25, 27, 30-32, 34-36, 38-39.

Central domestic — Centrally supplied systems that serve a minimum of 25 people or 15 service connections. Water requirements are based on expectations that per capita usage will remain about constant through the year 2000. It is estimated that actions taken to meet legal requirements and other needs for environmental protection will counteract expansion of demands.

Noncentral domestic — Noncentrally supplied or self-supplied systems that include those supplying fewer than 25 people or fewer than 15 service connections. Water requirements are based on expectations for increased per capita use but a declining percentage of population served.

Commercial — Water used mainly by wholesale and retail businesses not involved in manufacturing or minerals development. A large part of this water is used for cleaning.

Minerals mining — Water requirements based on OBERS Series E Projections and data from the Bureau of Mines. The estimates of water for fuels production and refining do not provide for all possible developments of new energy sources or the possibilty that reduced imports of fuels may increase the need for domestic fuel production above the levels projected in OBERS. Minerals mining is shown for the following SIC codes:

10	Metals
	Fuels
11	Coal (anthracite)
12	Coal (bituminous)
13	Crude petroleum & natural gas
14	Nonmetals

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TABLE II-4. ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES (BASE CONDITIONS) (continued)

Public lands — Water for national parks is mainly to provide water for visitors and developed facilities. Water requirements for BLM (Bureau of Land Management) lands and national forests are for all uses thereon.

Fish hatcheries — Withdrawal for Federal hatcheries. Consumption for this use is negligible and is treated as zero.

Misc. other — No other information is included.

Saline withdrawals — A combination of withdrawals for steam electric cooling and manufacturing cooling. Most saline withdrawals are for once-through cooling, which has little or no consumption.

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TABLE II-5. ANNUAL WATER ADEQUACY ANALYSIS (BASE CONDITIONS)

Water adequacy — For purposes of the second assessment, water adequacy is the capability of the river system to meet the requirements of both offstream and instream uses with no overdraft of ground-water sources.

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Above inflow points — Term equivalent to "above outflow point" except it excludes the information for the given region or subregion.

above inflow points = above outflow point — within hydro. unit

Above outflow point — Describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion (within the hydro. unit), plus the sum of values for all upstream regions or subregions. This information represents the total load on the upstream river network.

At outflow point — Describes streamflow information. All streamflow is measured at the downstream edge of the subregions and regions. In many cases, this is the downstream portion of the major river draining the area, but for other (particularly coastal) subregions, the "outflow point" is truly the sum of outflows from all of the major rivers and streams draining the area.

Downstream subregion — The next subregion downstream from a given subregion. If no downstream subregion exists, a notation is included to indicate what is downstream, e.g., Pacific Ocean, Atlantic Ocean, Gulf of Mexico, Canada, Mexico, or terminal lakes (closed basin).

Within hydro. unit — Refers to values within the appropriate hydrologic unit (region or subregion).

Note: numbers in parentheses refer to Table column headers.

(01) *Fish and wildlife instream use* /1/ — Instream flow approximations for habitat maintenance from Table II-1.

(02) *Navigation instream use* /1/ — Instream flow requirements for navigation from Table II-1.

(03) *Consumption above the inflow points* /1/ — Base conditions consumption for all upstream regions or subregions. This represents the consumptive load on the inflows entering the region or subregion. A value of zero indicates there are no upstream regions or subregions.

(04) *Consumption within the hydrologic unit* — Base conditions consumption for the region or subregion from Table II-4.

(05) *Net exports above the inflow points* /1/ — Net exports for all upstream regions or subregions.

(06) *Net exports within the hydrologic unit* — Net exports for the region or subregion. Negative values for net exports represent net imports. Basic export and import information is in Table II-2.

(07) *Change in net exports above the outflow point* /1/ — Represents a change in net exports from "1975". A positive value represents an increase in exports (or a decrease in imports) which decreases assessed streamflow (19); an increase in net exports is treated as an additional depletion for computing assessed streamflow depletion (22). A negative value represents an increase in imports (or a decrease in exports), which increases assessed streamflow; a decrease in net exports is not treated as a decrease in depletion for computing assessed streamflow depletion.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-5. ANNUAL WATER ADEQUACY ANALYSIS (BASE CONDITIONS) (continued)

(08) *Increase in net exports above the outflow point* /1/ — Represents that portion of the change in net exports (07) treated as an additional depletion.

(09) *Net evaporation above the inflow points* /1/ — Net evaporation for all upstream regions or subregions.

(10) *Net evaporation within the hydrologic unit* — Net evaporation for the region or subregion from Table II-2.

(11) *Change in net evaporation above the outflow point* /1/ — Represents an increase in net evaporation from "1975" due to construction of reservoirs and farm or stock ponds. This increase represents an additional depletion for computing assessed streamflow depletion (22) and causes a decrease in assessed streamflow (19).

(12) *Offstream use* — Total assessed depletions; sum of consumption [(03) + (04)] plus increases in net exports (08) plus changes in net evaporation (11).

(13) *Current streamflow* /1/ — Mean flow for "1975" from Table II-1, derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

(14) *"1975" consumption above the outflow point* /1/ — Sum of (03) plus (04).

(15) *Current streamflow supply* /1/ — Theoretical streamflow that would currently be available at the outflow point of a region or subregion if current consumption were eliminated. Current streamflow supply is a measure of currently utilized fresh-water supply but does not necessarily represent long-term supply.

current streamflow supply = current streamflow (13)
+ "1975" consumption (14)

(16) *Ground-water overdraft above outflow point* /1/ — Ground-water overdraft for this region or subregion plus overdraft for all upstream regions or subregions. This represents the total upstream overdraft that eventually may be exhausted and no longer available as supply. Basic overdraft information is in Table II-1.

(17) *Assessed total streamflow* /1/ — Long-range streamflow that would be available at the outflow point of a region or subregion if consumption were eliminated, if ground-water overdrafting were discontinued, and if "1975" water transfer and reservoir practices would continue. Total streamflow is the measure for supply utilized in the second assessment. Ground-water overdraft is subtracted as it is not considered to be a long-term supply.

assessed total streamflow = "1975" current streamflow (13)
+ "1975" consumption (14)
– "1975" ground-water overdraft (16)

(18) *Maximum instream use* /1/ — The second assessment has attempted to bring to the attention of water resources planners and policy makers the importance of instream uses. The key instream uses included in the analysis are (01) fish and wildlife habitat maintenance (instream flow approximations), and (02) navigation. The most demanding of these (18) is used in further analysis (20),(23),(24). Details on these uses are in the explanatory notes for Table II-3.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-5. ANNUAL WATER ADEQUACY ANALYSIS (BASE CONDITIONS) (continued)

(19) *Assessed streamflow* /1/ — Computed flow that includes effects of consumption, water transfers, and evaporation from manmade reservoirs, but ignores contributions from ground-water overdraft.

assessed streamflow = assessed total streamflow (17)
− offstream use (12)

"1975" assessed streamflow = "1975" current streamflow (13)
− "1975" ground-water overdraft (16)

(20) *Assessed surplus streamflow* /1/ — A measure of available supply for conflict-free development of offstream uses. A negative figure indicates a conflict between offstream uses and the estimated instream flow needs. See also (23),(24).

surplus streamflow = assessed streamflow (19)
− maximum instream use (18)

(21) *Current streamflow depletion* — Depletion rate under current ("1975") conditions of consumption, water transfer, evaporation, and ground-water overdraft. This figure best represents actual current depletion under base or average conditions.

$$\text{current streamflow depletion} = \frac{\text{consumption [(03) + (04)]}}{\text{current streamflow supply (15)}}$$

(22) *Offstream use to total streamflow (assessed streamflow depletion)* — Depletion rate if contributions from ground-water overdraft are ignored. This figure represents the long-range depletion under base or average conditions.

$$\text{assessed streamflow depletion} = \frac{\text{offstream use (12)}}{\text{assessed total streamflow (17)}}$$

(23) *Instream use to total streamflow* — A measure of instream use demands (18) upon assessed total streamflow. Note that a "1975" figure in excess of 100 percent indicates that exports from a region or subregion are already adversely affecting the instream environment. See also (20),(24).

$$\text{ratio} = \frac{\text{maximum instream use (18)}}{\text{assessed total streamflow (17)}}$$

(24) *Total use to total streamflow* — A measure of available supply for conflict-free development of offstream uses. A figure greater than 100 percent indicates a conflict between offstream uses and the estimated instream flow needs. See also (20),(23).

$$\text{ratio} = \frac{\text{total use}}{\text{assessed total streamflow (17)}} \quad \text{where:}$$

total use = maximum instream use (18)
+ offstream use (12)

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-6. NATURAL WATER SUPPLY ANALYSIS

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Natural water supply — An analysis that estimates conditions in the so-called natural state, i.e., before human influence. However, it is not truly natural in that vegetation and runoff patterns have been altered by humans (see also "natural outflows").

Above inflow points — Term equivalent to "above outflow point" except it excludes the information for the given region or subregion.

above inflow points = above outflow point — within hydro. unit

Above outflow point — Describes depletion (consumption and evaporation) and water transfer (export and import) information. Information described as "above the outflow point" is the value for the given region or subregion (within the hydro. unit), plus the sum of values for all upstream regions or subregions. This information represents the total load on the upstream river network.

At outflow point — Describes streamflow information. All streamflow is measured at the downstream edge of the subregions and regions. In many cases, this is the downstream portion of the major river draining the area, but for other (particularly coastal) subregions, the "outflow point" is truly the sum of outflows from all of the major streams and rivers draining the area.

Downstream subregion — The next subregion downstream from a given subregion. If no downstream subregion exists, a notation is included to indicate what is downstream, e.g., Pacific Ocean, Atlantic Ocean, Gulf of Mexico, Great Lakes, Canada, Mexico, or terminal lakes (closed basin).

Within hydro. unit — Refers to values within the appropriate hydrologic unit (region or subregion).

Note: numbers in parentheses refer to Table column headers.

(01) *Consumption above the inflow points* /1/ — Base conditions consumption for all upstream regions or subregions. This represents the consumptive load on the inflows entering the region or subregion. A value of zero indicates there are no upstream regions or subregions.

(02) *Consumption within the hydrologic unit* — Base conditions consumption for the region or subregion from Table II-4.

(03) *Net evaporation above the inflow points* /1/ — Net evaporation for all upstream regions or subregions.

(04) *Net evaporation within the hydrologic unit* — Net evaporation for the region or subregion from Table II-2.

(05) *Net exports above the inflow points* /1/ — Net exports for all upstream regions or subregions.

(06) *Net exports within the hydrologic unit* — Net exports for the region or subregion from Table II-2.

(07) *Net imports above the inflow points* /1/ — Net imports for all upstream regions or subregions.

(08) *Net imports within the hydrologic unit* — Net imports for the region or subregion from Table II-2.

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-6. NATURAL WATER SUPPLY ANALYSIS (continued)

(09) *Ground-water overdraft above the inflow points* /1/ — Ground-water overdraft for all upstream regions and subregions.

(10) *Ground-water overdraft within the hydrologic unit* — Ground-water overdraft for the region or subregion from Table II-1.

(11) *Total depletions above the inflow points* — For natural supply analysis, depletions include all man-induced uses that result in decreased streamflow.

total depletions = consumption (01)
+ net evaporation (03)
+ positive net exports (05) where net imports is zero

(12) *Total depletions within the hydrologic unit* — Depletions include all man-induced uses that result in decreased streamflow for the region or subregion.

total depletions = consumption (02)
+ net evaporation (04)
+ positive net exports (06) where net imports is zero

(13) *Inflows entering the hydrologic unit* /1/ — Sum of flows for all streams and rivers entering a region or subregion. Equivalently, the inflow to a subregion is the sum of the outflows from all upstream subregions. A value of zero indicates the most upstream subregion of a river network.

(14) *Current streamflow* /1/ — Mean flow for "1975" from Table II-1, derived from historical data; data includes effects of consumption, water transfers, evaporation, and ground-water overdraft.

(15) *Total depletions above the inflow points* /1/ — same as (11).

(16) *Total depletions within the hydrologic unit* — same as (12).

(17) *Natural outflow at the outflow point* (natural available streamflow) /1/ — Estimate of streamflow without artificial manmade constraints for comparison with current streamflow (Table II-5) and assessed streamflow (Table II-5). Natural flow indicates the average potential runoff available from precipitation before introducing human effects. It is not truly natural streamflow because vegetation and runoff patterns have been altered by man.

natural outflow = current streamflow (14)
+ total depletions (15) + (16)
− net imports (07) + (08)
− ground-water overdraft (09) + (10) where:

total depletions = consumption (01) + (02)
+ net evaporation (03) + (04)
+ net exports (05) + (06)

/1/ *Note* that regional and national totals for this information are not arithmetic sums of subregional values. Rather, they are sums of those subregions with streams flowing out of the region or Nation. National totals also include streamflow into terminal lakes in the Great Basin (Region 16), but exclude Alaska, Hawaii, and the Caribbean.

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TABLE II-6. NATURAL WATER SUPPLY ANALYSIS (continued)

(18) *Natural outflow within the hydrologic unit* (natural available streamflow) — Estimate of average potential runoff available from precipitation in the region or subregion before introducing human effects. Equivalently, the portion of water supply contributed by the region or subregion.

natural outflow = current streamflow (14)
− inflows (13)
+ total depletions (16)
− net imports (08)
− ground-water overdraft (10) where:

total depletions = consumption (02)
+ net evaporation (04)
+ net exports (06)

(19) *Natural flow depletion above the outflow point* — Estimated loss to total natural outflow (natural available streamflow) from all offstream demands (consumption, evaporation, and net exports).

$$\text{natural flow depletion} = \frac{\text{total depletions (15) + (16)}}{\text{natural available streamflow (17)}}$$

(20) *Natural flow depletion within the hydrologic unit* — Estimated loss to regional or subregional natural outflow (natural available streamflow) from offstream demands (consumption, evaporation, and net exports) within the region or subregion.

$$\text{natural flow depletion} = \frac{\text{total depletions (16)}}{\text{natural available streamflow (18)}}$$

(21) *Drainage area above the outflow point* — Hydrologic area of the watershed in the region or subregion (22), plus the hydrologic area of all upstream regions or subregions, measured in square miles.

(22) *Drainage area within the hydrologic unit* — Hydrologic area of the watershed in the region or subregion, measured in square miles.

(23) *Estimated runoff above the outflow point* — Estimated runoff for the region or subregion (see 24), plus the estimated runoff for all upstream regions or subregions, converted to equivalent inches of rainfall.

$$\text{estimated runoff} = \frac{\text{natural available streamflow (17)}}{\text{hydrologic drainage area (21)}}$$

(24) *Estimated runoff within the hydrologic unit* — Estimate of potential rainfall which would reach the outflow point of a region or subregion from rainfall occurring in that region or subregion. Using natural outflow (18) and drainage area (22), this figure has been converted to equivalent inches of rainfall. Due to diverse sources of data used in the assessment process, these estimated runoff figures are provided only for comparison with other regions or subregions in the assessment.

$$\text{estimated runoff} = \frac{\text{natural available streamflow (18)}}{\text{hydrologic drainage area (22)}}$$

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TABLE II-7. SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (BASE CONDITIONS AND DRY CONDITIONS)

Note — No regional or national information is available for monthly information.

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Dry conditions — Based on conditions of fresh-water use expected to occur at the 80 percent exceedance flow for fresh-water supply. The 80 percent flow represents a low streamflow which will be exceeded in about 80 years of a 100-year period. Offstream water uses, especially for irrigation and steam electric generation, are generally higher during dry conditions.

Note: numbers in parentheses refer to Table column headers.

CRITICAL MONTH INFORMATION — (Base Conditions)

(01) *Critical month and year* — The month and year in the assessment analysis when, under base conditions, the instream flow needs are least likely to be met. In terms of Table III-5 (Monthly Water Adequacy Analysis), the critical month is defined by the worst month and year for column (20), assessed surplus streamflow. The critical month applies to all years for extracting information.

(01) *Total streamflow for critical month* — Base conditions assessed total streamflow for the critical month from Table III-5, column (17).

(02) *Assessed surplus streamflow for critical month* — Base conditions assessed surplus streamflow for the critical month from Table III-5, column (20).

(03) *Current streamflow depletion for critical month* — Current base conditions depletion for the critical month, from Table III-5, column (21).

(04) *Assessed streamflow depletion for critical month* — Base conditions assessed streamflow depletion for the critical month, from Table III-5, column (22).

(05) *Instream use to total streamflow ratio for critical month* — Ratio of the maximum instream use to the base conditions assessed total streamflow for the critical month, from Table III-5, column (23).

MONTHLY SUMMARY INFORMATION — (Base conditions)

(06) *Number of months* — where base conditions assessed streamflow at the outflow point is less than the instream flow need. Alternatively, the number of months (Table III-5, column (20)), where surplus streamflow is negative. Note that a negative surplus streamflow indicates a conflict between offstream uses and the estimated instream flow needs.

(07) *Number of months* — where base conditions assessed streamflow depletion exceeds 40 percent / 70 percent / 90 percent (Table III-5, column (22)). In addressing instream flows, the following criteria were developed for describing the effects of streamflow depletion on fish and wildlife habitat:

40-percent depletion (sixty percent of average flow) — base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreation uses

70-percent depletion (thirty percent of average flow) — base flow that sustains good survival habitat for most aquatic life forms

90-percent depletion (ten percent of average flow) — flow that can sustain only short-term survival habitat for most aquatic life forms

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TABLE II-7. SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (BASE CONDITIONS AND DRY CONDITIONS) (continued)

ANNUAL INFORMATION — (Base conditions)

(08) *Assessed total streamflow* — Annual base conditions assessed total streamflow from Table II-5, column (17).

(09) *Assessed surplus streamflow* — Annual base conditions assessed surplus streamflow from Table II-5, column (20).

(10) *Current streamflow depletion* — Annual current base conditions depletion from Table II-5, column (21).

(11) *Assessed streamflow depletion* — Annual base conditions assessed streamflow depletion from Table II-5, column (22).

(12) *Instream use to total streamflow ratio* — Annual ratio of the maximum instream use to the base conditions assessed total streamflow, from Table II-5, column (23).

CRITICAL MONTH INFORMATION — (Dry conditions)

(13) *Critical month and year* — The month and year in the assessment analysis when, under *base* conditions, the instream flow needs are least likely to be met. In terms of Table III-5 (Monthly Water Adequacy Analysis — Base Conditions), the critical month is defined by the worst month and year for column (20), surplus streamflow. The critical month determined for base conditions is used in selecting dry conditions information for comparision /1/.

(13) *Total streamflow for critical month* — Dry conditions assessed total streamflow for the critical month from Table IV-4, column (17).

(14) *Assessed surplus streamflow for critical month* — Dry conditions assessed surplus streamflow for the critical month from Table IV-4, column (20).

(15) *Current streamflow depletion for critical month* — Current dry conditions depletion for the critical month, from Table IV-4, column (21).

(16) *Assessed streamflow depletion for critical month* — Dry conditions assessed streamflow depletion for the critical month, from Table IV-4, column (22).

(17) *Instream use to total streamflow ratio for critical month* /1/ — Ratio of the maximum instream use to the dry conditions assessed total streamflow for the critical month, from Table IV-4, column (23).

/1/ Actual fish and wildlife instream flow approximations should be lower for dry conditions analysis. Because methodology has not yet been developed for estimating these lower values, the base conditions instream flow approximations were used as the best available information.

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TABLE II-7. SUMMARY OF MONTHLY AND ANNUAL WATER ADEQUACY (BASE CONDITIONS AND DRY CONDITIONS) (continued)

MONTHLY SUMMARY INFORMATION — (Dry conditions)

(18) *Number of months* — where dry conditions assessed streamflow at the outflow point is less than the instream flow need /1/. Alternatively, the number of months (Table IV-4, column (20)), where surplus streamflow is negative. Note that a negative surplus streamflow indicates a conflict between offstream uses and the estimated instream flow needs.

(19) *Number of months* — where dry conditions assessed streamflow depletion exceeds 40 percent / 70 percent / 90 percent (Table IV-4, column (22)). In addressing instream flows, the following criteria were developed for describing the effects of streamflow depletion on fish and wildlife habitat:

40-percent depletion (sixty percent of *average* flow) — base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreation uses

70-percent depletion (thirty percent of *average* flow) — base flow that sustains good survival habitat for most aquatic life forms

90-percent depletion (ten percent of *average* flow) — flow that can sustain only short-term survival habitat for most aquatic life forms

ANNUAL INFORMATION — (Dry conditions)

(20) *Assessed total streamflow* — Annual dry conditions assessed total streamflow from Table IV-2, column (17).

(21) *Assessed surplus streamflow* — Annual dry conditions assessed surplus streamflow from Table IV-2, column (20).

(22) *Current streamflow depletion* — Annual current dry conditions depletion from Table IV-2, column (21).

(23) *Assessed streamflow depletion* — Annual dry conditions assessed streamflow depletion from Table IV-2, column (22).

(24) *Instream use to total streamflow ratio* /1/ — Annual ratio of the maximum instream use to the dry conditions assessed total streamflow, from Table IV-2, column (23).

/1/ Actual fish and wildlife instream flow approximations should be lower for dry conditions analysis. Because methodology has not yet been developed for estimating these lower values, the base conditions instream flow approximations were used as the best available information.

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TABLE II-8. WATER REQUIREMENTS FOR ENERGY (BASE CONDITIONS)

Base conditions — Based on typical conditions of fresh-water use compared to long-term fresh-water supply.

Fuels production — Includes water for fuels extraction and refining of nonpetroleum fuels. However, total water requirements for coal liquifacation or gasification and oil shale development are not estimated. This information is the fuels subcategory of minerals water use from Table II-4.

Petroleum refining — Includes water for establishments primarily engaged in petroleum refining, manufacturing of paving and roofing materials, and compounding of lubricating oils and greases. This information is the petroleum subcategory of manufacturing water use from Table II-4.

Electric power generation — Includes steam electric water use based on steam powered generation plants with 25 megawatts or more installed capacities. Most smaller plants operate for limited periods during the year so use relatively small quantities of water. The information for electric power generation does not include water used for hydroelectric generation, which is primarily instream use. Most of the consumption for hydroelectric generation is included in reservoir evaporation (Table II-1). Steam electric water use is from Table II-4.

Further energy-related information — Available in a supplementary report on *Water for Energy* published separately by the U.S. Water Resources Council in 1978 (GPO stock no. 052-045-00050-9).

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The purpose of the Council is to encourage the conservation, development, and utilization of water and related land resources on a comprehensive and coordinated basis by the Federal government, States, localities, and private enterprises with the cooperation of all affected Federal agencies, States, local government, individual corporations, business enterprises, and others concerned.

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