U.S. ARMY CORPS OF ENGINEERS
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LESSONS LEARNED FROM THE CALIFORNIA DROUGHT (1987-1992)

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NATIONAL STUDY OF WATER MANAGEMENT DURING DROUGHT

SEPTEMBER 1993

IWR REPORT 93-NDS-5

National Study of Water Management During Drought Reports

This report is part of a series of reports which are being published during the study. Reports on three studies conducted under the aegis of the National Study of Water Management During Drought were published in 1991:

> *The National Study of Water Management During Drought: Report on the First Year of Study (IWR Report 91-NDS-1) prepared by the Institute for Water Resources, U.S. Army Corps of Engineers, Fort Belvoir, Virginia.*
>
> *A Preliminary Assessment of Corps of Engineers Reservoirs, Their Purposes and Susceptibility to Drought (IWR Report 91-NDS-2), prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California.*
>
> *An Assessment of What is Known About Drought (IWR Report 91-NDS-3) prepared by Planning Management Consultants, Ltd., Carbondale, Illinois.*

A number of reports presenting the final results of the National Study are expected to published in 1993. Among these reports:

> *The National Drought Atlas (IWR Report 93-NDS-4). The drought atlas is a compendium of statistics which allows regional water managers to determine the probability that a given volume of precipitation will occur in an "n" month period, with "n" = 1, 2, 3, 6, 12, 24, 36, or 60. The Atlas can be used in may ways, but two uses are considered most important. First, planners can estimate the return interval of the drought of record, and thus can make a more informed judgement about whether this is a suitable design drought for planning purposes. Second, in the event of a drought, operators and managers can better estimate the probability of the drought continuing, or of reservoirs refilling to normal levels within the next n months. The Atlas also includes information on streamflow and the Palmer Drought Index.*
>
> *Managing Water for Drought will be a "how to" book for those interested in reducing drought impacts. The main text will explain how a variety of different readers can apply a model planning process on a very limited or very expansive budget and timetable. The process is designed to integrate across technical, political, and institutional boundaries, across water management purposes, and over the long and short term.*

For further information on the National Drought Study, contact the Study Manager:

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Reports may be ordered by writing (above address) or calling Arlene Nurthen, IWR Publications, at (703) 355-3042.

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REPLY TO ATTENTION OF

June 24, 1994

CEWRC-IWR

MEMORANDUM FOR COMMANDER, Defense Technical Information Center, Cameron Station, Alexandria, VA 22314

SUBJECT: Transmittal of IWR Report 93-NDS-5

1. Reference AR 70-31.

2. Two copies of IWR Report 93-NDS-5, "Lessons Learmed from the California Drought (1987-1992)", has hereby been submitted.

3. Initial distribution of this report has been made to appropriate Corps of Engineers agencies. It is recommended that copies of this report be forwarded to the National Technical Information Center.

4. Request for the DTIC Form 50 (Incl 2) be completed and returned to WRSC-IWR.

FOR THE DIRECTOR:

Enclosure

Kyle E. Schilling
Director

LESSONS LEARNED FROM THE

CALIFORNIA DROUGHT (1987-1992)

Prepared for the

Institute for Water Resources
Water Resources Support Center
U.S. Army Corps of Engineers
Fort Belvoir, Virginia 22060

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EXECUTIVE SUMMARY

As of the date of this report, the Governor of the State of California has declared the drought over. Although restoration of water to aquifers will take years to accomplish, the public and private sectors are turning their focus on other socioeconomic issues. This current condition should be assessed as only a reprieve—a temporary relief in the hardships and impacts delivered by a drought—and implies that it will occur again. Whether the next drought occurs later this year or 10 years from now is not the issue here. What is relevant are the lessons learned from this recent drought experience and the actions to be taken to protect against and plan for mitigating adverse drought-related impacts.

This report describes the lessons learned of the six-year California drought that are aimed at improving the management of water resources during future droughts in California and other states throughout the nation. These lessons capture the views of some 100 key members of the California water community representing 57 organizations. The participating organizations represented federal, state, regional, and local water supply agencies as well as environmental, private, and governmental entities that influence water management in the state.

STUDY APPROACH AND REPORT DESIGN

Our analytical approach is described in Chapter I, "Introduction." Our approach to identifying the important lessons of the drought consisted of three research activities: (1) literature review of published and unpublished documents, (2) field interviews, and (3) feedback critiques of the draft report by survey participants and other water professionals.

The 1987-92 drought in California put the long-term strategy of drought protection as well as short-term drought response measures to a severe test. In order to allow the readers to draw their own conclusions about the emerging lessons, we included the relevant background information and data on California's economy and water resources and on the existing water management system. This information is included in Chapter II, "California's Economy and Water Resources," and Chapter III, "Water Management System." Chapter IV, "Recount of the 1987-1992 Drought," contains the chronology of the major drought events and significant drought response actions during each consecutive year of the drought. Statewide statistics of water use during this drought by various types of water use sectors and water districts were not available and therefore were not included for evaluation.

The three chapters that follow the background information summarize the views of the survey participants. Chapter V, "Survey Results: General Perceptions," summarizes the contents of the interviews pertaining to four general aspects of the drought: (1) critical drought impacts, (2) communication and cooperation, (3) the role and responsibilities of the media, and (4) response to the drought of the general public and water users. Chapter VI, "Survey Results: Water Management Issues," summarizes the results of the interviews that pertain to four major aspects of water management during drought: (1) new developments and innovative approaches,

(2) critical legislation, (3) timing of drought response actions, and (4) performance of water institutions. Finally, Chapter VII, "Suggested Initiatives and Reforms," presents the views of survey participants on actions that should be taken to enhance the ability of California's water management system to cope with future droughts. These suggestions are presented under four broad categories including (1) water policy initiatives, (2) agricultural initiatives and needs, (3) urban water management, and (4) environmental protection.

In presenting the survey results in these three chapters, our purpose was to summarize the views of survey participants and draw some conclusions from these opinions while withholding our judgment to the extent possible. We necessarily had to use our judgment in Chapter VIII, "Synthesis of Lessons Learned." This synthesis represents our understanding of the experiences of survey participants and factual information which allowed us to formulate the lessons of the drought.

LESSONS FOR WATER MANAGEMENT

The California drought experience provided the water community with many important lessons. Some of these lessons have been learned and acted upon during the later stages of the drought. Other lessons are yet to be confirmed and are presented in this report as recommendations of the survey participants for water management initiatives and reforms. The drought experience and emerging lessons apply not only to California but to all states that face the potential of long-term (multiyear) water shortages. This report should be gleaned by the national water community for experiences that reflect similar possible impacts in their region. Drought planning will improve relative to who learns these lessons and to what actions are taken by them to create improved drought policy.

Table 1 lists the titles of new and continued lessons for long-term drought planning and for preparedness for drought response in the short term. A description of each lesson and background information can be found on pages shown after each title.

The experiences and lessons of the ongoing 1987-92 drought were translated by survey participants into specific actions that should be taken in order to enhance the capability of California's water management system to cope with future droughts. Table 2 presents some of the participants' suggestions under the categories of strategic and tactical measures. The sequence of these suggestions does not follow any particular order. Complete listings of these suggestions are included in Appendix D and discussed in Chapter VII.

The 1987-92 drought focused the attention of the public and water institutions in California on the shortcomings of the existing water management system in the state as defined by water infrastructure, institutional arrangement, and the current system of water rights. The drought experiences clearly demonstrated the need for enhancing the infrastructure and reforming water institutions in order to achieve greater efficiency in using the existing sources of water supply as well as restoring and maintaining the state's environmental resources. Without such improvements, additional growth of the state's population and economy will translate into increased hardships and damages to the environment during future droughts.

TABLE 1

SUMMARY OF LESSONS LEARNED

New Lessons for Strategic Planning

- The nature of social, environmental, and economic impacts of a sustained drought points to a need for careful and more realistic drought planning (p. 183).
- Severe drought can change longstanding relationships and balances of power in the competition for water (p. 185).
- Irrigation can provide complementary environmental benefits (p. 186).
- Land use regulation must be the mechanism for urban growth management policies which accept limited water supply (p. 187).
- The success of drought response plans should be measured in terms of the minimization and equitable redistribution of actual impacts (as opposed to water shortages), but there is much to be learned about the best ways of accomplishing it (p. 188).
- Severe droughts can expose some inadequacies in the performance and roles of state and federal water institutions (p.189).
- The overall success of water rationing plans depends on their design and reliance on increases in water rates (p. 190).
- Mass media can play a positive role in drought response, especially if some guidelines are followed (p. 192).
- Market forces are an effective way of reallocating restricted water supplies (p. 193).

TABLE 1 (Continued)

SUMMARY OF LESSONS LEARNED

Confirmed Lessons of Previous Droughts

- Water in the aquifers continues to be the most effective strategic weapon against drought (p. 194).
- The surest way to mitigate the adverse social, environmental, and economic impacts of a sustained drought is to obtain more water (p. 195).
- Early drought response actions and proper timing of tactical measures are essential in short-term management of droughts (p. 196).
- Local and regional interconnections among water supply systems proved to be a good insurance policy against severe water shortages (p. 197).

TABLE 2

SUMMARY OF SUGGESTED CHANGES NEEDED IN WATER MANAGEMENT

Strategic Measures Suggested by Survey Participants

- The Sacramento-San Joaquin Delta problem has to be resolved (p. 198).
- SWP facilities have to be completed (p. 198).
- A permanent Water Bank should be established (p. 198).
- The state should move away from "crisis management" and focus more on "long-term planning" (p. 198).
- Marginal cost pricing should be incorporated into long-term water plans (p. 198).
- Groundwater management should be improved (p. 198).
- Water management should be centrally coordinated (p. 198).
- The state should develop a computerized data bank (p. 198).
- California water law should be revised to allow for in-stream water rights (p. 198).
- Enforced mitigation of impacts on aquatic resources should be undertaken in order to enhance water quality and minimum-flow standards (p. 199).
- More conservation technology and know-how should be infused into California's agriculture (p. 199).
- Improved reliability of urban water supplies is needed (p. 199).
- Long-term water management plan should take environmental needs into account (p. 199).
- Environmental needs for water should be met (p. 199).
- A better management of fish and wildlife under normal conditions is needed (p. 199).

Tactical Measures Suggested by Survey Participants

- State should develop and adopt clear triggering mechanisms for drought response (p. 199).
- Californians should establish water use priorities (p. 199).

TABLE 2 (Continued)

SUMMARY OF SUGGESTED CHANGES NEEDED IN WATER MANAGEMENT

Tactical Measures Suggested by Survey Participants, Continued

- A streamlined approval process for all water transfers should be developed (p. 199).
- A massive public information and education program is needed (p. 200).
- The state should cut down on the amount of firm hydroelectricity production during drought (p. 200).
- Agricultural water districts should be more flexible (p. 200).
- A better accountability in agricultural water use must be achieved (p. 200).
- Urban water suppliers should develop very clearly defined carry-over storage goals and adhere to them during drought (p. 200).
- Urban water agencies should plan for water deficits (p. 200).
- Water rationing should be done through pricing (p. 200).
- Water agency representatives should improve the communication of their water supply situation (p. 200).
- Environmental impacts must be given greater attention (p. 200).

I. INTRODUCTION

PURPOSE

The purpose of this report is to identify, categorize, explain, and verify the important lessons learned during the multiyear California drought of 1987-92. The lessons of the drought were formed using a carefully designed research approach consisting of personal interviews with members of the California water community and other key individuals in the state as well as a thorough review of documents and reports pertaining to the drought. The resulting lessons pertain to various aspects of drought management. They are directed to federal, state, and local levels of government, water institutions, and water users (urban, agricultural, environmental, and others) for improving the management of water resources during future droughts in California and other states.

This report is part of a comprehensive study that has been undertaken in response to recommendations of the National Drought Study. After the drought of 1988-89 that affected many regions of the United States, the President's budget included funds to begin a National Water Management During Drought Study (NWMDS) as part of the administration's 1990 budget. Authority for the study was given to the Assistant Secretary of the Army for Civil Works as provided in Sections 707 and 729 of the Water Resources Development Act of 1986. The Institute for Water Resources managed the study for the Assistant Secretary and the U.S. Army Corps of Engineers Headquarters. The NWMDS team thought that the California drought would provide worthwhile lessons learned for the rest of the nation, especially given California's existing water projects and preparedness, which were thought to be better than most in the country.

This report follows several previous reports of the NWMDS performed by federal agencies. These reports include:

- The National Study of Water Management During Drought: Report on the First Year of Study IWR Report 91-NDS-1, U.S. Army Corps of Engineers, Institute for Water Resources, May 1991

- The National Study of Water Management During Drought: A Preliminary Assessment of Corps of Engineers Reservoirs, their Purposes and Susceptibility to Drought IWR Report 91-NDS-2, U.S. Army Corps of Engineers, Institute for Water Resources, September 1991

- The National Study of Water Management During Drought: A Research Assessment IWR Report 91-NDS-3, U.S. Army Corps of Engineers, Institute for Water Resources, August 1991

STUDY OBJECTIVES

The specific objectives and research design of the study have been developed based on extensive discussions between the Program Manager of the National Study of Water Management during Drought, his staff, the research study team, the staff of the California Department of Water Resources, and other water professionals in the state and the nation. Several research paradigms were considered in developing an appropriate approach. During preliminary discussions, it was recognized that the state of California has a sophisticated and complex water management system. Because of this complexity, the California system has not been addressed by a unified and comprehensive statewide drought management plan. In the absence of an evaluation of the performance of a formal statewide drought plan, the lessons learned had to be obtained by (1) contrasting "expectations" and "what actually happened," (2) examining the basis for decision making during the various stages of drought, and (3) analyzing the degree to which the California water management system met expectations.

In light of the complexity of water management in California, specific study objectives were formulated as follows:

- To characterize the setting for year-to-year management of water in the state in terms of the balance of supply and demand, legal framework, and water management institutions

- To identify the overall approach to drought management that prevailed in the state prior to the onset of the drought in terms of the roles and responsibilities of water institutions and prior drought experience

- To examine the current perceptions and concerns of key individuals in the California water community who control or influence water management at federal, state, regional, and local levels of government

- To identify the lessons learned from the drought as viewed by the key individuals, with respect to several aspects of drought management including:

  - Critical impacts of the drought (economic, environmental, and other)
  - Role and performance of water institutions
  - Public response to water shortages
  - Communication and cooperation
  - Role of the media
  - Critical water management legislation
  - Timing of drought response actions
  - Innovative drought management approaches
  - Most pressing needs for change in the present water management system

- To verify the validity of the lessons identified by the key individuals by placing them in the context of the:

  - Chronology of major events during the drought
  - Actual response actions and actual outcomes of these actions
  - Data on economic, social, and environmental impacts of the drought
  - Other measures of performance of drought management policies and actions

- To conduct a synthesis of findings stemming from the previous objectives in order to determine:

  - What worked and what did not work?
  - What were the major gaps between expectations and actual performance?
  - What needs to be changed, preserved, or done in the future?
  - What are the most valuable lessons for governments, water institutions, and other parties in California and other states?

By accomplishing these specific objectives, the sponsors of this study intended to use the lessons of the Great California Drought of 1987-92 in developing recommendations for a national strategy for better management of the nation's water resources during future droughts.

STUDY APPROACH

The following discussion describes the research method used to accomplish the preceding study objectives. It describes the process of identifying the water management structure in the state and selecting the key individuals of California's water community representing various levels and functions of this structure.

Development of a Research Platform

Several important design issues were confronted in devising an appropriate research approach:

- What are the best sources of information on the drought?

- How does one capture a full spectrum of opinions on lessons learned?

- How does one identify and separate the political agendas in order to identify the objective and genuine lessons learned?

- What is the best overall paradigm for identifying and verifying the important lessons of the drought?

These and other questions have led us to the development of the overall research platform that is presented in Figure I.1. This approach consisted of two intertwined research activities: literature search and field interviews. The purpose of each activity is briefly described below.

Literature Search

In order to understand the complexity of water resource management issues, especially in California, it was initially essential that we established and understood the existing water management system in the state. Literature sources and governmental documents were searched in order to obtain data and information that are indispensable to understanding the year-to-year management of water in California. These included statistical data on the state population, economy, water supply, and water use. In addition, information was collected regarding the legal framework for water management in the state, existing institutional structure, and major issues in water management.

Once the background information was collected, we identified California's approach to managing droughts that existed prior to the 1987-92 drought. Again this information was gleaned through the search of drought literature. Documents pertinent to the 1976-77 drought in California provided a primary source of information for identifying the existing approaches to managing droughts in the state.

The final component of the literature search was to obtain factual and, therefore, objective data and information on the 1987-92 drought. Extensive published information on drought events and response actions together with their chronology was obtained, studied, and assimilated into our knowledge base. Also, information on actual outcomes of response actions and data on impact measurements were recorded for further reference.

Field Interviews

The most important sources for identifying the lessons of drought are the key individuals who control or influence the management of water resources in California. By examining their firsthand views, opinions, and concerns and placing them in the context of factual data and information obtained through the literature review, we expected that the lessons of the drought would emerge.

Definition of a Lesson Learned

The Random House College Dictionary (Revised Edition, 1984) gives the following meanings of the word "lesson": (1) "something to be learned or studies as in 'the lessons of the past'" or (2) "a useful piece of a practical wisdom acquired by e erience or study." By adding the action modifier "learned," the identifiable lessons imply th e respondent has recognized

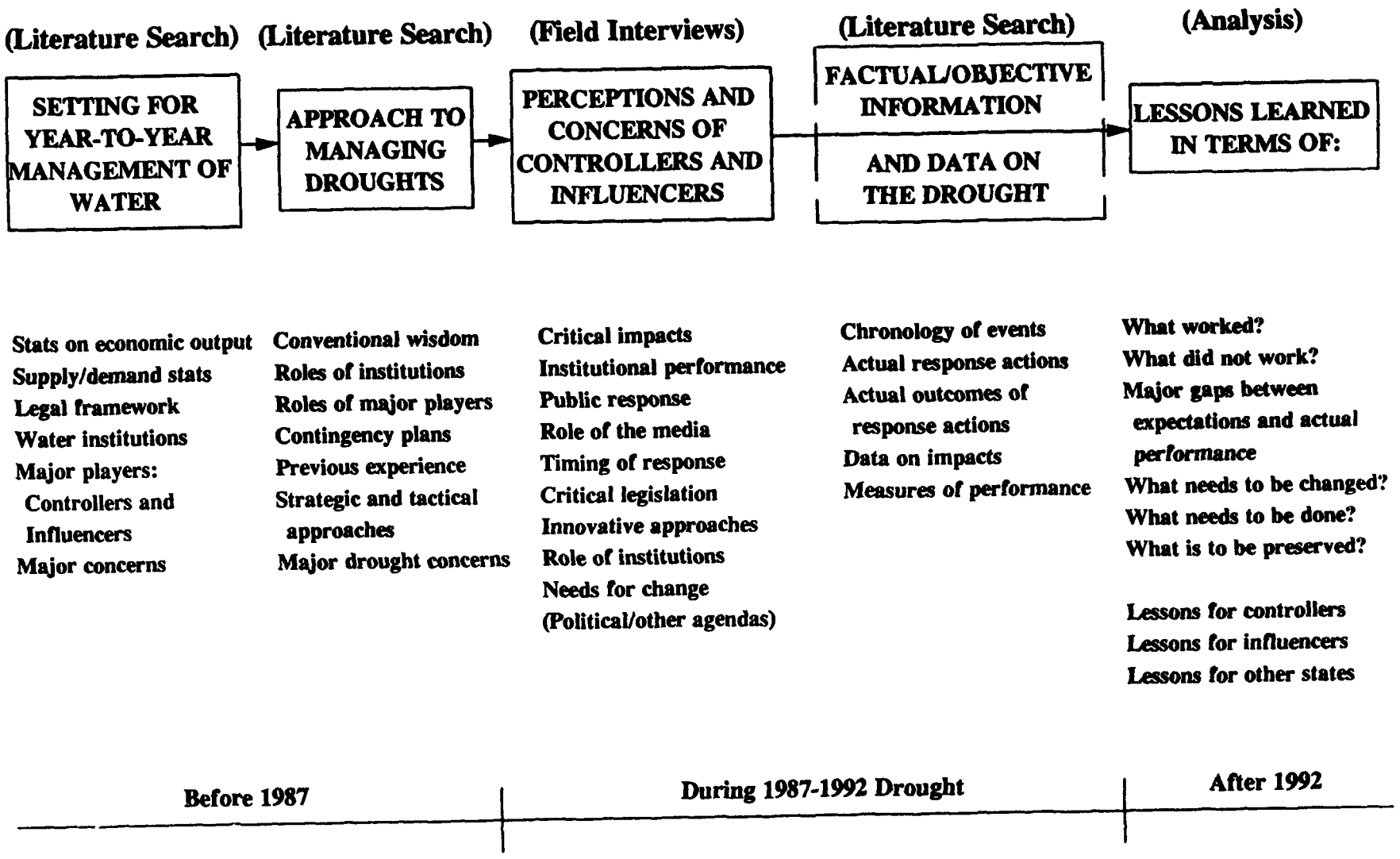

FIGURE I.1

RESEARCH APPROACH AND METHODS

the event as a lesson worth knowing and deserving attention during the development or revision of future drought contingency plans. The concept of a "learned" lesson should not be taken to mean that all who should have recognized the intrinsic value of the lesson have done so.

Our survey was designed with this broad definition of the term "lesson learned" in mind. Purposefully, we did not offer a specific definition of the term "lesson learned" at the beginning of each interview. Instead, we encouraged the survey participants to look retrospectively on their experiences during the drought and give us answers to such questions as, what worked and what did not work? and what needs to be changed, preserved, or done in the future? We also asked for the respondents' opinions on various aspects of drought management. We analyzed all answers to our questions, as well as all statements offered by the respondents that went beyond our questions, in order to identify lessons for water management. Finally, we used published sources in order to determine the chronology of events and used actual response actions and their outcomes, and data on drought impacts to identify additional lessons and to gain better insights into the lessons identified from the interview material.

Lessons that are presented in the concluding synthesis chapter are labeled as "lessons learned" because each lesson satisfies one or more of the following criteria:

- It represents "useful pieces of practical wisdom" acquired from drought experience.
- It represents new knowledge that was not available before the drought.
- It emerged by analyzing changes in decision-making processes during the drought or examining the performance of the water management system.
- It can be formulated as a recommendation for future actions that should be taken in order to avoid repeating the same errors or enhancing the performance of actions previously taken.

This broad definition allowed us to include a number of "useful pieces of practical wisdom" gleaned from the experiences of the 1987-92 drought in California. In formulating the lessons for water management, we made an attempt to cast each statement in a format that would indicate changes and conditions needed for making decisions and taking actions for managing future droughts and avoid statements indicating general conclusions and observations or statements of fact. The reader may conclude that there are additional lessons after reading all parts of this report.

Design of Survey Instruments

The field interviews were conducted using two survey instruments: personal interview design and group interview design. These instruments were designed to obtain the participants' views on the relevant aspects of water management during drought.

Personal Interview Content

Table I.1 shows the content of the personal interview. The interview consisted of five questions on general aspects of the drought, which were followed by five questions on specific drought issues. At the end of each interview, the respondents were asked to clarify their answers and offer their observations on some prominent issues that surfaced during previous interviews.

Each interview began with questions about the roles and responsibilities of the interviewee and his/her organization in drought management and about the interviewee views on the critical drought impacts, communication and cooperation, role of the media, and response of the public to the drought. Each of these topics delineated a potential category of lessons learned.

The questions on specific drought issues were focused on (1) new developments and innovative approaches to drought management, (2) critical state and federal legislation, (3) timing of drought response actions, (4) role and performance of water management institutions, and (5) critical needs for change in water management. Again, each of these topics was selected for its potential in surfacing lessons learned. The last question was directed toward focusing participant attention on the implications of his/her experiences for water management in the future.

Group Interview Guide

Corresponding information was gathered through group interview sessions. Table I.2 shows the group interview guide used during these sessions. The number of participants in each session ranged from two to seven.

The participants were graphically shown the identical areas of interest posed during the individual interviews. They were then asked to record on paper their views about the most important impacts of the drought and actions to be taken to preserve or change water management during drought. If some of the areas of interest did not surface during the participants' remarks or the free-flowing discussion, they were raised and appropriately discussed at the end of the session.

Selection of Participants

The usefulness of the field interviews was judged to be critically dependent on the selection of the institutions and individuals interviewed. In order to obtain representative views it was necessary to identify the institutional structure of water management in California.

TABLE I.1

PERSONAL INTERVIEW GUIDE

PART A. GENERAL ASPECTS

- Responsibilities and Roles
  Could you briefly describe the role of your organization and your personal involvement in drought management?

- Drought Impacts
  What do you see as the most critical impacts of this drought on you, your organization, as well as, on other parties and activities (environmental, financial, social, economic, political, etc.)?

- Communication and Cooperation
  How would you characterize the communication and cooperation between your organization and other water management organizations during the drought period?

- Role of the Media
  How do you view the performance of the media and their desired role during drought?

- Public Response
  What is your opinion of the public response and that of other water users to the drought?

PART B. SPECIFIC ACTIONS

- New Developments and Innovative Approaches
  Are there any new developments or innovative approaches to coping with drought that have been used during this drought?

- Critical Legislation
  Are there any state and federal acts or local ordinances that you consider critical to managing this drought?

- Timing of Drought Response Actions
  What is your view on the timing of response actions and the usefulness of triggering mechanisms?

- Role and Performance of Water Institutions
  How would you characterize the role and performance during this drought of water institutions such as retailers, wholesalers, and state and federal agencies?

- Things to Be Done
  What, in your view, are the things that should be done, changed, or preserved in the way water is managed during drought in California?

TABLE I.2

GROUP INTERVIEW GUIDE

- Introduce interviewers and participants.

- Present the objectives and design of the National Water Management During Drought Study and the Lessons Learned study.

- Provide verbal directions for individual written responses:

  "We would like you to use these cue cards and spend four to five minutes writing down your thoughts regarding two aspects of this drought."

  The first aspect is the **IMPORTANT IMPACTS OF THE DROUGHT**. What do you see as the most important impacts of this drought on you, your organization, as well as on other parties and activities (including environmental, financial, social, economic, political, and other).

  The second aspect is the **THINGS TO BE DONE**. What in your view are the things that should be done, changed, or preserved in the way water is handled during drought? For example, what are the needed changes pertaining to communication and cooperation, role of the media, public response, innovative approaches, legislation, timing of drought response actions, and performance of water institutions?

- Solicit remarks from each participant and encourage free-flowing discussion.

- Remind everyone to convey their personal thoughts based on their written notes.

- Ask follow-up questions as needed.

Figure I.2 gives a representation of the water management structure in California devised for the purpose of this study. The water management institutions were placed into a hierarchical structure rising from the local level of communities and industries to the state and federal levels. The pyramid shape of the aggregated hierarchy shows that the number of organizations is the largest at the local level. At the state and federal levels there are fewer agencies, but their actions have considerable impact on water management in California.

A horizontal distinction was also made within the pyramid. We distinguished "water controllers" from "water influencers" at each level of management. The controllers of water represent organizations and individuals who make direct decisions on water allocations, have been allocated water rights, and can decide on how, where, and when to release or move water.

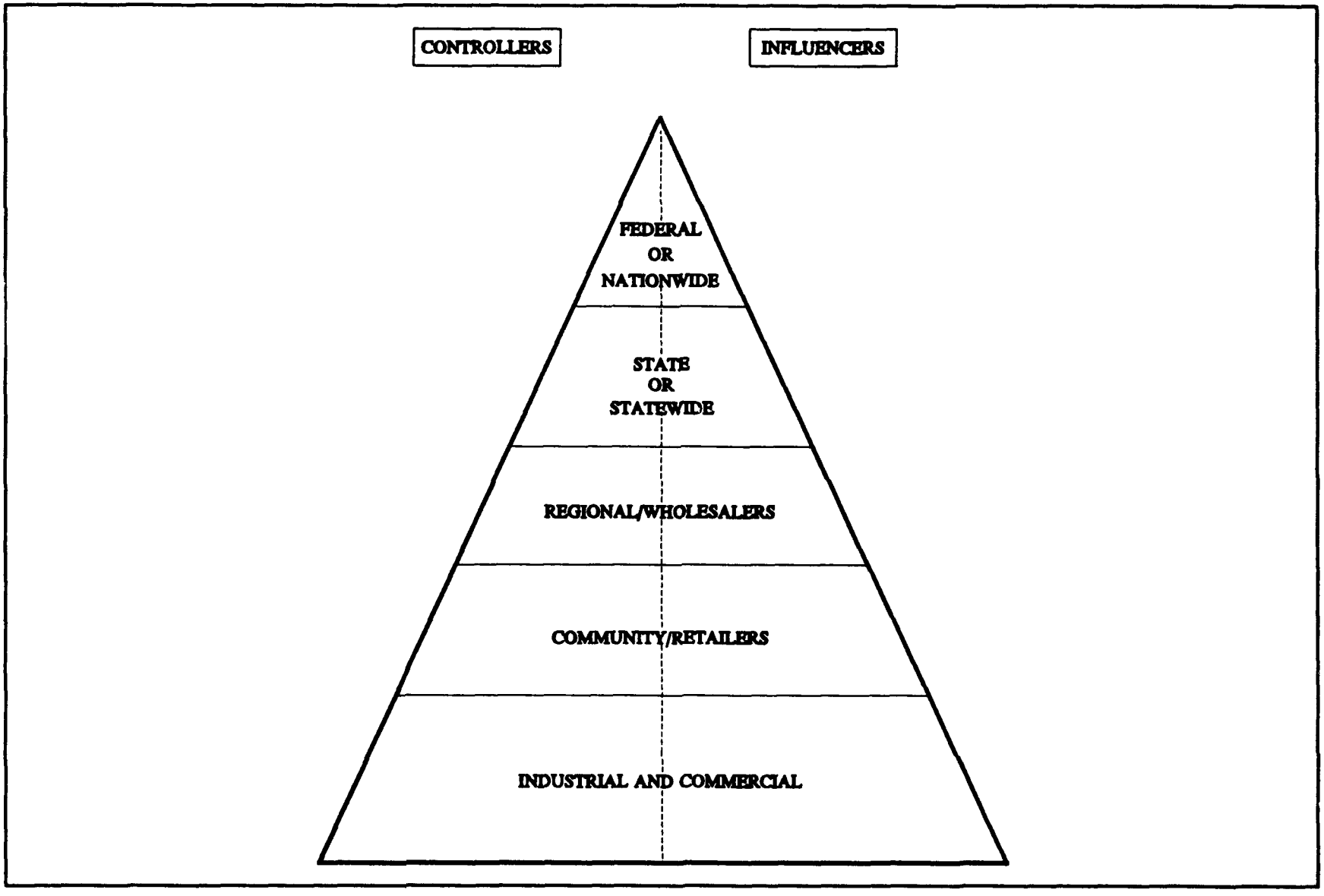

FIGURE I.2

INSTITUTIONAL WATER MANAGEMENT STRUCTURE

These groups include the State Water Project (SWP), the Central Valley Project (CVP), and all water districts (both urban and agricultural) in the state. The influencers in water management do not make day-to-day decisions in storing, releasing, and wheeling water and may not have water rights, but they have critical influence on the decisions of water controllers. The influencer group includes all environmental organizations and government agencies that regulate water and related land resources.

The participants were closely involved in preparing this report. Two workshops were held at the California Department of Water Resources in December 1992 at which they critically reviewed the preliminary draft report, especially its conclusions and lessons learned. Eleven of the organizations interviewed for the study participated in the workshops, representing about one quarter of all the agencies interviewed. Their comments and critique were considered and included in the final study document.

Table I.3 lists all institutions who participated in the individual interviews or group interview sessions and classifies them according to hierarchy and their controlling/influencing role. Several other organizations were approached but could or did not participate for various reasons. Some institutions cannot be readily compartmentalized because of their dual roles as controllers and influencers. However, the most important purpose of this structural representation was to make sure that all key players in California's water management were included in our survey.

A total of 101 key individuals participated in 12 personal interviews and 22 group interview sessions. The participants represented 57 organizations. Some interviews of institutions included representatives of member organizations. Table I.3 does not list all 57 organizations. The 34 interviews were conducted over a six-month period. The first 14 interviews conducted in December 1991 represented 20 organizations. The remaining 20 interviews were completed in May-June 1992. Those participants represented 37 organizations. The total survey was made up of 20 interviews with controllers and 14 interviews with influencers. A summary of each personal interview or a group interview session was prepared from the interview notes and notes taken during playback of the recorded interviews. The summaries were used to identify the lessons learned.

CHAPTER SYNOPSES

The sequence of chapters of this report generally follows the research sequence of this study. Chapters II-IV give the necessary background information on population, economy, and management of water resources in California and also present a chronological recount of the major events and response actions during the 1987-92 ongoing drought. Chapters V-VIII present perceptions of targeted interview participants in light of the background information and identify lessons learned.

Chapter II gives background information on the state economy and water resources and presents the breakdown of water use in the state.

TABLE I.3

PARTICIPATING INSTITUTIONS

Controllers	Influencers
I. Federal and nationwide	
U.S. Bureau of Reclamation	U.S. Fish and Wildlife Service
U.S. Army Corps of Engineers	Environmental Defense Fund
	Sierra Club
	Soil Conservation Service
II. State or statewide	
Department of Water Resources	Department of Parks and Recreation
C-DWR State Water Project	Department of Fish and Game
C-DWR Drought Center	California Farm Bureau
California Resources Agency	
III. Regional and wholesalers	
San Francisco Water Department	State Water Project Contractors
Metropolitan Water District of Southern California	Committee for Water Policy Consensus
	CVP Water Users Association
Westlands Water District	California Urban Water Agencies
Kern County Water Agency	
Glenn-Colusa Irrigation District	
Santa Barbara County Water Agency	
IV. Community and retailers	
Southern California Water Company	*Sacramento Bee*
East Bay Municipal Utility District	Mono Lake Committee
Los Angeles Department of Water and Power	
City of Santa Barbara	
City of Goleta	
V. Commercial and industrial	
Pacific Gas and Electric	California Landscape Contractors Assn.
	California Energy Commission
	Green Industry Council

Chapter III displays the balance of water supply and demand under normal conditions and characterizes the existing water management system in California. The water management system is presented in terms of its legal and institutional setting. The chapter also describes the overall approach to preparing and responding to droughts in the state that existed prior to the 1987-92 drought. It describes the roles of water institutions and other parties in drought management and contrasts these roles with experiences of the 1976-77 drought. The status of drought preparedness and the level of long-term drought protection are assessed. The chapter concludes with a summary of the major concerns and challenges facing the managers of water resources in the state.

Chapter IV gives a recount of the major events and developments during the 1987-92 drought. A chronology of events is re-created beginning with the early signs of drought followed by a description of significant drought response actions during each consecutive year of the drought. The last section of this chapter characterizes the current status of the drought.

Chapter V presents the results of personal interviews and group interview discussions concerning four general aspects of the drought: (1) critical drought impacts, (2) communication and cooperation, (3) the role and responsibilities of the media, and (4) response of the general public and water users to the drought.

Chapter VI summarizes the views of the key individuals concerning four specific issues of water management during the drought. These include (1) new development and innovative approaches, (2) critical legislation, (3) timing of drought response actions, and (4) performance of water institutions.

Chapter VII presents views on initiatives and reforms needed in water management. The discussion summarizes the views of the survey participants on actions that should be taken to enhance California's water management system handling of future droughts.

Throughout Chapters V-VII, the responses of the survey participants are supplemented with factual information to verify the opinions and perceptions of the participants.

Finally, Chapter VIII delivers nine new lessons learned from the drought and four confirmed lessons of previous droughts based upon an analysis and synthesis of collected data. It outlines the expected approach to drought response and describes the important lessons for the development of future drought management policies in California and other states. Specific lessons and recommendations are given for strategic (long-term) and tactical (short-term) measures for drought planning.

II. CALIFORNIA'S ECONOMY AND WATER RESOURCES

This chapter gives background information on water supplies and water uses in the state and characterizes the overall water management system.

POPULATION AND ECONOMY

Population Growth

California's population was approximately 32 million in early 1993 and is projected to reach 41.4 million by 2010 (C-DWR, Statewide Planning Branch 1992h). Between 1980 and 1990, California's population increased 27 percent (6.3 million persons). From 1980-85, net migration to California accounted for about 52.5 percent of the increase in population, while natural increase made up 47.5 percent. Average annual population increase in the state between 1980 and 1985 was 2 percent or 481,000. The South Coast region constituted about 54 percent of the state population in 1985 and this region grew by the greatest number of people: 1.25 million, between 1980 and 1985; and 3.3 million from 1980-90. Table II.1 and Figure II.1 depict the historical and projected population in California.

Population growth in the counties of the South Coast region has been triggered by several factors. Increased migration from Asia and Latin America together with natural increase induced growth in Los Angeles County. The location of the San Bernardino and Riverside counties within the commute zone for the metropolitan Los Angeles area has made these counties major growth areas. Growth in Kern County since 1980 can be attributed to the incentives of relatively low living costs and the county's proximity to the Los Angeles metropolitan market area. The slowest growth in the state has occurred in the San Francisco Bay and Central Coast regions.

Economic Activity

California's economy ranks eighth largest in the world, slightly smaller than the United Kingdom (Spectrum Economics, Inc. 1991). The California gross state product has more than doubled during the last decade, from about $319 billion in 1980 to $697 billion in 1989 (U.S. Department of Commerce 1992). Private industries generally account for about 89 percent of the gross state product and the government makes up the remaining 11 percent. The top three contributors to the economy in 1989 were the services sector (21 percent); the finance, insurance, and real estate sector (20 percent); and the manufacturing sector (17 percent). Other private industry sectors listed in descending order of their contribution to the economy include

TABLE II.1

CALIFORNIA'S POPULATION — 1980, 1985, AND 2010
(In Millions)

Region	1980	1990	2010	Increase 1980-1990		Increase 1990-2010	
San Francisco Bay and Central Coast	5.8	6.8	8.3	1.0	17%	1.5	22%
South Coast	12.9	16.2	21.9	3.3	26%	5.7	35%
Sacramento River	1.7	2.2	3.3	0.5	29%	1.1	50%
San Joaquin River and Tulare Lake	2.2	3.0	4.7	0.8	36%	1.7	57%
Colorado River	0.3	0.5	0.8	0.2	67%	0.3	60%
Remaining regions	0.8	1.2	2.3	0.4	50%	1.1	92%
California total	**23.7**	**30.0**	**41.4**	**6.3**	**27%**	**11.4**	**38%**

Adapted from: C-DWR, Statewide Planning Branch 1992h.

retail trade; transportation, communication, and utilities; construction; agriculture, forestry, and fishing; and mining (Table II.2).

Major Contributors to the California Economy

Services Sector. The services sector leads the private industries in its contribution to economic development in California. Services constituted more than $146 billion of the gross state product in 1989. The leading tertiary activities included business services, health services, miscellaneous professional services, and legal services.

Finance, Insurance, and Real Estate. This sector closely follows the services sector in stimulating economic development in California. Finance, insurance, and real estate services made up over $139 billion of the gross state product in 1989.

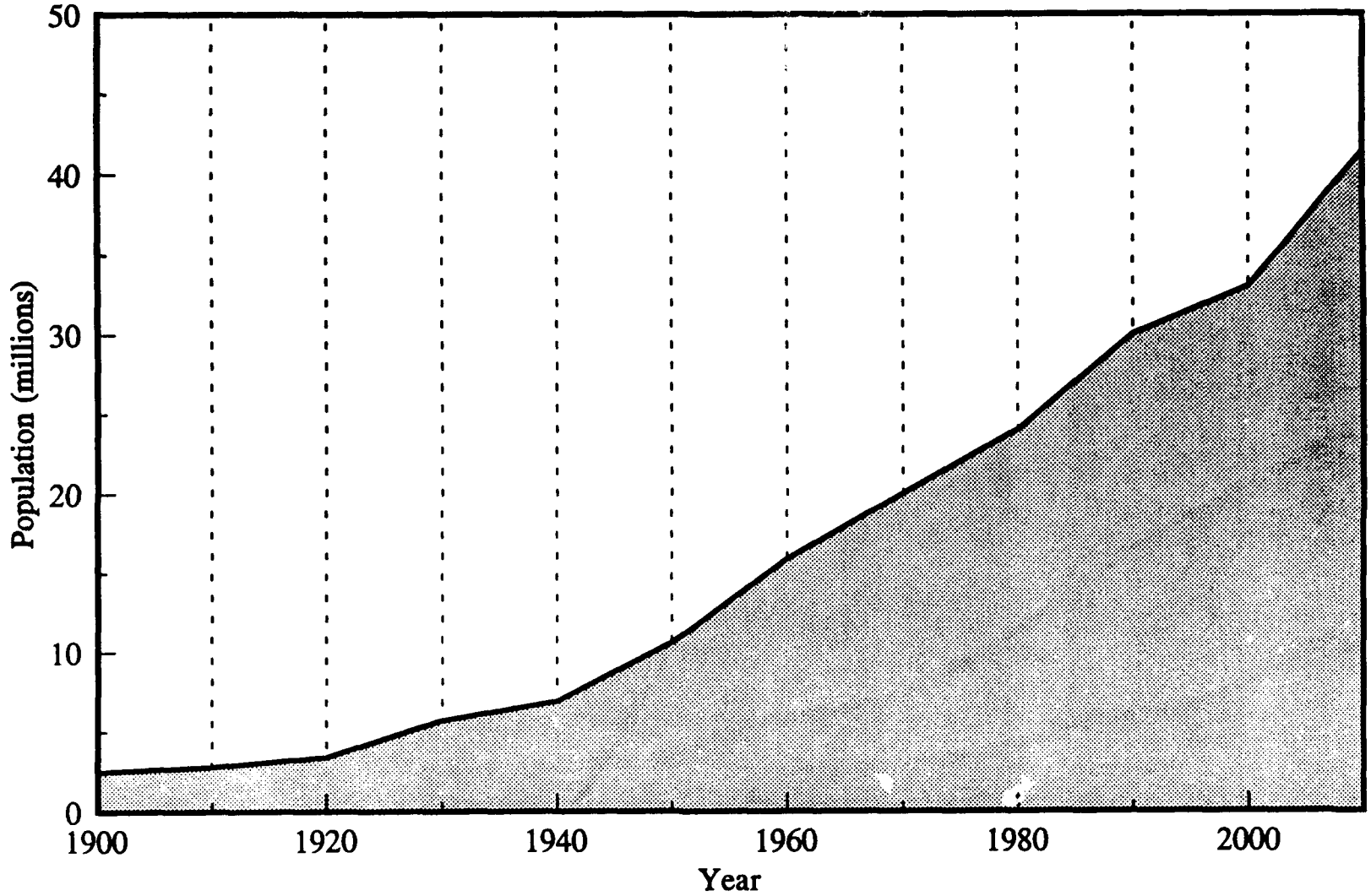

FIGURE II.1

HISTORICAL AND PROJECTED POPULATION IN CALIFORNIA, 1900-2010

Source: C-DWR 1987.

TABLE II.2

CALIFORNIA GROSS STATE PRODUCT, SELECTED YEARS
(Millions of Dollars)

	1980	1985	1986	1987	1988	1989
Private industries						
Agriculture, forestry, and fishing	10,883	12,142	12,920	15,043	15,800	16,039
Mining	6,018	7,361	4,470	4,871	5,389	5,111
Construction	16,132	21,765	24,593	27,686	30,577	33,590
Manufacturing	58,892	92,572	98,495	105,827	113,010	117,782
Transportation, communication, and utilities	24,051	39,208	42,273	44,005	46,526	48,852
Wholesale trade	23,654	36,625	37,239	38,655	42,419	46,325
Retail trade	32,806	50,721	53,579	57,168	61,946	66,213
Finance, insurance, and real estate	55,236	87,060	97,334	109,189	120,613	139,138
Services	53,336	95,343	105,736	119,870	133,866	146,121
Private industries total	**281,010**	**442,797**	**476,639**	**522,314**	**570,145**	**619,169**
Government total	**38,311**	**57,742**	**62,667**	**66,997**	**72,165**	**78,212**
Grand total	**319,321**	**500,538**	**539,307**	**589,311**	**642,309**	**697,381**

Source: U.S. Department of Commerce, Bureau of Economic Analysis, Department of Finance, Financial and Economic Research (California Statistical Abstract 1992).

Manufacturing Sector. Manufacturing ranks third among the private industries and this sector contributed to over $117 billion of the gross state product in 1989. The manufacturing sector is led by high technology and defense industry groups—aircraft aerospace, computer, and computer components. These groups provide 27 percent of manufacturing employment in Southern California and 42 percent in the San Francisco Bay area. Each job in these industry groups indirectly supports 1.8 additional jobs in trade, services, and diversified manufacturing in the state (Spectrum Economics, Inc. 1991). California's manufacturing sector contributes to 11 percent of the manufacturing employment in the United States (1987 Census of Manufacturers).

Other Contributors to the California Economy

The three major contributors described above made up 58 percent of the California economy in 1989. Additionally, a number of sectors contribute to the state economy. The discussion that follows examines the role played by three of these sectors, agriculture, the "green industry," and recreation and tourism in the economy.

Agricultural Sector. California agriculture is considered one of the most diversified in the world with over 250 different crops and livestock commodities (California Department of Food and Agriculture, 1990). According to the California Department of Food and Agriculture (DFA), agriculture had $18.3 billion in farm production in 1990, and it plays a dynamically influencing role in the state's and nation's economy. The 1990 statistics from the DFA revealed that California's 30 million acres of farmland (of which irrigable acreage is about 9 million acres) account for only 4 percent of the country's farmland but produce 50 percent of the value of the nation's fruits, nuts, and vegetables. California has been the leading agricultural state in the U.S. for the last 43 years and cash farm receipts for 1990 were estimated to have generated over $70 billion in related economic activities.

In the livestock industry, cattle constitutes the largest livestock population, followed by sheep and lambs, and then hogs and pigs. The cattle population has varied from 4.65 million to 5.0 million from 1981 to 1991 (Table II.3). Cash receipts for cattle showed a boost during 1988 to 1990, and overall receipts for cattle and hogs (Table II.3 and Figure II.2) recorded a second high in 1990 (Gleick and Nash 1991).

Green Industry. The "green industry" includes landscaping services, retail and wholesale nurseries, florists, garden stores, golf courses, and garden equipment manufacturers. California's environmental horticulture industry has economic activity exceeding $7.2 billion annually, but its various segments are not unified (Pittenger, Gibeault, and Cockerham 1991). Additionally, an equipment category and industry service segments such as public facilities and golf courses were identified, but the value could not be determined. The previously cited report predicts that these segments would account for another $2 to $4 billion in value.

Recreation and Tourism. Recreation and tourism is the largest single industry in California (Gleick and Nash 1991). This industry includes a number of activities such as hiking, boating, tourism to theme parks and beaches, and skiing in the Sierra Nevada. The 1989 estimates reveal that nearly $50 billion was spent in California on recreation and tourism, and over 700,000 jobs are associated with this industry (Gleick and Nash 1991).

TABLE II.3

CALIFORNIA LIVESTOCK POPULATIONS AND CASH RECEIPTS

	Population (1,000 animals) (a)			Cash Receipts (1,000 dollars) (b)		
Year	All Cattle	Sheep and Lambs	Hogs and Pigs	All Cattle	Sheep and Lambs	Hogs and Pigs
1981	4,760	1,205	180	1,262,907	37,867	29,627
1982	5,000	1,210	160	1,481,400	52,541	28,169
1983	4,900	1,115	160	1,325,141	44,358	27,952
1984	5,000	1,115	155	1,463,485	51,209	26,811
1985	4,960	1,065	140	1,275,693	51,771	22,142
1986	5,000	1,065	145	1,347,044	57,830	28,134
1987	4,750	980	150	1,350,012	74,034	33,414
1988	4,650	970	140	1,616,615	61,250	20,860
1989	4,700	940	130	1,575,944	53,698	21,617
1990	4,800	1,000	140	1,739,859	44,583	38,486
1991	4,750	1,015	180	--	--	--

Notes:
(a) Population numbers are for January 1981 to January 1991.
(b) Cash receipts are for marketings ending December 1 of each year.
Source: CASS 1991c, Gleick and Nash 1991.

WATER RESOURCES

Precipitation and Runoff

The average annual precipitation in California is nearly 21 inches, ranging from almost zero in desert areas to more than 100 inches in the mountainous North Coast region (C-DWR 1987). Table II.4 shows that the North Coast region averages 53.5 inches of precipitation per year, while the annual average for the Central Valley region (including drainage areas of Sacramento and San Joaquin rivers) is about 27.8 inches. The region experiencing the lowest precipitation is the Colorado River region with 4.1 inches annually.

About 60 percent of the total supply from precipitation, or almost 108 million acre-feet (MAF), is evaporated and transpired by native trees, brush, and other vegetation. The remaining 40 percent constitutes 71 MAF of streamflow that drains from the land in an average year (C-DWR 1987). It is evident from Table II.4 that almost 29 MAF, or 40 percent, of the

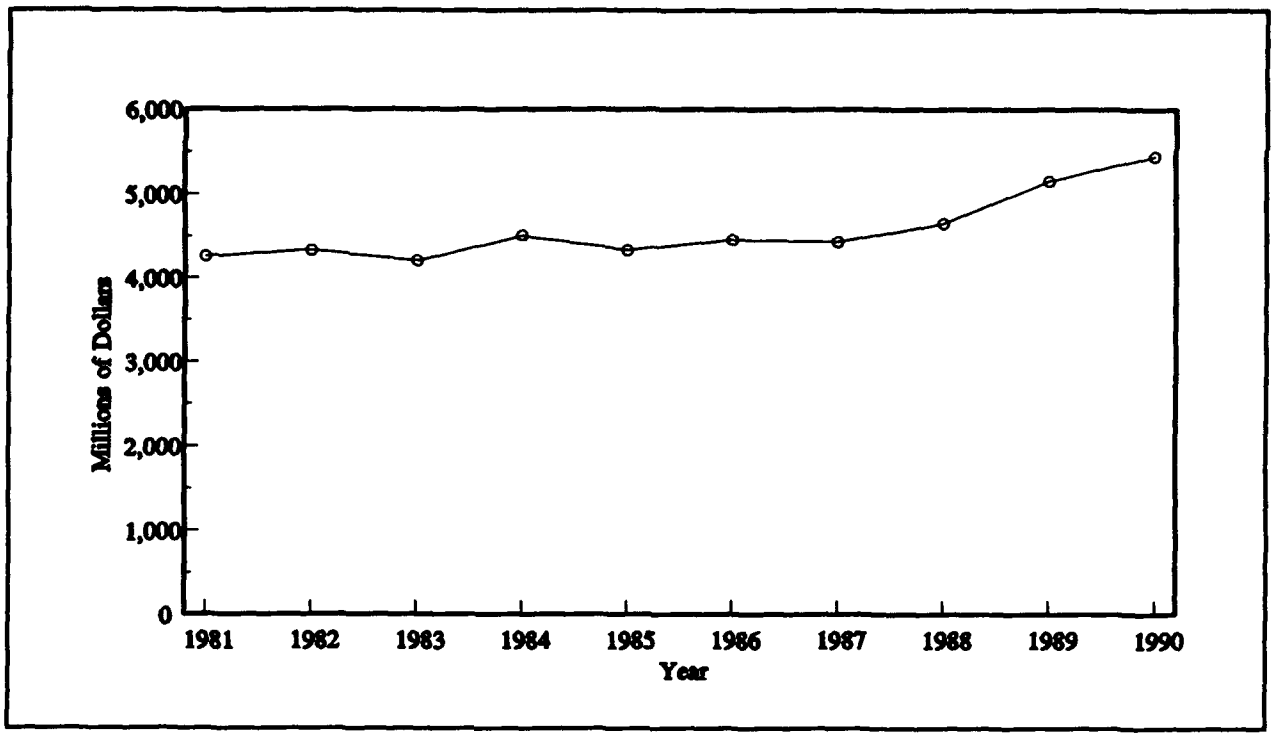

FIGURE II.2

CASH RECEIPTS FROM MARKETING OF LIVESTOCK, POULTRY, AND HONEY, 1981-1990

Sources: CASS 1991c, Gleick and Nash 1991.

average statewide runoff occur in the North Coast region. However, flows of North Coast rivers contribute only one water diversion to the rest of the state, since many rivers in the north are protected by state and federal laws that do not allow major export water developments. The Sacramento River region contributes 22 MAF annually to natural runoff, and the lowest runoff, about 0.2 MAF occurs in the Colorado River region. California's 71 million acre-feet average annual runoff displays a huge 120 MAF range, varying from an annual low of about 15 MAF in 1977 to an annual high of 135 MAF in 1983.

Surface-Water Resources

Most of the surface-water resources in the state originate from runoff that is generated within the state. Relatively small amounts are provided from Oregon and from the Colorado

TABLE II.4

CALIFORNIA WATER RESOURCES

Average annual precipitation (Inches)	
Statewide by hydrologic region	
North Coast	53.5
Central Valley	27.8
San Francisco Bay	23.4
Central Coast	20.4
South Coast	18.5
Lahontan	8.7
Colorado River	4.1
Average annual natural runoff (MAF)	
Statewide by hydrologic region	
North Coast	28.9
Sacramento River	22.4
San Joaquin River	7.9
Tulare Lake	3.3
Central Coast	2.4
North Lahontan	1.8
South Lahontan	1.3
San Francisco Bay	1.2
South Coast	1.2
Colorado River	0.2
Surface-Water storage	
State jurisdiction	
Dams and reservoirs	1,188
Gross storage capacity, acre-feet	19,700,000
Federal (in and adjacent to California)	
Dams and reservoirs	125
Gross storage capacity, acre-feet	22,900,000
Total number of dams and reservoirs	1,313
Total storage capacity, acre-feet	42,600,000

TABLE II.4 (Continued)

CALIFORNIA WATER RESOURCES

Number of major reservoirs	155
Total capacity, acre-feet	37,688,000
Historical average storage on October 1, 1990, acre-feet	22,497,000
Area of California, sq. mi.	158,295
Average renewable supply, acre-feet/year	78,600,000
Groundwater resources	
Number of wells	
Irrigation wells	67,770
Public supply wells	8,143
Community supply wells	3,320
Household wells	359,584
Total number of wells	438,817
Annual overdraft, acre-feet	2,000,000

Sources:
1. USGS 1984.
2. C-DWR 1991b.
3. C-DWR 1987, including updated information from C-DWR, Statewide Planning Office.

River. The Oregon streams provide an inflow of about 1.4 MAF, and imported water from the Colorado River contributes an additional supply of 4.8 MAF.

The North Coast is California's wettest region, but the abundance of distributable water has been curtailed by designation of wild and scenic rivers to protect their natural state. This category includes about 1,200 miles of streams contributing about 17.8 MAF of runoff. The wild and scenic category incorporate parts of the Klamath, Trinity, Eel, Smith, Van Duzen, Salmon, and Scott rivers (C-DWR 1987).

The state has jurisdiction over the safety of 1,188 dams and reservoirs with a total storage capacity of 19.7 MAF. In addition, there are 125 federal dams and reservoirs in and adjacent to the state of California with a gross storage capacity of 22.9 MAF. Altogether there are 1,313 state and federal dams and reservoirs that store about 43 MAF. Figure II.3 shows the location of the major storage reservoirs and aqueducts that are found in California (C-DWR 1987).

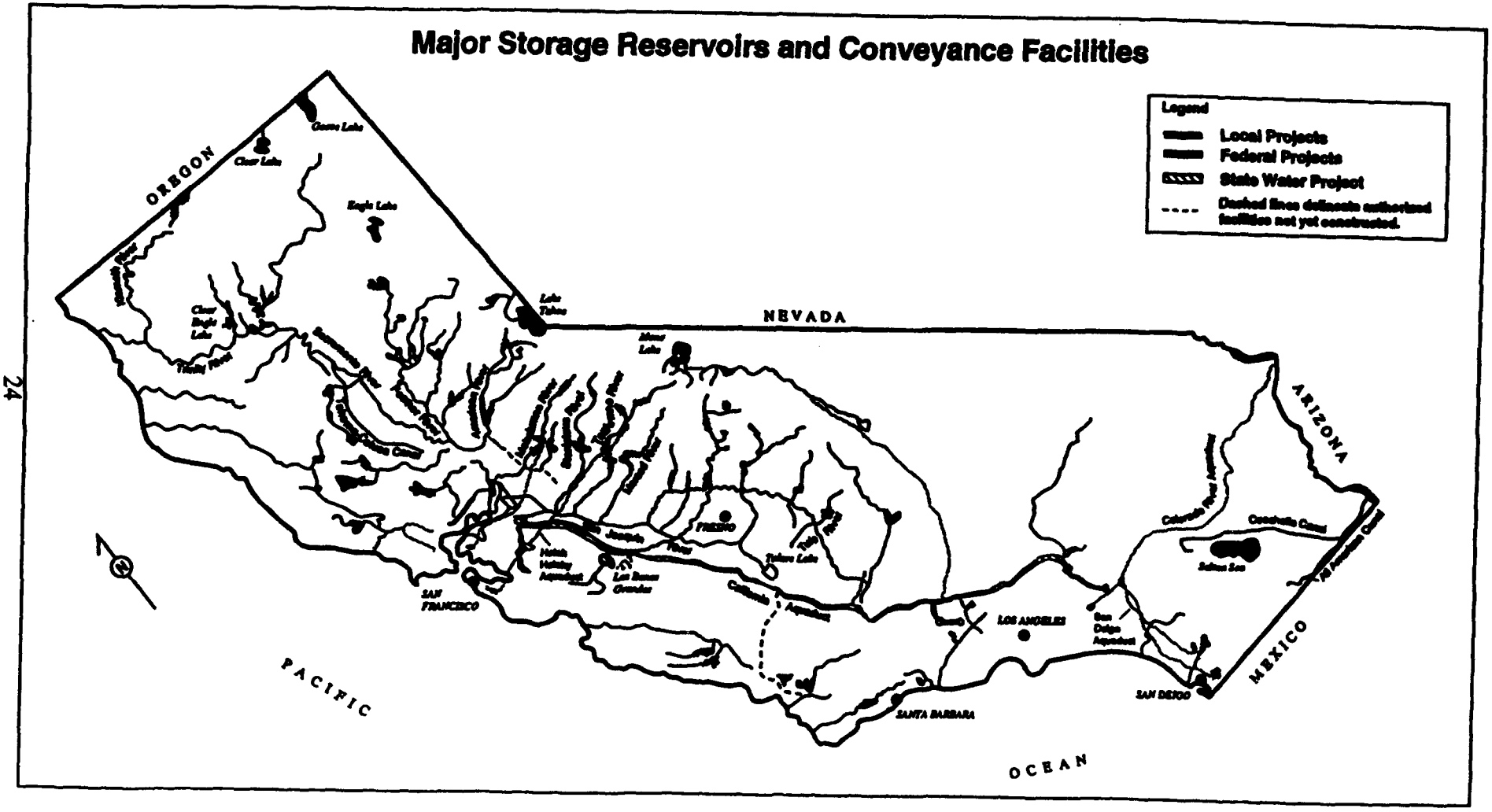

FIGURE II.3

MAJOR STORAGE RESERVOIRS AND CONVEYANCE FACILITIES

Source: C-DWR 1987.

Groundwater Resources

Major Groundwater Aquifers

Groundwater occurs primarily in unconsolidated sedimentary deposits that underlie much of the state's agricultural lands and large portions of the urban areas. California has abundant groundwater resources, and in absolute terms, these resources are much larger than the state's surface-water reservoirs. On a statewide basis, there are nearly 400 groundwater basins that store nearly 850 MAF (C-DWR 1987). However, much of the groundwater is not available for use because of factors such as economical extraction, high pumping lifts, usable storage capacity of good quality water, limited potential for annual natural recharge, and distribution limitations. In areas overlying usable groundwater basins, the basin characteristics, hydrology, and water quality must be examined to determine the amounts and qualities of groundwater that may be utilized.

Groundwater Storage and Safe Yield

Groundwater pumpage in California amounts to an average of 16.6 MAF on a yearly basis, accounting for about 39 percent of the state's applied water requirements for municipal, industrial, and agricultural uses (C-DWR 1987). Groundwater basins in the state range from hundreds to millions of acres in size. However, much less than half the groundwater in storage lies close enough to the earth's surface to be pumped economically. The usable groundwater reserves are estimated to be 250 MAF (C-DWR, personal communication 1992h).

Groundwater recharge plays a significant role in assuring the production of reliable good quality water from groundwater basins. Recharge occurs in various ways (C-DWR 1987) in the state and these include the following:

- An average of 5.8 MAF occurs through natural recharge from rainfall, snowmelt, and stream seepage.
- Annual return flows from agricultural, municipal, and industrial uses account for 7.4 MAF.
- Imported surface water of about 1.1 million MAF annually is used to recharge groundwater basins in the southern area of the state.
- Seepage water from unlined irrigation canals makes up about 300,000 acre-feet of additional annual recharge.

Artificial and natural recharge makes up about 14.6 MAF of total recharge, but it does not completely replace the 16.6 MAF volume of water pumped annually. Statewide groundwater pumping exceeds recharge by an average of 2.0 MAF annually. This condition is referred to as overdraft (or groundwater mining). However, the amount of groundwater extracted varies considerably from year to year. The ability to increase withdrawals from the groundwater basins during drought emergencies is California's most important drought management mechanism.

ENVIRONMENTAL RESOURCES

The drought impacted fisheries and aquatic resources. The chinook salmon emerge from eggs in the cold headwaters of a river and then move downstream to the saltwater conditions of the ocean, where they mature into 20- to 50-pound adults. At 3 to 4 years of age, they respond to instinct and return from the ocean, completing the trip upstream to spawn. This trip upstream by the chinook salmon is referred to as escapement. The numbers of troll salmon (chinook and coho) were about 1.06 million in 1979 and about 0.68 million in 1990. During these years, the catch value was $22 million and $12 million, respectively. Figure II.4 illustrates the annual salmon catch and catch value for the state from 1979 to 1990 (Pacific Fishery Management Council-PFMC 1991, Gleick and Nash 1991). The numbers of fish reveal a fluctuating trend, recording a low of 0.48 million in 1983 and a high of 1.56 million in 1988. The record catch of salmon during the 1979-90 period occurred in 1988, the second year of the drought. The fisherman were catching upward of three-quarters of all salmon in the ocean moving toward California streams.

The Sacramento-San Joaquin system has the major salmon runs in the state. A total of 120,000 fall-run chinook salmon returned to spawn in the Sacramento River basin in 1990. However, the salmon runs exhibit declining trends. The 1990 estimate of 26 percent was below the escapement averaged in the 1971-75 period (Gleick and Nash 1991). The escapement of fall chinook in the San Joaquin in 1990 was about 1,100 fish, and this represented only 8 percent of the 1971-75 average (Figure II.5).

In addition to the fall-run chinook, which represents the major salmon fishery in California, there are three other distinct runs of salmon: late fall, winter, and spring (Table II.5). All of these salmon runs have fluctuated and declined since 1987 (Gleick and Nash 1991). Since 1989, the winter run, which is already classified as a threatened species, has reached extremely low numbers and it may be near extinction.

San Francisco Bay, one of the world's largest estuaries, is vulnerable to "Delta outflow," i.e., reduced freshwater inflows from the Sacramento and San Joaquin Delta. The striped bass, an introduced species representing the principal sport fish in the estuary, has been a common indication of the Bay's ecological condition. The industries related to striped bass contribute about $45 million to local economies. Figure II.6 shows the fluctuations of the index in larval abundance from a high of about 110 in 1967 to about 80 in 1974, and to less than 10 during the 1976-77 drought. Besides the striped bass, the abundance of the Delta smelt in the San Francisco Bay Delta region has shown considerable decline since 1984, and this is closely correlated with the prevalence of reversed flows in the Delta (Gleick and Nash 1991).

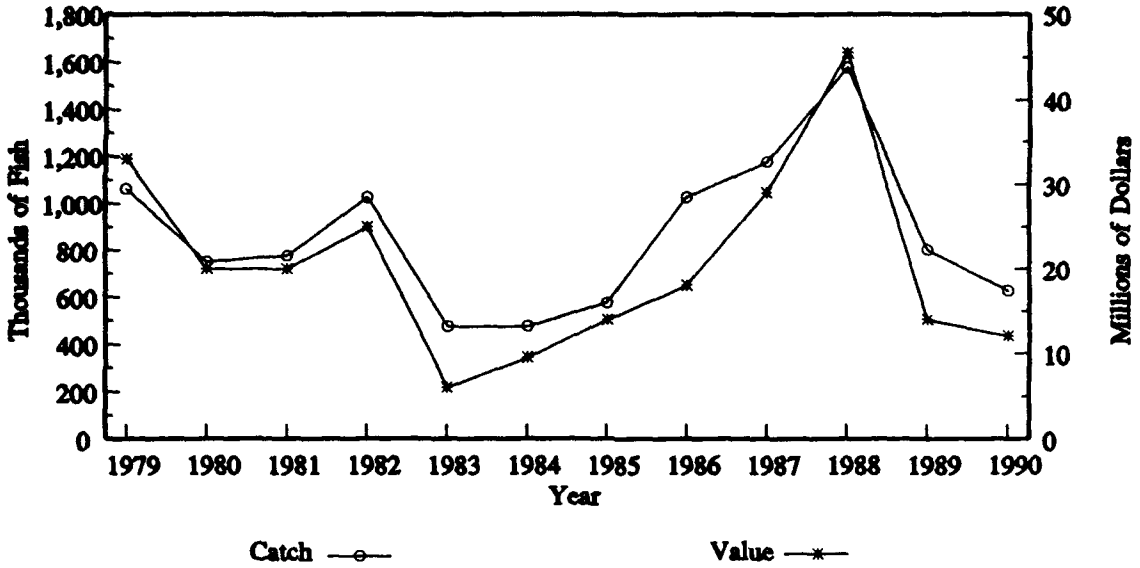

FIGURE II.4

TROLL SALMON (CHINOOK AND COHO) LANDED IN CALIFORNIA, 1979-1990

Note: Value is given in 1990 dollars.

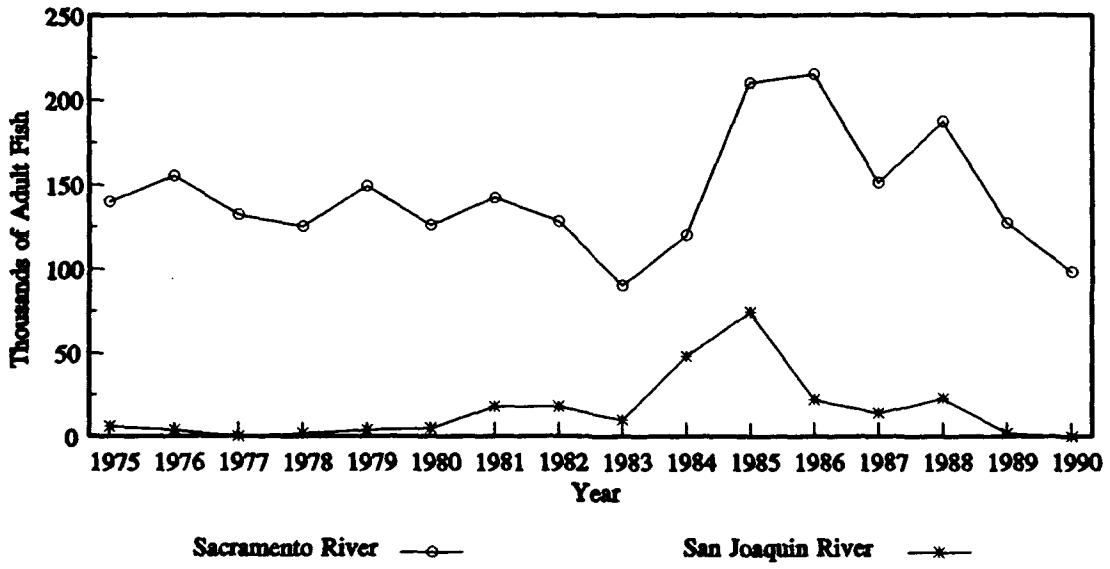

FIGURE II.5

CENTRAL VALLEY NATURAL FALL-RUN CHINOOK SALMON SPAWNING ESCAPEMENT, 1975-1990

Figures II.4 and II.5 sources: PFMC 1991, Gleick and Nash 1991.

TABLE II.5

SACRAMENTO RIVER LATE FALL, WINTER, AND SPRING CHINOOK SALMON SPAWNING ESCAPEMENT[a] ESTIMATES, 1981-1991 (Thousands of Fish)

Year	Late Fall	Winter	Spring[b]
1971-75 [c]	19.0	30.6	7.2
1976-80 [c]	11.2	15.4	11.7
1981	7.0	20.0	22.0
1982	4.9	1.2	27.4
1983	15.2	1.8	8.0
1984	10.4	2.6	9.4
1985	10.2	5.0	14.9
1986	7.0	2.3	17.2
1987	15.7	2.3	12.4
1988	16.6	2.1	16.7
1989	11.4	0.5	10.8
1990	8.4	0.5	8.3
1991	7.1	unknown	unknown

Notes: a Escapement refers to the number of fish that successfully complete the trip upstream to spawn.
b Spring-run totals include Feather River hatchery fish.
c 5-year average.
Sources: PFMC 1991, Gleick and Nash 1991.

The Central Valley of California also supports millions of wintering waterfowl. However, the bird populations have declined over the last decade. In 1980, long-term averages indicated that the wintering population was about 10 to 12 million,while the 1990 population was estimated at around 2 million (Gleick and Nash 1991). The state and national wildlife refuges that receive water from the SWP and CVP project supplies provide a major part of the wetlands for the waterfowl. The current average annual water deliveries (1975-85) to the refuge, which are designated as Level 2 condition of the wetlands, have been estimated at 380,000 acre-feet (Table II.6). For the current potential of the refuge to be fully used, an average annual supply of 493,000 acre-feet would be needed, and with full development of the refuges optimum management would required 526,200 acre-feet (Gleick and Nash 1991).

WATER USE

California's agricultural, urban, and other regional uses were approximately 40.5 million acre-feet (MAF) of freshwater in 1985 (Table II.7), two years before the current drought (C-DWR 1987). This amount represents water removed from the ground or diverted from surface-

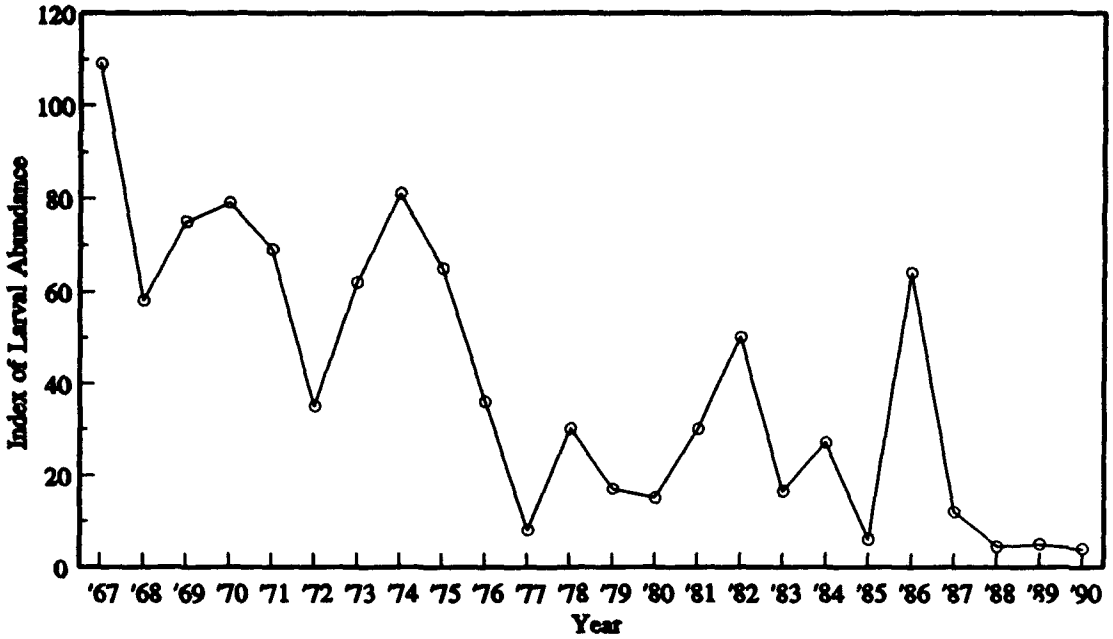

FIGURE II.6

SAN FRANCISCO BAY STRIPED BASS INDEX

Sources: SWRCB 1991, Gleick and Nash 1991.

water sources for public water supply, industry, irrigation, livestock, thermoelectric power generation, and other uses. Approximately 24 MAF (or 57 percent) of water withdrawn is not available for further use and is referred to as consumptive use. This portion of water is evaporated, transpired, incorporated into products or crops, or consumed by humans or livestock. Much of the difference between applied water and consumptive use is reused either as groundwater percolation or as surface drainage water (irrigation return flows).

Approximately 60 percent of freshwater use is supported by surface-water sources (i.e., reservoirs, lakes, and rivers). The other 40 percent is withdrawn from groundwater aquifers. The availability of groundwater and surface-water storage affords the state a fair degree of protection against droughts.

California accounts for the highest percent of total freshwater withdrawals in the nation, because the withdrawn water also serves the highest percent of the United States' population. In 1985, 10.9 percent of the United States' population lived in California, and the state used 11.1 percent of total freshwater withdrawals in the nation. These withdrawals were equivalent to 1,420 gallons of water per capita per day. The national average per capita use of freshwater was 1,400 gallons per day.

TABLE II.6

WATER SUPPLY NEEDS FOR WILDLIFE REFUGES IN THE CENTRAL VALLEY (In Acre-Feet)

Refuge	Level 1	Level 2	Level 3	Level 4
Modoc NWR	18,500	15,550	19,550	20,550
Sacramento NWR	0	46,400	50,000	50,000
Delevan NWR	0	20,950	25,000	30,000
Colusa NWR	0	25,000	25,000	25,000
Sutter NWR	0	23,500	30,000	30,000
Gray Lodge WMA	8,000	35,400	41,000	44,000
Total Sacramento Valley	**26,550**	**169,800**	**190,500**	**199,550**
Grassland RCD[a]	50,000	125,000	180,000	180,000
Volta WMA	10,000	10,000	13,000	16,000
Los Banos WMA	6,200	16,670	22,500	25,000
Kesterson NWR	35,000	3,500	10,000	10,000
San Luis NWR	0	13,350	19,000	19,000
Merced NWR	0	13,500	16,000	16,000
Mendota NWR	25,463 [b]	18,500	24,000	29,650
Pixley NWR	0	1,280	3,000	6,000
Kern	0	9,950	15,050	25,000
Total San Joaquin Valley	**95,163**	**211,750**	**302,550**	**326,650**
Total	**121,713**	**381,550**	**493,050**	**526,200**

Level 1: Existing firm water supply.
Level 2: Current average annual water delivers.
Level 3: Full use of existing development.
Level 4: Optimum management if refuge were fully developed.

(a) As of 1985, Grassland River Conservation District (RCD) no longer receives agricultural drainage flows due to water quality concerns.
(b) Only 18,500 acre-feet can be delivered to the Mendota Wildlife Management Area (WMA) without modifications of existing facilities.
Source: USBR 1989, Gleick and Nash 1991.

TABLE II.7

REGIONAL USE OF CALIFORNIA'S DEVELOPED WATER SUPPLIES, 1980, 1985, AND 2010 (In 1,000s of Acre-Feet)

APPLIED WATER

Regions	Agricultural 1980	Agricultural 1985	Agricultural 2010	Urban 1980	Urban 1985	Urban 2010	Other 1980	Other 1985	Other 2010	Totals 1980	Totals 1985	Totals 2010
San Francisco Bay and Central Coast	1,310	1,320	1,260	1,210	1,360	1,600	110	100	110	2,630	2,780	2,980
South Coast	990	900	650	2,780	3,120	4,020	30	20	30	3,800	4,040	4,700
Sacramento River	9,600	7,800	9,000	560	630	840	250	270	270	10,410	8,700	10,110
San Joaquin River and Tulare Lake	18,890	17,600	17,680	830	920	1,400	170	170	190	19,890	18,690	19,270
Colorado River	3,580	3,660	3,280	210	250	410	20	20	20	3,810	3,930	3,710
Remaining regions	1,750	1,630	1,620	270	310	440	280	380	400	2,300	2,320	2,460
STATE TOTALS	36,120	32,910	33,490	5,860	6,590	8,710	860	960	1,020	42,840	40,460	43,220
Percent of total	84.3	81.3	77.5	13.7	16.3	20.2	2.0	2.4	2.4	100	100	100

APPLIED WATER is the quantity of water delivered to the intake to a city's water system or a farm headgate; water diverted from a stream or pumped from underground sources, as in self-developed supplies; and water supplied to a wetland for wildlife. Because of the large amount of reuse that occurs, this term overstates the supply of water needed for a large region.

NET WATER USE

Regions	Agricultural 1980	Agricultural 1985	Agricultural 2010	Urban 1980	Urban 1985	Urban 2010	Other 1980	Other 1985	Other 2010	Totals 1980	Totals 1985	Totals 2010
San Francisco Bay and Central Coast	1,020	1,010	980	1,160	1,310	1,530	130	130	130	2,310	2,450	2,640
South Coast	790	750	570	2,510	2,820	3,590	210	190	200	3,510	3,760	4,360
Sacramento River	6,900	6,710	6,880	460	500	680	270	270	270	7,630	7,480	7,830
San Joaquin River and Tulare Lake	13,880	13,650	13,860	490	530	760	340	370	390	14,710	14,550	15,010
Colorado River	3,400	3,480	3,120	140	170	270	560	380	300	4,110	4,030	3,690
Remaining regions	1,350	1,350	1,340	220	260	360	320	340	390	1,890	1,950	2,090
STATE TOTALS	27,340	26,950	26,750	4,980	5,590	7,190	1,830	1,680	1,680	34,150	34,220	35,620
Percent of total	80.1	78.8	75.1	14.5	16.3	20.2	5.4	4.9	4.7	100	100	100

NET WATER USE is computed by adding evapotranspiration (the amount of water taken up by plants, transpired by them, and evaporated from the soil), the losses from a water distribution system that cannot be recovered, and outflow leaving an area. This estimate is essential in determining whether an area needs more water..

Source: C-DWR 1987.

While the statistics on freshwater withdrawals do not distinguish California from other states in the union, the statistics on consumptive water use do. The state accounts for almost 23 percent of total consumptive use in the nation, more than two times its share of population. This situation can be attributed to the nature of agricultural and manufacturing activities found in the state. Approximately 17 percent of all irrigated land in the United States is located in California, and the size of livestock in the state almost equals the livestock in Texas. Also, the state has a large food-processing industry. These factors and the desert climate of the major agricultural areas contribute to the high consumptive use of water.

Agricultural Water Use

Irrigation Use

According to the C-DWR, 1985 agricultural withdrawals amounted to 32.9 MAF and accounted for almost 81 percent of total freshwater withdrawals in the state (Table II.7). Approximately two-thirds of the withdrawals came from surface-water sources, with the balance obtained from groundwater. An additional 263,000 acre-feet of irrigation water were obtained by reclaiming wastewater (Solley et al. 1988).

According to the USGS 1985 estimates, the irrigation withdrawals (net of 1.04 MAF of conveyance losses) were applied on 9,580,000 acres of irrigated lands including farm and horticultural crops, as well as public and private golf courses. Irrigation water is primarily applied to land through flood irrigation (including flooding, furrow, and ditch methods). Approximately 80 percent of irrigated acres are flooded, and the remaining 20 percent are irrigated using center pivot, traveling gun, trickle, and drip irrigation methods.

In 1987, slightly more that 90 percent of 7,676,000 acres, representing total harvested cropland, were irrigated (U.S. Department of Commerce 1989). In 1982, the agricultural products from irrigated farms were valued at $10.3 billion, or 82 percent of all farm production. On average, 3 acre-feet of water are applied per acre of irrigated land (Bajwa, Crosswhite, and Hostetter 1987).

Livestock Use

Livestock use is sometimes referred to as agricultural nonirrigation use. Livestock water use includes multipurpose uses, including water for stock watering, feed lots, dairy operations, fish farming, and other on-farm needs. Livestock freshwater use in California totaled 201 million gallons per day (or 225,000 acre-feet per year). About 80 percent of the total applied use came from surface-water withdrawals and 20 percent from groundwater withdrawals. About 78 percent (176,000 acre-feet per year) of the total applied livestock water was consumptive use.

Urban Water Use

There are about 300 urban water agencies in California that were affected by the Urban Water Management Planning Act (Act), Section 10610 of division 6 of the Water Code. This act was known as Assembly Bill (AB) 797 and became effective on January 1, 1984. The 300 urban agencies that have to prepare and adopt an urban water management plan represent water suppliers providing water for municipal purposes to more than 3,000 customers, or supplying more than 3,000 acre-feet of water annually.

A recent survey by the C-DWR's District Offices summarized per capita water use for 129 of the 300 urban agencies from 1980 through 1990 (C-DWR 1992b). The analysis conducted through the survey indicates that most urban areas reduced their peak summer use during the drought years 1988 through 1990. The average annual statewide per capita water use for 1987 was 195 gallons per capita per day (GPCD), and this decreased to 191 GPCD for the 1988-90 period. Some of the reductions, however, were accompanied by increases in water use during the dry winters (C-DWR 1992b).

The magnitude of the state's projected urban growth will increase the need for additional water supplies. California's projected increase in population is estimated to increase urban applied water deliveries by 32 percent from 1985 to 2010 (Table II.7). The consumptive use or net urban water use is projected to increase by about 4 percent from 1985 to 2010. This increase is due largely to the state's coastal regions, where 80 percent of California's population lives. More specifically, net urban use is increasing in the warmer inland coastal areas. The projected increase in urban consumptive use is accompanied by the development of several significant trends aimed at reducing per capita water consumption. These trends (outlined in C-DWR 1987) include:

- Construction of more multiunit housing
- Reduction in residential lot sizes
- Increasing the number of residences built since mandatory low water use fixtures have been instituted
- Local agency water conservation programs including the influence of Best Management Practices (BMPs)
- Increased plantings of low water-using landscapes
- More efficient watering
- Increased recycling of industrial process water

Baseline unit urban demand is projected to increase 10 percent in the 1990-2020 period due to increased growth in the warmer, drier areas inland from the coast. However, the trends

outlined above should cause a downward shift of about 15 percent, so the net change in unit urban demand is projected to be about -5 percent.

This also reflects other factors:

- More parks
- More landscape greenery for highways and businesses
- Population shifts inward to hotter drier climates
- Smaller household sizes

SUMMARY

California's economy was worth more than $760 billion in 1992, and the three major contributors have been the services sector; the finance, insurance, and real estate sector; and the manufacturing sector. These sectors made up 58 percent of the California state product in 1989. Agriculture, forestry, and fishing accounted for about 2 1/2 percent of the state's GDP, but one dependent upon the availability and usability of more than three-fourths of California's delivered water resources.

California has abundant groundwater resources, and in absolute terms, these resources are much larger than the state's surface-water reservoirs. However, much of the groundwater is not available for use, and annual groundwater pumpage amounts to an average of 16.6 MAF. The state and federal dams and reservoirs store about 43 MAF. The 1985 net water use for agriculture accounted for 78.8 percent, urban use was 16.3 percent, and other uses accounted for 4.9 percent. The water use is based on 1985 conditions and will vary with changing assumptions across time.

With this underpinning knowledge of the California economy and water-using sectors, let us now move to a discussion of the management systems for the delivery and allocation of this water.

III. WATER MANAGEMENT SYSTEM

This chapter describes the existing water management system in California. It characterizes (1) the statewide balance of water supply and demand, and regional differences in supply availability, (2) the large-scale water development projects that serve to mitigate regional supply deficiencies, (3) the California system of water law, (4) the institutional structure of water management, and (5) the overall approach to managing the recurrent droughts in the state that existed prior to the 1987-92 drought.

SUPPLY-AND-DEMAND BALANCE

The atmospheric circulation patterns and the location of the major mountain chains of the Coast Ranges, southern Cascade Range, and Sierra Nevada produce very uneven spatial distribution of precipitation and runoff. The values of normal annual precipitation range from 3 inches in the desert areas of Southern California to 120 inches in the coastal mountains in the northwestern corner of the state. At the same time, the areas of highest precipitation and runoff are least populated and removed from the areas with irrigated agriculture. As a result, the northern half of the state is rich in renewable water supplies, while the southern half has to deal with a natural condition of water scarcity. In addition to the uneven spatial distribution of water surplus and deficit areas, there is a temporal disparity between the seasonal water needs for irrigated agriculture and seasonal precipitation. Precipitation is rare during the summer growing season. Most of the annual precipitation falls during the winter months of November through March, with much of that precipitation as snowfall in the higher elevations.

In order to alleviate the uneven temporal and spatial distribution of precipitation and runoff and the mismatch of water supply-and-demand areas, a complex water management system has been developed. Hundreds of reservoirs and extensive water conveyance systems have been built to compensate for the seasonal and year-to-year variation in runoff, as well as to move water to deficit areas. This supply system has developed in response to water needs of each local area and region and over the 140-year period since California was declared a state.

On average (or during years of normal precipitation and runoff), California can be viewed as a water surplus state. Average renewable statewide surface supply is 78.6 million acre-feet. This estimate includes 72.4 MAF of runoff generated within the state, 1.4 MAF from Oregon streams, and 4.8 MAF of imported water from the Colorado River. Total freshwater withdrawals are estimated at 40 MAF per year. They consist of 16 MAF of groundwater and 24 MAF of surface water. Groundwater withdrawals exceed natural and artificial recharge by about 2.0 MAF. This condition is referred to as groundwater overdraft. The consumptive use in the state is 24.0 MAF or approximately 30 percent of average renewable supply. However, statewide statistics may give a false impression of the availability of water supply for all regional areas within the state. Severe imbalances between the demand for water and the available supply can be found in various regions, especially in the densely populated southwestern corner of the

state. Because of these imbalances, California has developed an extensive plumbing system of intrastate water transfers illustrated in Figure III.1.

Widespread water development continues. However, the pace of development has slowed during the last two decades because of environmental concerns and other issues affecting water management. The following section describes the major water development projects that when taken together, constitute a major portion of the existing system of water supply and distribution in the state (and are referred by California water professionals as "developed water").

CALIFORNIA MAJOR WATER PROJECTS

A major portion of the state can be served by water obtained from two prime water suppliers who operate major storage reservoirs and aqueducts—State Water Project and Central Valley Project. The water distribution systems operated by SWP and CVP can reach more than 75 percent of the state's population (C-DWR 1987). Both projects export water from the Sacramento-San Joaquin Delta, which has become the focal point for a number of water-related issues. The complex network of the natural and man-made Delta channels is shown in Figure III.2. The Delta is a major hub for California water transfers and, because of the problems of saltwater flows, creates a bottleneck in the operations of SWP and CVP. Currently the pumping stations in the Delta are operated by releasing extra water to the Bay (called carriage water) in order to control reverse flows. Depending on the existing flow conditions, the amount of carriage water may reach a significant portion of water released for export during a period of drought.

According to Contra Costa Water District (CCWD 1992), limitations on CVP and SWP pumping are imposed by the SWRCB, which requires salinity and flow standards to be met by the projects. It has been assumed for about 30 years that there is a carriage water requirement, with carriage water being additional outflow required to maintain some salinity standards when exports cause net reverse flows. The C-DWR proposed the hypothesis in the early 1960s, but never tested its validity (CCWD 1992). The District maintains that the data of the last 20 years contradict the hypothesis and the carriage water model. In fact, the data suggest that outflow requirements to meet a standard decrease with increased pumping, not increase, the exact opposite of the assumptions. The CCWD maintains that C-DWR acknowledged that the District had "raised valid points." However, C-DWR's official position, i.e., carriage water is needed, remains unchanged.

In addition to the SWP and the CVP, there are four large regional projects—Colorado River, Hetch Hetchy, Mokelumne River, and Los Angeles aqueducts. In addition to the Colorado River aqueduct in the southeastern corner of the state, the Colorado River water is distributed by two federal aqueducts—Coachella Canal and All American Canal. A brief description of each major project is given below.

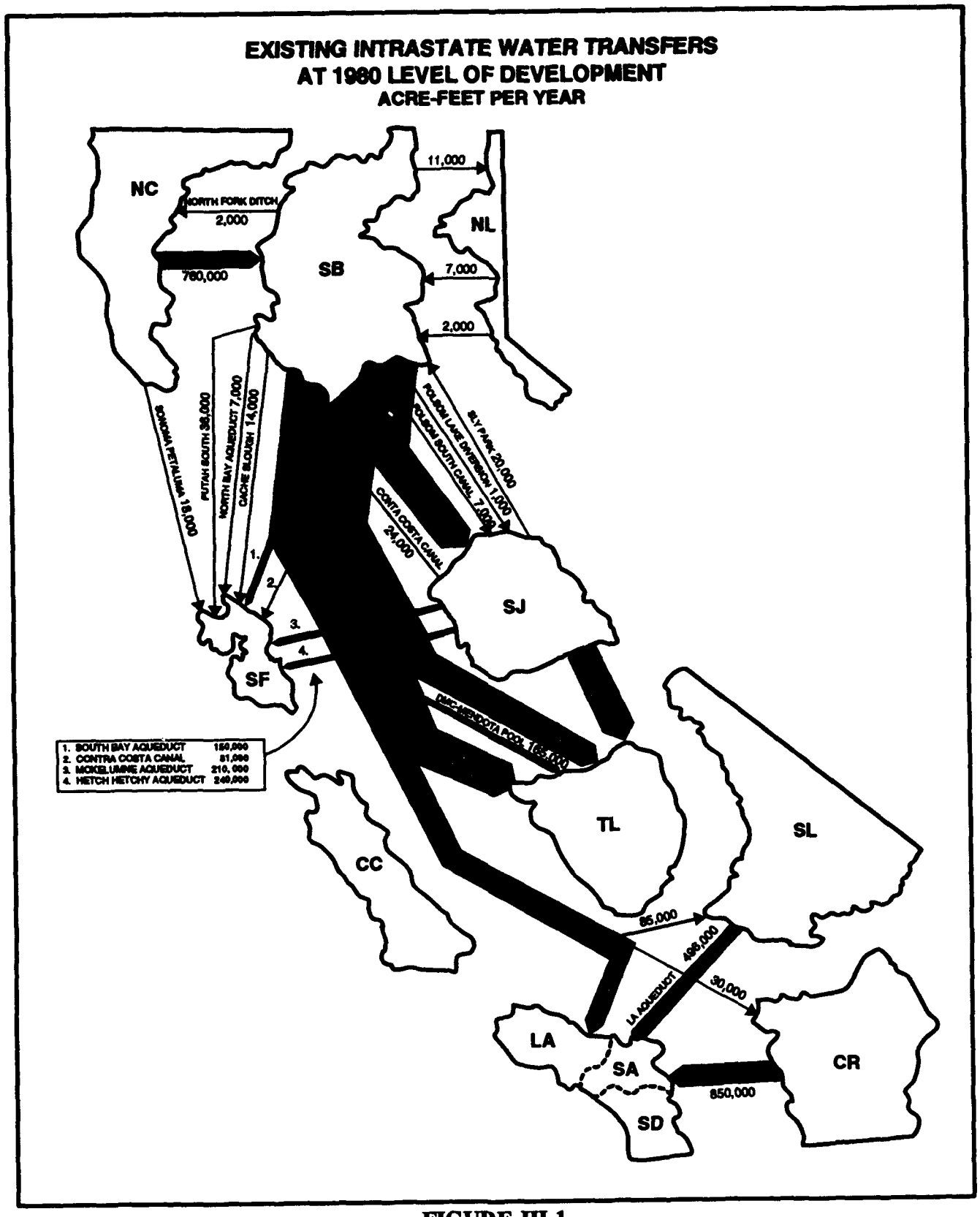

FIGURE III.1
EXISTING INTRASTATE WATER TRANSFERS
AT 1980 LEVEL OF DEVELOPMENT (Acre-Feet per Year)

Source: C-DWR 1983.

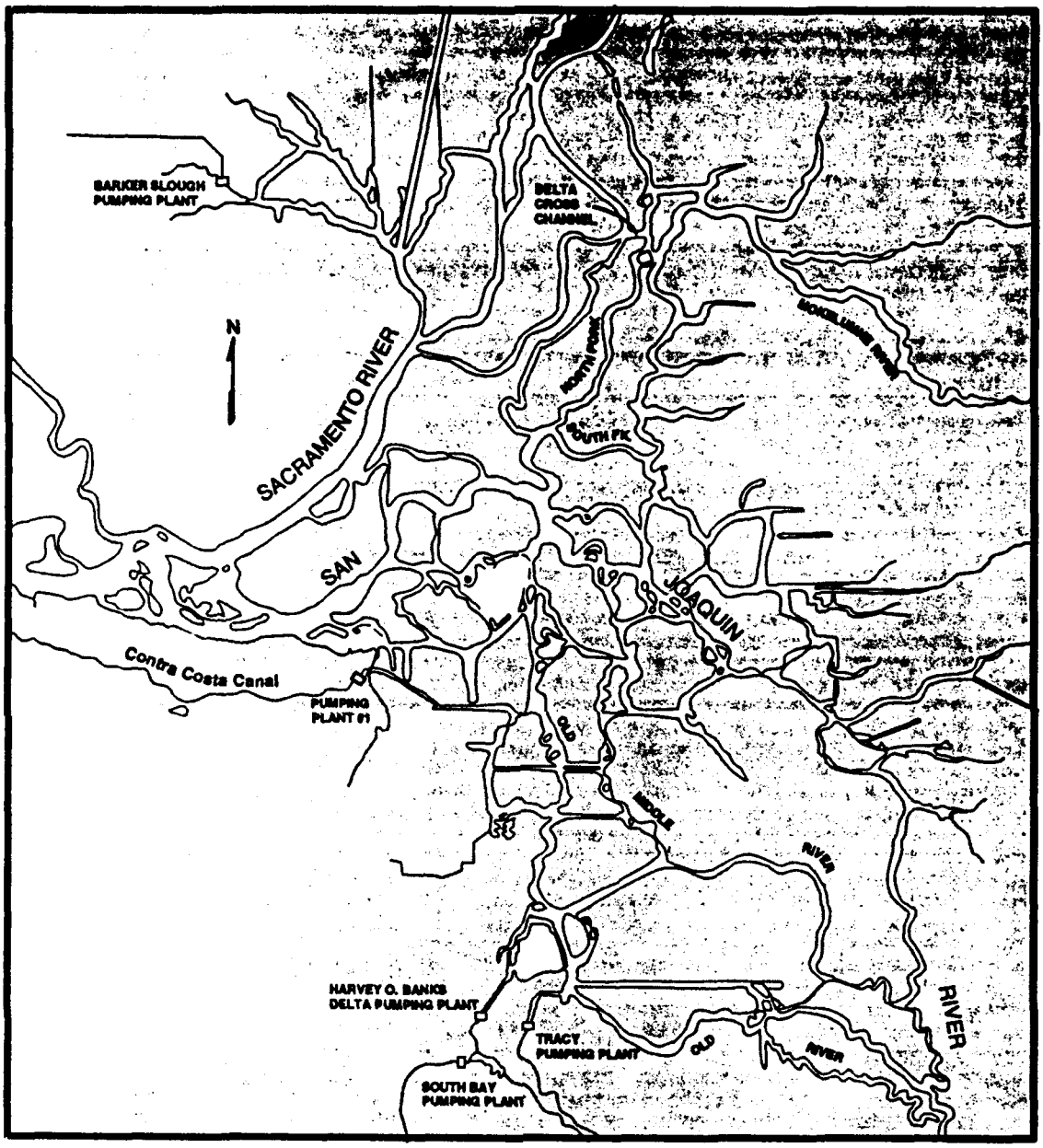

FIGURE III.2

NATURAL AND MAN-MADE DELTA CHANNELS

Source: C-DWR 1987.

State Water Project

The history of the State Water Project dates back to 1947, when the state legislature funded the water resource investigation that resulted in the publication of The California Water Plan. The plan laid a foundation for the design of waterworks for transferring surplus water from the north to the water-deficient south (C-DWR 1990). In 1959, the state legislature enacted the California Water Resources Development Act (known as the Burns-Potter Act) that authorized funding for the construction of SWP facilities. Initial facilities included two dams and reservoirs (Oroville and San Luis) and three aqueducts (South Bay Aqueduct, North Bay Aqueduct, and California Aqueduct). The first SWP water deliveries were made in 1962.

Currently the existing SWP facilities consist of 22 reservoirs including 2 built and operated in cooperation with the Central Valley Project. The total storage of the 20 SWP reservoirs is 5,279,000 acre-feet, with additional 1,062,000 acre-feet share of SWP in San Luis Reservoir and 29,600 acre-feet in O'Neill Forebay Reservoir. These reservoirs are connected with 445 miles of aqueducts served by 21 pumping plants with design flows ranging from 80 to 13,200 cubic feet per second (cfs) and an average annual energy demand of 12.4 billion kilowatt-hours (kwh), which constitutes the SWP share. The SWP facilities also include 13 power plants capable of producing 7.324 billion kwh of hydropower.

The SWP is managed by the California Department of Water Resources. In 1960, C-DWR and the Metropolitan Water District of Southern California signed the first water supply contract. Currently 30 agencies have long-term water supply contracts that call for water deliveries to eventually total 4.2 MAF. The current firm yield of SWP is estimated at 2.3 MAF. In 1990, the contractors' requests for water totaled about 3.2 MAF.

The service areas of the SWP long-term water supply contractors total 24.8 million acres, or 25 percent of the state's total area. Population of these areas totals 19.7 million persons, or 70 percent of the total state population. The SWP water is used primarily for urban and industrial purpose in all of the SWP service areas except for the San Joaquin and Feather River areas.

Central Valley Project

The federal Central Valley Project (CVP) was developed in order to transfer surplus water from the northern to the southern portion of the great Central Valley of California. Although the California legislature and the voters authorized the construction of CVP in 1933, federal authorization and financing were requested under the Rivers and Harbor Act of 1937, due to lack of funds. The U.S. Congress authorized the construction of the project by the Bureau of Reclamation (USBR) for the purpose of flood control, irrigation and domestic uses, and power generation on the San Joaquin and Sacramento Rivers. Subsequent reauthorization

of the project added recreation and fish and wildlife as project purposes. The export of water to the south began in 1940 after a partial completion of the 48-mile-long Contra Costa Canal.

Today the Central Valley Project includes twenty reservoirs with combined storage capacity of 13.6 MAF. Five reservoirs (i.e., Shasta Lake, Clair Engle Lake, Folsom Lake, San Luis, and New Melones) represent 92 percent of the total storage (approximately 12.5 MAF). San Luis and three smaller reservoirs (O'Neill, Los Banos, and Little Panoche) are operated by the state and used jointly with the SWP. The project water is distributed within the region by eight aqueducts with a combined length of 613 miles. The four longest aqueducts include Friant-Kern (151 mi.), Delta-Mendota (116 mi.), Tehama-Colusa (113 mi.), and San Luis (101 mi.).

CVP delivers about 7 MAF of water annually to some 300 water contractors. The long-range net yield of the CVP presently available for allocation to water users is about 7.8 MAF per year, assuming full use of water by present and potential water contractors (C-DWR 1987).

Colorado River Project

The Colorado River Aqueduct extends 242 miles from Lake Havasu to its terminal reservoir, Lake Mathews, near Riverside. The aqueduct and pumping plants were completed in 1941 by the Metropolitan Water District of Southern California. The facilities were expanded in 1961 to a capacity of about 1.2 MAF per year. Metropolitan's dependable supply from the Colorado River water is 550,000 acre-feet (entitlement amount).

Coachella and All American Canals

California's basic apportionment of Colorado River supplies is 4.4 MAF per year plus not more than half of any surplus water. The Colorado River Project waters are part of California's basic apportionment of Colorado River supplies. The major portion of this supply (almost 4 MAF) is delivered to the Imperial Valley and Coachella Valley by the Coachella and All American canals and to the Palo Verde Valley. These canals are operated by the U.S. Bureau of Reclamation. The four agricultural agencies that receive the Colorado River water include Imperial Irrigation District, Coachella Valley Water District, Palo Verde Irrigation District, and the Yuma District.

Los Angeles Aqueducts

The city of Los Angeles obtains a major portion of its water supply from the Owens Valley and Mono Basin through the Los Angeles aqueducts. The first aqueduct was completed in 1913 and extended from the city to Owens Valley. In 1940, this aqueduct was extended to Mono Basin. In 1970, a second barrel was added to the aqueduct.

The Los Angeles Aqueduct has historically supplied an average of about 450,000 acre-feet/year, of which 360,000 acre-feet/year were obtained from the Owens Valley and 90,000 acre-feet/year from the Mono Basin. Recently, the city's diversions from the Mono Basin have been reduced because of litigation.

East Bay MUD Project

In 1929, the East Bay Municipal Utility District built the 90-mile Mokelumne Aqueduct in order to import water from the Pardee Reservoir on the Mokelumne River. In 1963, another reservoir, Comanche, was built. The combined storage of these two reservoirs is 640,000 acre-feet.

The San Francisco Hetch Hetchy Project

In 1934, the city and county of San Francisco completed the construction of a 152-mile-long Hetch Hetchy Aqueduct in order to import water from the Hetch Hetchy reservoir. The Hetch Hetchy reservoir, which lies within Yosemite National Park on the western slope of the Sierra, about 170 miles east of San Francisco, has a capacity of 360,400 acre-feet. In 1956, a second reservoir, Lake Lloyd (Cherry Valley), was added. The combined storage capacity of all San Francisco reservoirs is approximately 880,000 acre-feet.

CALIFORNIA SYSTEM OF WATER LAW

There are two major tenets of water law in California. First, water within the state is "the property of the people of California [i.e., the state] and the people of California have an interest in its use." Second, individuals can obtain "a right to the use of that water," but that right is limited by what is "reasonable and beneficial." The guiding water law regime in the state recognizes both riparian and prior appropriation water rights and is referred to as a "dual" system. In addition to the riparian and appropriative rights to surface water, historic pueblo rights and unique groundwater doctrines also exist.

Surface-Water Laws

The adoption of the prior appropriation system dates back to the 1849 gold rush that brought about judicial protection of the "first in time, first in right" customary use of water in mining operations. After California acquired statehood in 1850, the California Supreme Court decided that both riparian and appropriative rights were to be recognized. Today, California remains the only western state to permit the initiation of new riparian uses.

Riparian Rights

The riparian rights in California are subject to several limitations. The riparian parcel of land must be contiguous at some point to the stream in which the right is claimed. Water may be used only on the portion of the riparian parcel that is within the watershed of the stream. If a portion of the riparian parcel is severed from contiguity, it loses its riparian right unless such a right is expressly reserved. Finally, the right does not extend to seasonal storage of water on the riparian land.

Riparian rights are not quantified in terms of the amount of water that can be diverted. However, they designate only the amount of water that can be reasonably and beneficially used on the riparian parcel without imposing on other riparian rights on the watercourse. Transfer of riparian rights occurs only through the conveyance of the riparian parcel. A transfer of right for use on nonriparian land can be permitted only if it harms no other riparian rights holder or is approved by the other holders.

Appropriative Rights

Prior appropriation rights were recognized by the courts as early as the mid-1850s but were not administered by the state until 1914. The Water Commission Act of 1913 required all new appropriations to make application to, and be approved by, a state agency (now the State Water Resources Control Board [SWRCB]). Currently the permit system is the only mechanism for acquiring a new nonriparian water right in California. The SWRCB, prior to granting an appropriative permit, must investigate existing water rights, conduct a public hearing, and issue a finding that unappropriated water is available. All existing riparian uses in a watercourse must be satisfied before appropriators may take water. Upon issuing the permit, water must be put into beneficial use before the right is perfected and a license for use is granted. Once perfected, water right carries a priority dating back to the time of permit application. Water rights carrying senior priority dates must be satisfied even if this requires the suspension of uses by junior rights holders. Domestic use does carry a statutory preference, but this applies primarily to competing applications for unappropriated water rather than to existing appropriative rights. Appropriative surface-water rights are transferrable, but changes in the type of use, place of use, and point of diversion must be approved by the SWRCB.

Pueblo Rights

A small number of communities founded under Spanish laws hold pueblo water rights that are based on the needs of a community to serve its inhabitants. Today's water rights priorities for the cities of Los Angeles and San Diego have pueblo rights that have been recognized by the California Supreme Court (Layperson's Guide to Water Rights Law 1986). The pueblo rights may be considered to expand with the growth of the municipality and are

senior to all riparian and appropriative rights. They are not transferrable and are not subject to loss through nonuse.

In-stream Water Rights

Historically, the development of water rights in the United States was focused more on providing water for human needs, industry, and agriculture than on protecting in-stream uses such as navigation, hydropower, fish and wildlife habitat, and recreation. An increasing environmental awareness brought about greater attention to in-stream flow values. In the western United States, 16 of the 18 states have a specific in-stream-flow water law, or the state law has been interpreted to include in-stream water rights (Wright 1986).

In California, flow for in-stream beneficial use may be provided by water right permit conditions, protected rivers authorizing legislation for water projects, project operation, or application of the public trust doctrine. In determining the amount of water available for appropriation, the SWRCB refers the application for a permit to the Department of Fish and Game for recommendation regarding the amount of water that may be required for the preservation and enhancement of fish and wildlife. The SWRCB is also required to take into account the water required for recreation. In addition, California adopted a Wild and Scenic Rivers Act that identified and closed natural rivers in Northern California to all or some types of water appropriations.

Also, many of the federal and state water projects in California are required to provide, in addition to other water uses, in-stream flows for navigation, water quality maintenance, hydropower, fish and wildlife management, recreation, and protection of endangered species. Another method of protecting in-stream uses in California is through the operation of water storage projects to provide the desired in-stream flows.

Finally, protection of in-stream flows in the state can be achieved by the application of public trust doctrine. This doctrine rests on the premise that each state owns certain property that it holds in trust for public uses. The public trust doctrine has been invoked in a recent Mono Lake case. The California Supreme Court directed the city of Los Angeles to reduce its diversions from tributaries to Mono Lake in order to prevent extensive environmental damage to the lake.

Groundwater Rights

Groundwater in California is not subject to administrative allocation by the SWRCB. Groundwater rights are defined by the "correlative rights doctrine" under which owners of land overlying a groundwater basin are to share the water in common for reasonable beneficial use upon the overlying lands. When the availability of groundwater becomes limited, the reductions in use are shared proportionately by all.

Groundwater may not be exported outside of the basin unless there is surplus water. If nonoverlying users continue their withdrawals after the overdraft begins, those uses may acquire prescriptive rights against the existing correlative rights.

California legislature has adopted very few statutes affecting groundwater rights. This is an unusual situation in western states water law. Only Texas is similar in this regard. The existing laws (as described below) have been developed by the courts. In dealing with depleted basins in Southern California, the courts developed a doctrine of "mutual prescription" under which the water users are given a share of the "safe yield" of the basin. Usually the rights were prorated on the basis of the use of water during the five years prior to adjudication.

In 1975, the California Supreme Court overturned the "mutual prescription" doctrine and held that prescriptive rights do not apply against public entities. Under the court rulings, the operators of major water projects can spread and have a prior right to recapture imported water in basins with empty storage exceeding the present uses. Figure III.3 depicts the existing rights to groundwater in full and overdrawn basins in California. Currently total withdrawals are limited to amounts that will not adversely affect the basin (i.e., permanent damage or adverse effects on the basins's long-term supply).

Administration of Water Rights

Before 1914 appropriators secured their water rights by taking and using the water or by posting a notice at the point of diversion and filing a copy of the notice with the county recorder. After 1914 the state established a permit system to administer appropriations of surface water. Permits for post-1914 appropriative rights are now under the jurisdiction of the State Water Resources Control Board.

The SWRCB was created by the state legislative in 1967 and was given the authority to allocate surface-water rights and regulate water quality control. The board is composed of five full-time appointees of the Governor supported by a staff.

STATUTORY LAWS AND OTHER LEGAL INSTRUMENTS

In addition to the common-law principles of riparianism and prior appropriation, the development and use of water in California is governed by (1) constitutional provisions, (2) statutes approved by the state legislature or the Congress, (3) statutes approved by the state legislature and then approved by the people, (4) judicial decisions in both state and federal courts, and (5) contracts and agreements between water management organizations. Appendix A contains an extensive list of significant water policy legislation, litigation and agreements and drought legislation since 1991. Brief descriptions of state and federal laws and regulations are given below.

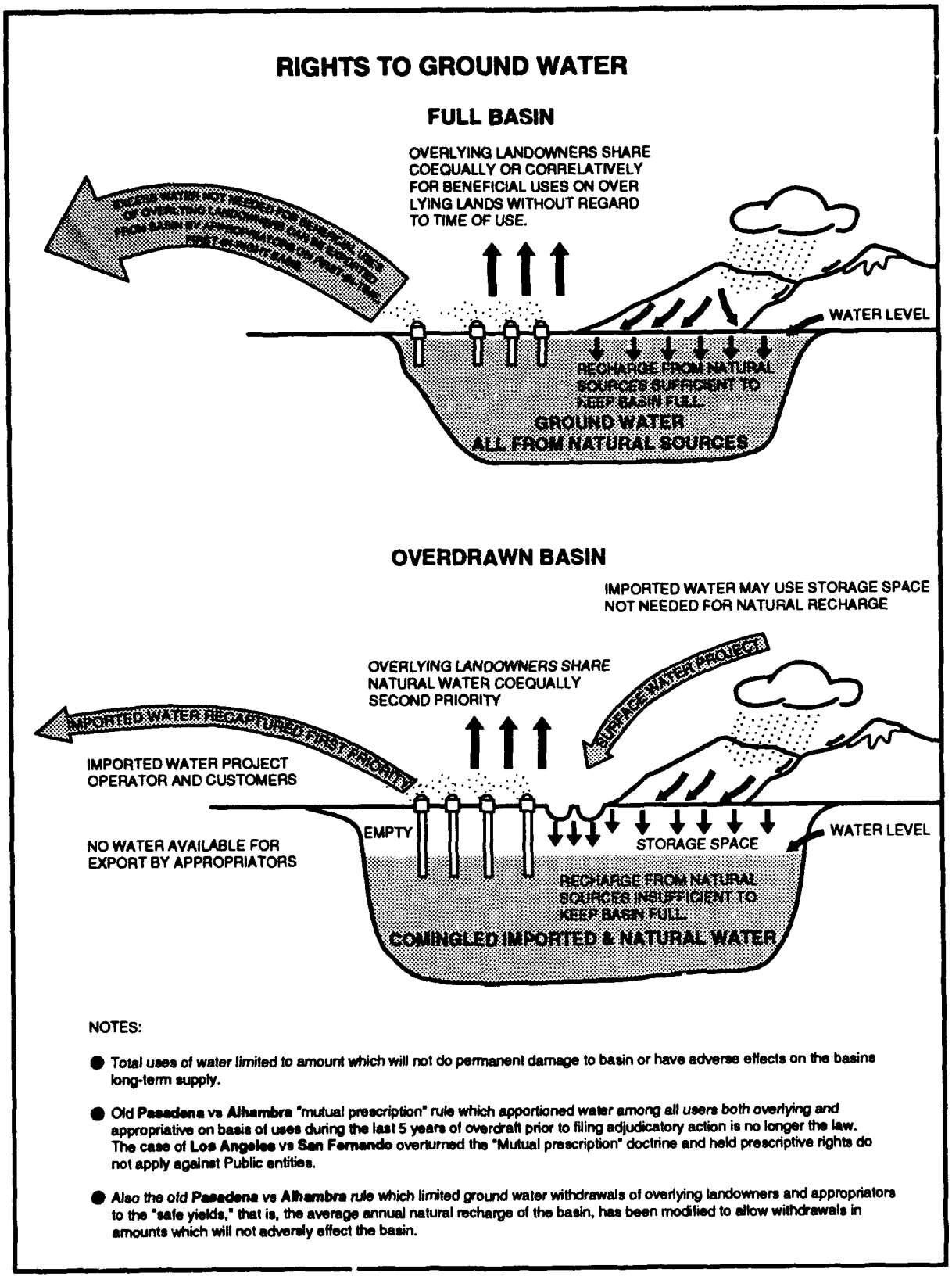

FIGURE III.3

RIGHTS TO GROUNDWATER IN CALIFORNIA

Source: C-DWR 1975.

Constitutional Provisions

A 1928 amendment to the California State Constitution was adopted to limit the amount of water controlled by riparian rights holders. It included the requirement of reasonable and beneficial use of water which is not typically a part of common-law riparianism.

State Water Policy Legislation

A number of state laws have been enacted to enhance water management in the areas of water conservation, water transfers, groundwater protection and water quality, and safe drinking water.

Water Conservation. The basis of California statutes regarding water conservation is that water should be put to reasonable and beneficial use. Article X, Section 2, of the California Constitution in 1928 aimed at preventing the waste of water and promoting conservation. The conservation programs instituted during the 1976-77 drought revealed the significant amount of water savings achieved by the people of California. This cutback in water use led to an upsurge of local and state conservation programs during the 1980s. Executive Order B-62-80 of February 1980 emphasized the implementation of water conservation practices among all state agencies, departments, boards, and commissions. Executive Order B-68-80 of July 1980 required the C-DWR to take specific steps to ensure that conservation was high priority in the management of SWP. Additionally, C-DWR was to recycle agricultural and brackish water. The SWRCB was also urged to request water conservation plans when authorizing water rights. Water conservation in the private sector was promoted by Public Utilities Code Section 761 and 770. This law gave the California Public Utilities Commission (PUC) the authority to ensure that water conservation was practiced among private utilities regulated by the PUC. Assembly Bill 797 (AB 797), the Urban Water Management Planning Act of 1983 required all urban water suppliers, serving more than 3,000 customers or supplying more than 3,000 acre-feet/year, to design water management plans and submit them to C-DWR. Similarly, agricultural water suppliers were expected to prepare water management plans through Assembly Bill 1658 (AB 1658).

Water Transfers. Water transfers assisted the state in coping with the 1976-77 drought and this marketing and sharing process was expanded after the drought. During the period 1980-86, six laws were enacted to promote water transfers. Water transfer legislation was designed to:

- Encourage voluntary transfers.
- Allow water agencies to transfer their surplus water.

- Facilitate the use of unused conveyance capacity by public agencies.

- Generally allow for greater flexibility in effecting transfers.

Groundwater Protection and Water Quality. Generally, groundwater is controlled by overlying pumpers who mainly represent local government agencies (C-DWR 1987). Senate Bill 187 (SB 187) was enacted in 1985, authorizing C-DWR to include feasible groundwater projects as features of the State Water Project. AB 2668 and AB 3127, legislated in 1986, applied existing provisions pertaining to well construction standards and reporting requirements to monitoring wells. These laws were also designed to improve groundwater quality by ensuring the protection of groundwater aquifers from contamination. Water quality gained even greater prominence in the state since the 1960s, and the Water Quality Control Act of 1969 authorized the state to regulate the quality of surface- and groundwater reserves. Additionally, a number of state laws have been passed to deal with groundwater problems and groundwater protection. For example, the Water Conservation and Water Quality Bond Law of 1986 authorized financial assistance for water conservation, groundwater recharge, and agricultural drainage management.

Other State Legislation

The 1980s have also witnessed the enactment of other state legislation and these included:

- AB 3792 of 1984 dealing with off-stream storage, authorizing as part of the SWP, the construction of Los Banos Grandes Reservoir, south of the Delta

- Four laws enacted from 1984 to 1986 aimed at the protection and enhancement of fish and wildlife

- Legislation aimed at ensuring the protection and maintenance of Delta levees

Federal Legislation

The federal government's Clean Water Act was passed in 1972, providing capital to control pollution mainly through the construction of municipal and industrial sewage treatment facilities. The Clean Water Act proved to be the forerunner of a number of federal and state laws to deal with the issue of water quality. Problems and issues included (C-DWR 1987):

- Land disposal
- Groundwater protection
- Underground storage tanks
- Solid waste management
- Agricultural chemicals and pesticides
- Hazardous and toxic wastes

Environmental protection has been the focus of most federal legislation since the 1980s. Public Law 98-541 (PL 98-541) and PL 99-552 were designed to maintain fish and wildlife in the Trinity and Klamath River basins, respectively. Previously referred to as H.R. 429, Public Law 102-575, Title 34-Central Valley Project Improvement Act (October 1992), was introduced to protect, restore, and enhance fish, wildlife, and associated habitats in Central Valley and Trinity River basins of California. The law also addresses the impacts of the CVP on fish, wildlife, and associated habitats.

Judicial Decisions

Water management in California is also significantly affected by the major court decisions pertaining to the state and federal authority over water projects, environmental protection, and the authority of the SWRCB.

United States Supreme Court Cases

The 1978 litigation, California v. United States strengthened the state's water rights appropriation process and increased the authority of SWRCB over water rights matters. The 1978 case of United States v. New Mexico, applied state law to determine the acquisition of water for primary and secondary purposes.

California Cases

The 1986 cases, Imperial Irrigation District v. SWRCB and United States v. SWRCB confirmed the authority of the SWRCB to impose conditions on federal projects, to protect public trust values wherever feasible, and to apply its discretionary powers over water rights and water quality issues. The state's responsibility for its navigable waters was affirmed in the 1983 case of National Audubon Society v. Superior Court. The state, under the supervision of the SWRCB, was to ensure protection of public trust values such as navigation, fisheries, and environmental values.

Agreements

The Joint Exercise of Powers Act enables agencies to enter into agreements aimed at improved management of water resources in the state. Several such agreements are described below.

The Coordinated Operation Agreement

In 1986, the California Department of Water Resources and the U.S. Bureau of Reclamation signed the Coordinated Operation Agreement (COA) for coordinating operation of the Central Valley Project and the State Water Project to ensure that each project shares equitably in the obligation to limit exports to meet Delta water quality standards (under controlled flow conditions).

Suisun Marsh Preservation Agreement

The Suisun Marsh covers 55,000 acres of wetland area in the Central Valley and provides a feeding and resting area for wintering waterfowl along the Pacific Flyway. Reduction in Delta outflows affected the viability of the marsh, and this led the SWRCB in 1978 to impose water rights Decision 1485 requiring the USBR and C-DWR to establish a plan to protect the marsh. The C-DWR developed the plan, and in 1981 initial facilities were completed. The Suisun Marsh Preservation Agreement of 1987 involved four agencies: C-DWR, USBR, the Department of Fish and Game (DFG), and the Suisun Resource Conservation District. The agreement was designed to protect the water quality in the marsh by moderating the effects of future upstream diversion and construction of proposed facilities. These facilities are beneficial to the nontidal portions of Suisun Marsh (about 80 percent), but they do not afford the same protection to the tidal marshes.

Fish Protection Agreement

The Delta Pumping Plant, at the head of the California Aqueduct, had initially installed seven of its eleven pumping units. The intended installation of the four additional units in the 1980s led to negotiations between C-DWR and DFG concerning the preservation of fish affected by the operation of the Delta pumps. The Fish Protection Agreement was signed by these two departments in December 1986 in order to ensure the protection of fisheries from adverse impacts of the SWP. The agreement requires the calculation of direct annual fishery losses, and the C-DWR is responsible to pay for mitigation projects that would compensate for the losses. Initial actions will be directed at offsetting losses of striped bass, chinook salmon, and steelhead. Mitigation of losses impacted on other species will be handled later. C-DWR will also begin a restoration program to stabilize fishery levels to what they would have been, had the Delta Pumping Plant not been in operation.

PREVIOUS DROUGHT EXPERIENCE IN CALIFORNIA

Lessons of the 1976-1977 Drought

As stated in Chapter I, there is no formal statewide drought plan in California. Accordingly, this study was not designed to track the performance of a specific drought plan during the 1987-92 drought. If a preexisting plan was available, then the structure of the study would have been different. It would have been scientifically most feasible to first identify the elements of the drought plan prior to the onset of the 1987-92 drought; thereafter, look at the actions taken during the drought; and finally examine these actions in light of the plan in order to determine the lessons learned. However, this evaluation was not possible, since there was no written and comprehensive statewide plan developed, nor was there a plan on hand at the beginning of this drought. Additionally, there was no documentation of expected actions of controllers and influencers prior to the onset of the current drought. Therefore, we first defined a general drought strategy from historical records of actions taken during and following the 1976-77 drought. Second, we qualified those actions as being unannounced ingredients of a plan. Third, through the interview process, we compared what actually happened during the drought with what was perceived by controllers and influencers in California.

The lessons learned during the 1976-77 drought had a significant influence on the overall approach to managing droughts in California. Therefore it is important to remember these lessons and contrast them with drought response actions of the 1987-92 drought. The following is a list of lessons learned as presented in two sources: (1) a memorandum to the Secretary of the California Resource Agency dated September 8, 1977, and (2) the C-DWR Bulletin "The 1976-77 California Drought: A Review" published in May 1978.

Lessons of the 1976-1977 Drought by C-DWR Drought Group

The Drought Group prepared a memorandum on September 8, 1977, to answer two questions asked by the Director of the Department of Water Resources: (1) What have we learned from this drought? and (2) What should we do differently on the basis of what we have learned so far? The following ten lessons were identified.

- There is a considerable waste of water during normal water years.
- Freshwater is a more limited resource than many people had realized before the drought.
- Water agencies, farmers, and people in general have not prepared advance contingency plans for a drought as severe as the 1976-77 drought.

- In a drought, urban residents will generally conserve water voluntarily, without mandatory rationing, if they perceive a legitimate need. Mandatory rationing with fines serves best to impress the public with the seriousness of the situation.

- Industrial use also can be reduced but probably not as much as urban use. Many industries are capable of taking cuts up to 25 percent without substantial economic loss.

- Farmers can get by on somewhat less water, but not to the same degree (in terms of percentages) as urban users.

- Farmers tend to use total available water supply in a given year rather than cut back to save water in case the following year is dry.

- In a dry year, more water is generally needed and would be used if available. The patterns of water use also change as more water than normal is used earlier in the year to make up for lower-than-normal soil moisture and because of higher air temperatures.

- Although the carry-over surface-water storage helped in maintaining the economy and domestic uses during the drought, it was primarily the state's vast groundwater resources that have prevented 1977 from becoming a disaster. The pumpage of groundwater basins in 1977 was about 25 MAF, and this exceeded natural recharge by 10-11 MAF.

- There is always a possibility of a severe drought. To be prepared, water systems should be capable of being put into full operation, despite the fact that full capacity operations are almost never required under normal conditions because of redundancies in design.

The last lesson pertains to the operation of the Colorado River Aqueduct. On March 1, 1977, Metropolitan Water District turned on all nine pumps at each of its five pumping plants on the aqueduct to maximize th[illegible]ortation of Colorado River water into the state. All 45 pumps went into operation on a [illegible]ur day, 7-day per week schedule, with no backup pumps available. As a result, 320,000 acre-feet of Metropolitan's entitlement water from SWP were released for use in the northern and central portions of the state that had no alternate sources of supply.

In recommendations stemming from the 1976-77 drought that pertained to the "things to be done," the Drought Group emphasized (1) the need for preparing drought contingency plans both by the state and all local water supply agencies, (2) promotion of water conservation, (3) high priority for conjunctive use of surface and groundwater storage and groundwater recharge, and (4) reevaluation of California water law, particularly groundwater law to take into account the unique water needs that are encountered in a drought.

Lessons of the 1976-1977 Drought by C-DWR Drought Review

In its fifth and final report on the 1976-77 California drought, the Department of Water Resources discussed lessons learned from the drought and suggested future actions for improved water management in the state. The following is an abbreviated listing of the lessons learned section of this report ("The 1976-1977 California Drought: A Review," pp. 167-75).

- An extreme variation in year-to-year annual precipitation is possible, giving the state no guarantees that any of the next several years will not be dry.

- Runoff in California rivers also has an extreme year-to-year variation with no apparent weather cycles.

- An important role of the Department is to educate the public and provide information useful in making more beneficial use of the water resource.

- The social and economic impacts of a repeat of the 1976-77 drought can be minimized so as to create even less strain than in 1977. There is a substantial advantage in spreading out the urban impacts of drought over two years. The urban problems encountered in 1977, including the rationing and its adverse consequences, were a direct result of starting urban water conservation too late.

- Some water conservation in urban areas persists beyond the end of the critical period, thus forcing some agencies to increase water rates and leading some water district officials to believe that during the drought urban dwellers have learned how to conserve water and will continue to do it.

- The experience of 1977 clearly showed that Californians can carry on nearly all domestic activities, with little more than a minor crimp in lifestyles, with a rather substantial reduction in water consumption. Few people really suffered from water shortage; they changed habits to "waste" less.

- Urban conservation in 1977 achieved an estimated one-year reduction in water usage of 1 MAF (or approximately 3 percent of 32 MAF used annually in the state prior to the drought and about 20 percent of urban water use statewide).

- Urban areas are able to reduce water consumption more readily than agricultural users and should be expected to do so. The existing contract priorities that require agriculture to take the first and largest deficiencies seem to be backward. The drought has shown that the reverse is easier and less disruptive economically.

- California agriculture has demonstrated its ability to take shortages by changing cropping patterns, using the more efficient drip and sprinkler irrigation techniques, and reusing tail water supplies.

- The ability to interconnect urban and agricultural water systems is necessary because it allows the ready exchange of water from areas of surplus to areas of need.

- Farmers and urban users were willing to pay more for water during the drought. Farmers who normally pay $7 to $25 per acre-foot paid from $40 to $80 per acre-foot (three to five times more). Urban users who normally pay $40 to $150 per acre-foot paid from $50 to $375 per acre-foot (two times or more higher).

- The drought allowed the SWRCB to "fine tune" the standards for water quality in the Sacramento-San Joaquin Delta during extremely dry years. During 1977, C-DWR and the USBR were unable to provide normal minimum releases from the upstream storage for purposes of maintaining Delta water quality.

- The drought demonstrated the need for cooperation among various users in the Delta, as well as upstream users in order to maintain water quality standards in order to protect existing water rights, anadromous fish, wildlife, and the productivity of the bay. During the drought, the actions of each users, in many cases, adversely affected the other users.

- Conventional hydrologic techniques for predicting water supply were inadequate. Because of the extreme dryness of the ground, much of the precipitation during the drought percolated directly into the ground, thus reducing expected river flows. Water from the rivers flowed to the lowered groundwater tables, reducing still further the expected surface-water supply. Also, agricultural water demand began earlier in the year and increased during drought because natural rainfall did not "preirrigate" the fields.

- The drought has shown that operational techniques and criteria long used by major water projects do not work well enough in a major drought. For example, SWP delivered too much surplus water in 1976 instead of maintaining higher carry-over storage for 1977. The CVP forced low-quality water upon one of its major urban customers. Other multipurpose projects made large releases for power generation at the expense of other uses.

- Federal drought response efforts were too slow, inflexible, and lacking communication with the public. Because of the delayed response, what might have become "mitigation measures" actually became "relief efforts."

- The drought and the growth of California showed that additional water supplies must be found so that a recurrence of the natural drought cycles does not find the state unprepared.

Several conclusions (i.e., lessons) from the experience of 1976-77 drought call for additional elaboration. First, water managers kept hoping that the drought-induced conservation behavior of water users would continue into the future. By 1980, water use did return to normal predrought levels. Second, urban users who responded so well to drought by conserving almost

20 percent of water used in urban areas were only given credit for "wasting less" with "a minor crimp in lifestyles." Third, although it is true that urban areas can reduce consumption on a short notice, shifting the burden of water deficiencies from agriculture to urban areas cannot be justified on the case of urban conservation alone. Economic impacts of urban conservation are not small, and the achievements of urban conservation from the statewide perspective is not high (i.e., 20 percent cutback represents about 1 MAF in applied urban use but about 7 MAF in applied agricultural use). Fourth, the criticism of reservoir operation rules has to be considered in the context of the worst dry year on record, it clearly was unexpected. Finally, the environmental impacts as well as role of the media are absent from the lessons learned. Actually, the water quality standards in the Delta were relaxed in order to conserve water stored.

Summary of the 1976-1977 Drought Lessons for Water Management

A water management strategy has emerged from the 1976-77 drought. The drought has shown that water storage alone cannot solve the drought problem. It has to be supplemented with efficient water delivery systems and efficient use for urban, agricultural, and other purposes including greater recycling. To accomplish this, it was suggested that the major water projects and groundwater basins in the state would best be operated as a single system under a set of coordinated policies. In lieu of this, water transfers allowed by the construction of the appropriate facilities as well as the development of additional conjunctive use capacity can serve to improve the existing system (C-DWR personal communication 1992i).

These lessons of the 1976-77 drought were used by the authors in this study to formulate (or reconstruct) a statewide drought management plan that existed prior to the onset of the 1987-92 drought. The reader should be aware that what follows is a "conceived and derived" plan that is not documented or formally adopted except within the framework of this study.

PRE-1987 CALIFORNIA'S DROUGHT MANAGEMENT PLAN

The approach to drought management that existed prior to the 1987-92 drought can be defined in terms of strategies and tactical response actions that would be expected given the experiences of the 1976-77 drought. The sponsor of this study, Institute for Water Resources of the U.S. Army Corps of Engineers, has devised a planning framework for studying the performance of water management systems and developing a better way to manage water during drought. According to this framework, all responses toward water shortages can be categorized as strategic, tactical, or emergency.

Strategic measures are defined as long-term planning actions that tend to reflect permanent water conservation or drought mitigation measures. They may involve changes to existing water storage or source infrastructures, local ordinances, or regional/statewide legislation. Tactical drought preparedness measures tend to lessen the impact of a recognized, oncoming drought, with actions to induce reductions in water use proportional to the growing drought intensity. Finally, emergency measures are taken to reduce immediately water use or

loss when all other measures have been exploited. Tactical and emergency measures are short-term drought response actions instituted and governed by existing laws and infrastructure. These measures can be divided into two categories: demand reduction measures and supply management measures (The National Study of Water Management During Drought: A Research Assessment. U.S. Army Corps of Engineers, Institute for Water Resources, August 1991).

A proper understanding of the roles of strategic, tactical, and emergency measures is critical to the effective overall drought management. Water supply agencies emphasize strategic long-term measures which would limit the need for tactical (short-term) measures and minimize the chances of reaching crisis situations during which emergency measures must be invoked. Environmental community tends to favor tactical measures, since these actions will prevent additional water development at the expense of in-stream uses of water. The U.S. Army Corps of Engineers planning framework designates strategic and tactical measures as "drought planning." By definition, a crisis situation cannot be "planned for" because we pursue drought planning in order to prevent "crisis." We can only prepare for crisis by designating the disaster declarations and relief assistance responsibilities.

The California water community is not clear on what constitutes "a crisis in water supply." Some outcomes of a water supply shortage, such as drained or contaminated water distribution system in a community, would likely be seen as a crisis by the majority of water professionals and general population. It is less clear, however, whether "water rationing" represents a crisis situation. If water rationing represents a crisis, then the tactical and strategic measures should be developed to minimize the chances of having to implement water rationing during future droughts. If rationing is an acceptable tactical measure, then it can become a component of the plan for coping with droughts. This dilemma can only be solved by California's society. The social behavior during the 1976-77 drought indicates that the general population views severe water rationing with enforcement as an emergency measure taken in response to a "real crisis situation." Numerous studies show that individuals will change their behavior (i.e., conserve water) if they believe that there is a crisis. In other words, the general public tends to see water supply conditions as either "crisis" or "normal" (i.e., noncrisis). The success of rationing programs measured as deep cutbacks in water use provides a proof that the situation was perceived as a crisis. If the supply shortages were not viewed by the public as "crisis," then most rationing programs would fail to produce the called-for reductions in water use.

Accordingly, we can classify rationing programs as tactical measures as long as they are aimed at eliminating water waste and improving the efficiency of water use. All plans that call for "significant sacrifice" by allocating fixed quantities of water to each user that are insufficient for supporting normal lifestyles and that result in property damage, inconvenience, and significant burden should be classified as emergency measures taken in response to a crisis situation. Such a distinction is by no means arbitrary. It reflects the views of the general population as to what is a crisis that calls for a temporary change in their behavior and sacrifice in their lifestyles. Again, if crisis conditions can be avoided by planning, then they should be. We can include "water deficits" in water supply plans, but not "water shortages" that would result in crisis conditions.

Strategic Long-Term Drought Protection

The water management system in California has been established in order to provide "dependable supplies" to the major population centers and agricultural areas in the state. The dependability of supplies relates to drought protection and planning preparedness. Therefore the major water development projects, such as the Central Valley Project and the State Water Project, were designed and are operated to provide adequate protection to water users against periodic droughts. Given the existing water storage capacity, the degree of drought protection is a function of the amount of "carry-over" storage in the major reservoirs. However, a higher level of drought protection (or dependability in water supply) can only be achieved at the expense of the amount of water made available to users during normal and slightly less-than-normal supply. In other words, much of water management in California centers on the trade-off between the amount of water stored for a potential drought year and water made available during a normal year.

In general, the long-term drought protection in the state consists of the following five features:

- Provision of extra storage in surface-water reservoirs and maintenance of the stored water as carry-over water
- Conjunctive use of surface water and groundwater to optimize the availability of total supply during periods of drought
- Development of a statewide water distribution system to move water from supply surplus areas to water shortage areas
- Improvement in the balance of supply and demand by increases in efficiency of water use (i.e., water conservation)
- Development of additional supplies to enhance supply reliability

The above long-term features of the water management approach in California, if provided at some optimal level of development and optimal operation, would carry the state through all drought events less severe than the droughts of record without the need to impose restrictions on water use or adverse impacts on the state environmental resources. Only during the most rare events would there be a need to mitigate potential shortages of water supply through tactical drought response measures. However, the experience of the 1976-77 drought demonstrated that the level of long-term drought protection in California is not adequate for protecting against drought events that approach in severity the bench-mark events used for planning purposes. This lack of reliability is viewed by water supply agencies as being due in large measure to the failure to complete the SWP and other planned projects because of the virtual standstill of project development for the last two decades. Tactical restrictions on water use must be used in order to reduce the risk of running out of water at the end of two critically dry years. In some communities, water shortages lead to crisis conditions calling for emergency measures.

Long-term drought planning and preparedness for a potential drought implies adequate planning and preparation to cope with an occurrence. In California, drought planning is required by the California Urban Water Management Planning Act (Water Code Sections 10610 through 10656 were added by Statute 1983, Chapter 1009) which became effective on January 1, 1984. The act was known as Assembly Bill (AB) 797 while pending before the Legislature. The act requires that "every urban water supplier providing water for municipal purposes to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually to prepare and adopt ... an urban water management plan."

Water-conserving codes passed by the local city council can require water-conserving plumbing devices such as low-flow showerheads and 1.6 gallon capacity toilets in new residential developments. Long-term drought impact reduction can include the provision of sufficient local and regional storage of water in times of high rainfall for use during periods of drought. Long-term protection against regional drought can also be achieved by developing interregional water transportation systems (i.e., aqueducts) that can import water from distant sources.

The SWP and the CVP facilities in California are examples of interregional water transportation systems. Local city ordinances and state and federal legislation also include strategic adjustments to drought. For example, the Warren Act restricts the movement of water through the CVP to urban users. This legislation is presently under revision. The six-year drought in California revealed that the Warren Act is outdated. Presently, there is verbal opinion from the Regional solicitor with concurrence from the Washington, D.C. solicitor that restricts the Bureau of Reclamation from executing Warren Act-type contracts for agricultural purposes. However, this verbal opinion does not restrict the Bureau from executing Warren Act-type contracts for municipal and industrial purposes (USBR, personal communication 1993). During the sixth year of the drought there was a move to bring the CVP under state control. Presently, these negotiations are for all practical purposes "dead," and the issue remains unresolved (USBR, personal communication 1993).

Other long-term adjustments to drought are evident in the agricultural sectors. These include better management of existing systems during shortages and technological innovations such as drip irrigation systems.

Tactical Short-Term Drought Response Plans

The majority of the developed water supply systems in the state are operated with provisions for reducing water deliveries during periods of shortage. For example, the basis for the design and operation of most large surface storage reservoirs in Northern California is the 1928-34 drought in the Sacramento River basin. The amount of water that could be delivered if the 1928-34 dry weather conditions were repeated is referred to as "firm yield" of the CVP and SWP. The actual operating criteria rely on a rule curve that balances the need for drought protection and the amount of water delivered in any given year.

The onset of a drought is marked by public awareness campaigns and conservation programs to reduce water demand. Public awareness campaigns persuade consumers that they

should conserve water and provide consumers with information on how to conserve. Changing behaviors associated with high water use and promoting the use of water-saving devices are often viewed as the most effective means for achieving reduction in water use (Dziegielewski et al. 1988). Technological devices usually are readily accepted by consumers. Retrofit campaigns also increase public awareness of drought and thus enhance the overall conservation effects. For example, mass mailings of conservation kits during the 1976-77 drought in California reduced indoor residential water use by 5 to 10 percent (California Department of Water Resources 1978). As the magnitude and intensity of a drought increases, selected commercial uses such as car washes can be prohibited, and drought emergency prices and rationing programs are enforced. Restrictions on selected urban uses of water and water-rationing plans were reported to reduce water use by up to 65 percent for the targeted uses (Hoffman et al. 1979).

Supply management techniques can include water system improvements such as modifications of the distribution system and emergency supply sources such as interdistrict transfers. Water banking is a resource management alternative that has proved effective in California. For example, the Metropolitan Water District of Southern California (MWD) has two ongoing water-banking efforts. MWD has concluded negotiations with the Arvin-Edison Water Storage District for a program that would allow MWD to store SWP water during wet periods and receive in exchange a portion of Arvin-Edison's entitlement to water from the Central Valley Project (CVP) during dry periods. MWD also has a local banking program, the Seasonal Storage Program, that is a rebate program encouraging customers who have facilities to store water during high-flow months. Furthermore, the recent California drought led to the development of the Emergency State Water Bank during the fifth year of the drought. This alternative proved effective in generating water supplies by buying water from water rich areas and selling it to areas that needed it. However, much of the "generated" water was pumped in the areas of origin so that the long-term impacts of this alternative on ground water levels are a concern.

The following sections describe the preexisting strategies and tactical measures that existed in California prior to the six-year drought of 1987-92.

In general, the short-term drought response plan in the state consists of the following response actions:

- Curtailment of surface-water deliveries to urban and agricultural users in order to maintain adequate carry-over storage for possible subsequent dry year

- Relaxation of in-stream water quality standards

- Increase in the use of groundwater in order to replace the surface-water supply shortages (or water left in storage)

- Transfers of water within the state from sources with available water (e.g., Colorado River, Yuba River) to water-short areas (e.g., Santa Barbara County)

- Reduction of water use through conservation and rationing in urban areas and in agriculture to make up for the reduced deliveries and protect the remaining supplies

- Activation of emergency supply alternatives such as reclamation of brackish or saline water and municipal wastewater, cloud seeding, and other alternatives

The importance of these actions depends on actual drought conditions and the feasibility of each action. For some areas, the use of groundwater and emergency supplies are not feasible. Generally, large-scale transfers of water depend on the availability of interconnections to the major state distribution network and available water that can be transferred. Some options exist for significant intraregional transfers. The two short-term response options always available are protection of the remaining supplies and reduction in water use. This is actually a single option if viewed from the perspective of a local self-contained water supply system. At the state level, reduced deliveries of the CVP or SWP water can be met (replaced) using alternative sources, water conservation, or cessation of some uses.

The success of the drought response plan is critically dependent on the timing of drought response actions. Normally, significant shortages in precipitation and runoff in the Sacramento River basin will not translate to automatic proportionate reductions in water deliveries. The large amount of water storage affords the operators of the projects some response lag time. However, two consecutive dry years will most likely trigger a response action. Once the drought conditions are in effect, the decisions on water deliveries and the amount of carry-over storage are made for one year in advance and can be changed from year to year. The following sections describe the operation of the supply sources during drought and the use of other drought response options.

The SWP "Rule Curve" Criteria

Water deliveries by the SWP are determined using the concept of "firm yield" operation, which is defined as the "dependable annual water supply that can be made available without exceeding specified allowable reductions in deliveries to agriculture during extended dry periods" (C-DWR 1987). Figure III.4 shows the availability of the SWP water supply under conservative firm yield operating criteria with total annual demand set at 3.27 million acre-feet (MAF).

The operating criteria are derived by examining the historical record of natural runoff as measured by the Sacramento River-Four Rivers Index. This index is the sum of unimpaired water year runoff from the Sacramento, Feather, Yuba, and American rivers. Figure III.5 shows the Sacramento River Index flows since 1906. The State Water Resources Control Board used the index to designate five hydrologic classes of water years in order to set the outflow requirements to meet the water quality standards in the Delta adopted in 1978 (Decision 1485). These operating criteria determine total water deliveries in a given hydrologic year. These criteria are based on the amount of water in storage at the beginning of the year and the required amount of carry-over storage, assuming that there is a seven-year drought in the Sacramento River basin like the one experienced during 1928-34.

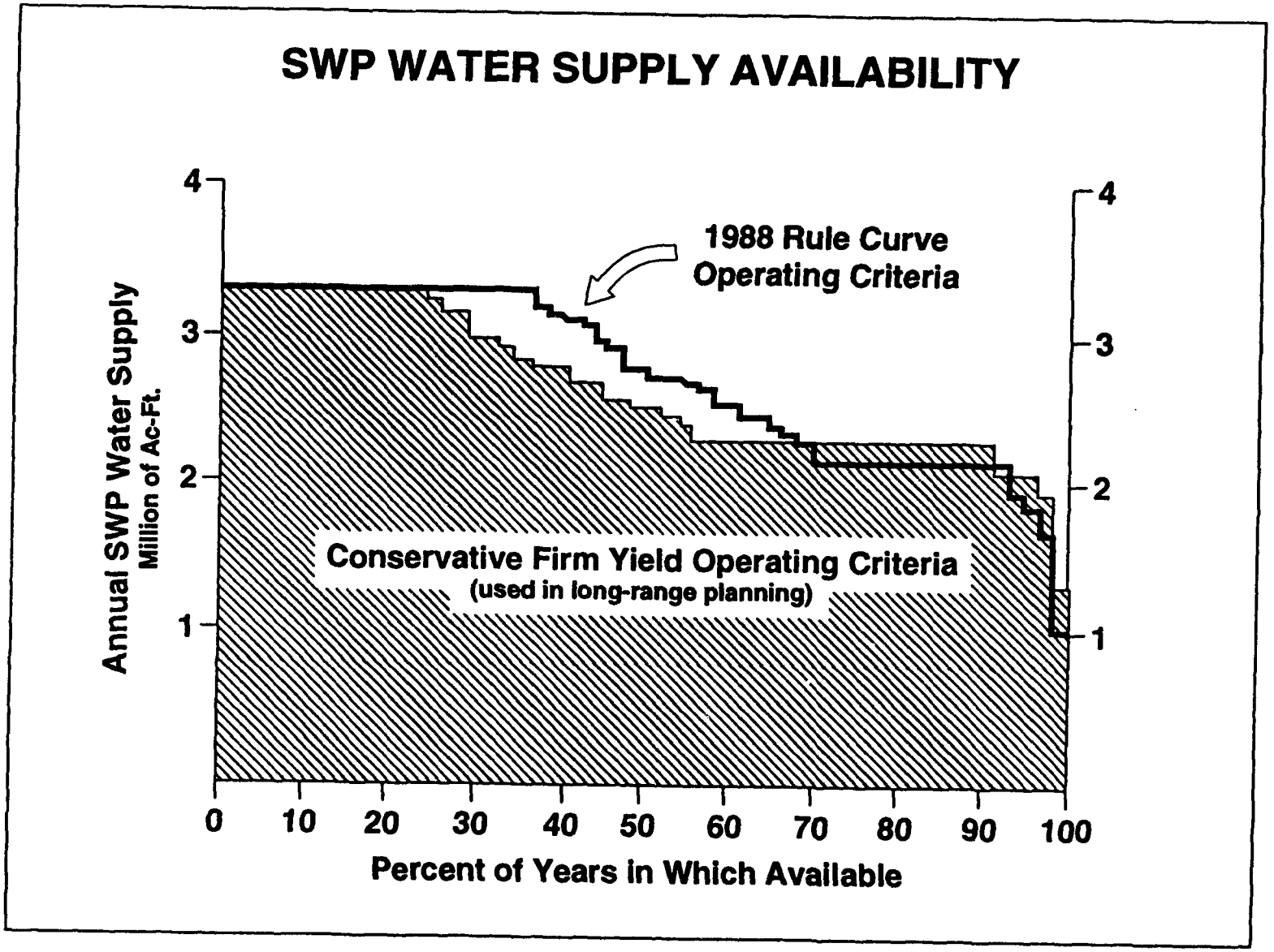

FIGURE III.4

SWP WATER SUPPLY AVAILABILITY

Source: C-DWR 1987.

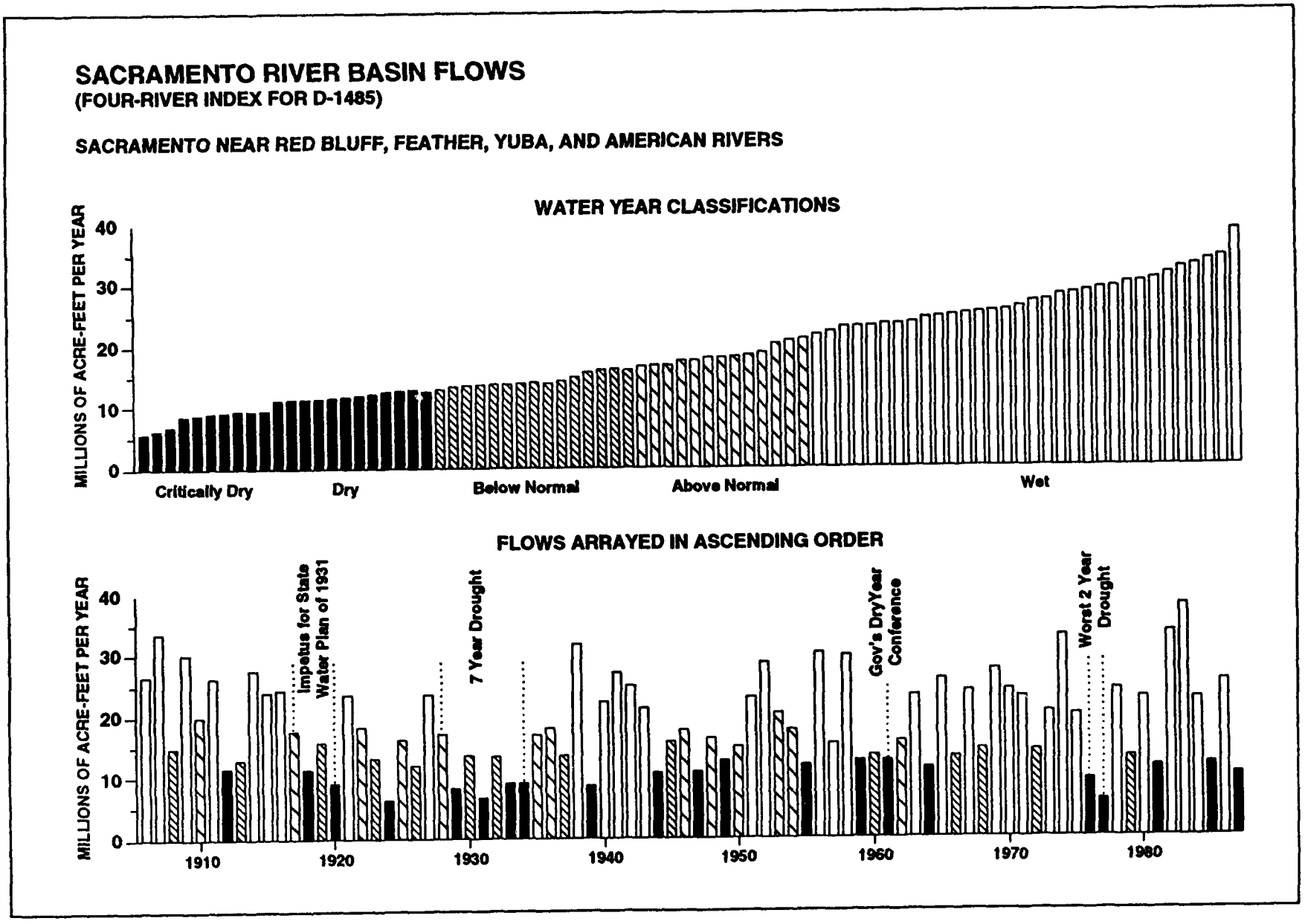

FIGURE III.5

SACRAMENTO RIVER BASIN FLOWS

Source: C-DWR 1991b.

The SWP contractors perceived that the firm yield operations are too conservative and therefore too restrictive in determining annual water deliveries. Figure III.4 shows water availability under the 1986 rule curve operating criteria that relaxed the minimum reservoir carry-over storage requirements, thus permitting increased deliveries in all but the driest years. Under the 1986 rule curve, the average dry period deliveries during a repeat of the 1928-34 drought would have been about the same as those obtained under the firm yield criteria. The actual operating criteria of the SWP are not fixed. They can be changed from year to year in response not only to the amount of water in storage but also to other circumstances such as contractual and legal limitations, hydropower requirements, Delta and upstream user's needs, and other considerations. For example, the rule curve for 1978 shown on Figure III.6 shows that SWP expected that the delivery of full entitlement amounts of 1.8 MAF to SWP contractors would be made if the combined runoff of the four basins reached 10 MAF. Each water year's curve is distinct. A detailed discussion of the SWP's water delivery risk analysis and criteria for 1989 is presented in Appendix B (C-DWR 1988).

The CVP Operations

The surface-water storage reservoirs of the CVP are operated according to rules established by the United States Congress which authorized the project and its facilities. The specific operating criteria are similar to those used by the SWP. The project is operated to deliver the entitlement water to its contractors and to meet water quality standards in the Delta according to the Coordinated Operation Agreement with the SWP. The operating criteria include provisions for reduction of water deliveries during drought years. However, the CVP deficiency criteria vary from contract to contract and are therefore characterized by a number of different criteria rather than a single set of criteria.

Groundwater Reserves

The conjunctive use of groundwater and surface water is an important element of long-term drought protection. The CVP, SWP, and other surface-water supply projects are capable of delivering significant quantities of surplus water during wet years. This water can be "banked" in groundwater basins for use during periods when surface-water deliveries are reduced. The actual banking can take a form of conjunctive use (i.e., surface water is used in place of groundwater, thus leaving water in the ground) or groundwater recharge (i.e., surface-water is pumped into spreading basins or injected into deep wells for direct storage).

The total storage capacity of all groundwater basins, which underlie about 40 percent of California, was at one time estimated to be some 1.3 billion acre-feet, with 143 MAF representing known usable storage (C-DWR 1975). The most recent estimates show only 850 MAF of water stored, but a higher estimate of 250 MAF of usable groundwater. For example, 6,400 square miles of the Sacramento Basin Hydrologic Study Area (HSA) is underlain by 24 significant groundwater aquifers, of which the largest Sacramento Valley basin covers an area of 5,000 square miles and has usable storage capacity of 22 MAF. One of the largest

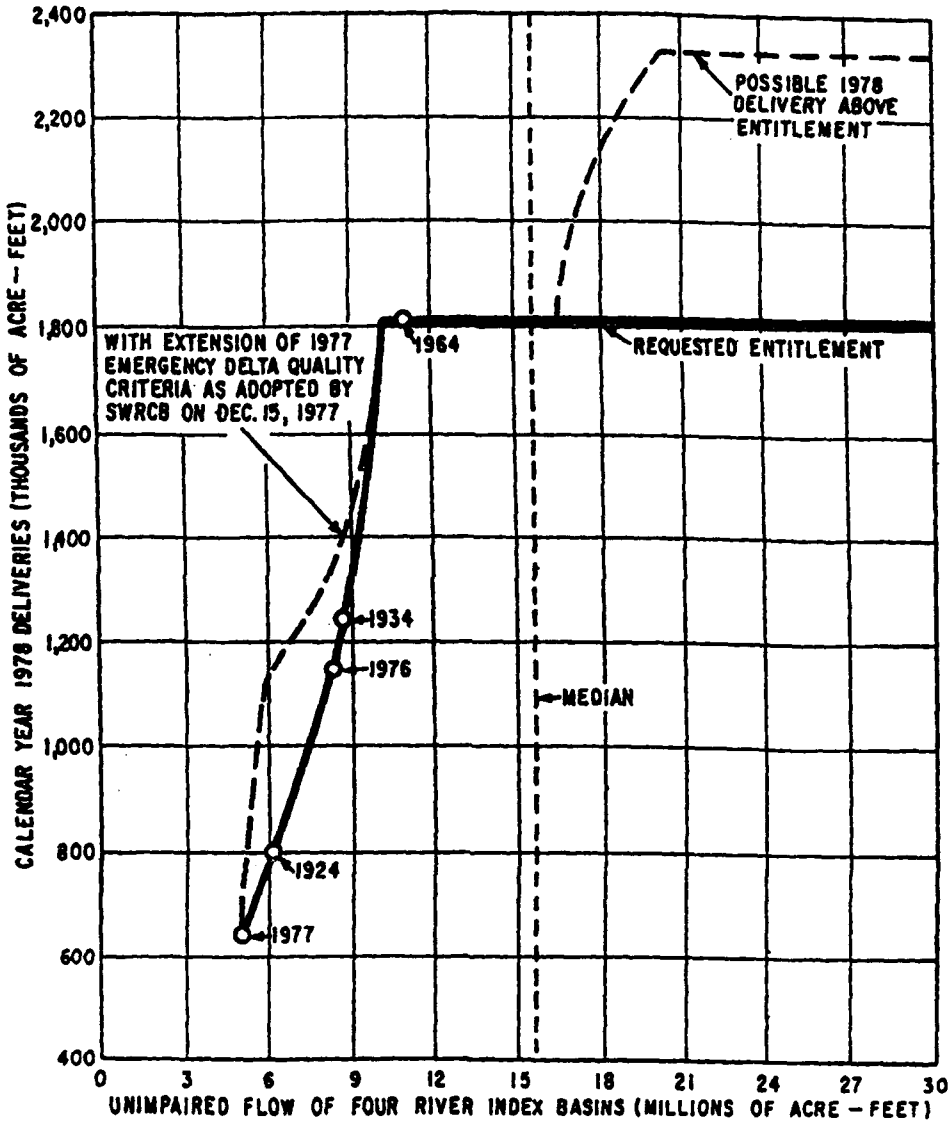

FIGURE III.6

STATE WATER PROJECT OPERATIONS RULE CURVE FOR 1978

Source: C-DWR 1978.

groundwater basins in California, located in San Joaquin Valley, contains more than 80 MAF and covers an area of 13,500 square miles. Finally, the Southern California region contains 42 basins, of which 29 have the combined usable storage capacity of 10.4 MAF.

During a normal year, about 40 percent (14.8 MAF in 1985) of California's applied water supply comes from groundwater basins. Groundwater pumping exceeds natural recharge in some basins, causing an estimated statewide overdraft of 2.2 MAF. During drought, the use of groundwater tends to increase to about 60 percent of all freshwater withdrawals, thus representing about an 8 MAF increase in the amount of groundwater pumped during normal years. Although this increase represents an overdraft, it provides an excellent option for mitigating surface-water shortages during drought.

However, not all groundwater districts have access to abundant groundwater supplies or have groundwater rights. Fortunately, some recent court decisions have established rules facilitating conjunctive operation of groundwater basins with surface-water supplies. Agencies who import water into a basin have a right to recapture the imported water that percolates into the aquifer and can prevent the capture of that water by overlying landowners or appropriators. If recharge from natural sources is not sufficient to keep the basin full, the imported water may use the empty storage space not needed for natural recharge. Additionly, in adjudicated basins, an old court rule that limited groundwater withdrawals of overlying landowners and appropriators to the average annual natural recharge of the basin (i.e., safe yield) has been modified to allow overdrafts as long as the basin is not adversely affected.

The availability of groundwater storage and the existing groundwater laws make this drought response option very important. Significant amounts of water are artificially recharged into groundwater basins in Southern California and in Kern County for the purpose of banking the surplus water for droughts.

Water Transfers

Large-scale transfers of water are the main element of California's existing water management system. Many communities and farmlands use water imported by aqueducts to supplement local sources. The federal, state, and local aqueduct systems have been interconnected over the years to allow the sharing and exchange of water supplies. Such interconnections are invaluable during drought because they make it possible to move surplus water from distant areas to alleviate local shortages.

The existence of interconnected aqueducts allowed the state to receive significant supplies of surplus water from the Colorado River. For example, during the 1976-77 drought, the Metropolitan Water District of Southern California released to SWP more than 300,000 acre-feet of water to be used in northern and central regions of the state. Metropolitan replaced the SWP water with imports of the surplus Colorado River water.

Prior to the 1987-92 drought, there were a number of water-sharing and exchange agreements among water districts to alleviate potential water shortages. Some examples of these

agreements include the San Luis Dam Emergency (1981-82), the Kern River Intertie (1983), and the agreement for interim water supply for the city of Needles (1984). Many agreements are negotiated and implemented during periods when there is a need for them. Additional interconnections are built to make more exchanges and transfers possible. Also, between 1980 and 1986, several laws were enacted to encourage voluntary transfers and facilitate such transfers by encouraging public agencies to allow other public agencies to make use of unused conveyance capacity.

Water Conservation

Temporary reduction of water demand plays an increasingly important role in coping with California droughts. During the 1976-77 drought, significant reductions in water use were achieved, thus demonstrating that people can cut back on water use if they have to because of a drought crisis. Many conservation measures implemented during a drought crisis are of a permanent nature (e.g., retrofit of showers and replacement of standard toilets with ultralow-flush toilets), therefore they contribute to the long-term drought protection through permanent increases in water use efficiency. Although in extreme crisis conditions, some communities implemented rationing programs requiring close to 50 percent reduction in water use, moderate rationing calling for 10-20 percent reduction in use is more easily absorbed by water users and generally does not cause major economic impacts (if properly structured). However, as communities adopt and implement conservation practices, their ability to absorb reductions decreases. Generally, no significant business-related economic impacts occurred in urban areas other than employment losses within the "green industry."

Standby Water Supplies

When water supplies become critically depleted, communities and water supply agencies usually consider a number of options for obtaining emergency supplies other than those discussed above. These may include (1) building dual distribution systems (although very limited) and reusing wastewater for urban irrigation and other nonpotable uses, (2) desalination of brackish and seawater to drinking-water quality levels, (3) importation of water by cisterns or hauling of icebergs, (4) cloud seeding to increase precipitation, and (5) many other possible options such as blending water of poor quality with good water. The first two options require substantial lead times in order to make them available.

Some emergency options are also available to the state. For example, about a dozen different weather modification programs are conducted each year in the mountain watersheds in California. Although during a drought there are few cloud-seeding opportunities, there is a chance of up to 10 percent increase in runoff if all opportunities are used. It is estimated that a two-seeder aircraft should be able to generate 70,000 acre-feet of additional runoff during a single wet season at a cost of $10 per acre-foot or less. However, it should be noted that not all experts believe that cloud seeding can augment rainfall totals.

Emergency Measures

The current drought and the previous 1976-77 drought in California revealed that major disaster declaration and relief assistance responsibilities fall upon state and federal governments. Government relief has come to the limelight as a high-priority issue since 1976, in response to increasing impacts of drought.

Although the government has readily responded in creating relief programs, not all agencies affected by drought received emergency assistance. This was due mainly to a lack of awareness of what assistance is available. Federal programs approved in California as loans and grants in the 1976-77 drought made up about $222 million while state assistance contributed about $17 million. Federal and state drought assistance programs are available to an individual, or community, provided the entity meets the following criteria:

- The entity is located in a county designated as a disaster or emergency area.
- The entity is designated as an Emergency Drought Impact Area by an appropriate agency (C-DWR 1978).

In the first case, designations are made by the President at the request of the Governor. In the second case, designations area made by the Interagency Drought Emergency Coordinating Committee (IDECC). This committee includes representatives of the Secretaries of Agriculture, Commerce, and Interior, and of the Administrator, U.S. Small Business Administration. These representatives are the administrators of the Farmers Home Administration (FmHA), Economic Development Administration (EDA), U.S. Bureau of Reclamation (USBR), and Small Business Administration (SBA). The secretary of this committee is the Administrator (or his designee) of the Federal Disaster Assistance Administration (FDAA) (C-DWR 1978). A summary of the major drought assistance programs approved in California by the end of the 1976-77 drought is provided in Table III.1. Water shortage emergencies are governed by Sections 350-358 of the California Water Code (Appendix C).

Summary of Emergency Measures and the Pre-1987 Statewide Drought Plan

The pre-1987 statewide drought plan was characterized mainly by strategic and tactical drought response measures. Strategic or long-term drought protection is targeted toward providing extra storage in surface-water reservoirs, conjunctive use, developing the statewide water distribution system, and increasing the efficiency of water use. Short-term tactical response measures include reduction in water deliveries to urban and agricultural users, increased use of groundwater, increased transfer of water to areas of need, increased conservation in urban and agricultural areas, and implementation of emergency supply alternatives. The emergency measures primarily consist of declarations of disaster areas and provisions for relief measures.

TABLE III.1

MAJOR DROUGHT ASSISTANCE PROGRAMS
Loans and Grants Approved in California
(Amounts Approximate at End of November 1977)

FEDERAL PROGRAMS	Approvals
U.S. Department of Agriculture	
Farmers Home Administration (FmHA) (Individuals and small communities; soil and water, emergency livestock loans)	$ 65.4 million
Agricultural Stabilization and Conservation Service (ASCS) (Individual farmers and ranchers)	22.3 million
Emergency livestock feed and transportation programs	8.9 million
U.S. Department of the Interior	
Bureau of Reclamation (USBR) (Irrigators served by federal water projects)	19.5 million
U.S. Department of Commerce	
Economic Development Administration (EDA) (Loans and grants to large communities)	79.2 million
Small Business Administration (SBA)	
Physical loss loans	7.4 million
Economic injury loans	19.4 million
Total federal assistance	**$222.1 million**
STATE OF CALIFORNIA PROGRAMS	
California Safe Drinking Water Bond Act of 1976 (Water companies serving at least 25 persons and 15 connections)	$ 4.2 million
California Davis-Grunsky Act (Communities under 200,000 population)	.7 million
Tax relief available	
SB 1033 (Vuich) for livestock ranchers (available)	2.5 million
AB 776 (Fazio) for dry-land farmers (available)	10.0 million
Total State Assistance	**$ 17.4 million**

Source: C-DWR 1978.

IV. RECOUNT OF THE 1987-1992 DROUGHT

This chapter, recounting the 1987-92 drought in California, is based on a thorough literature review of available reports, documents, and newspaper coverage of the drought. The story of the drought begins with its onset, followed by the subsequent progress of drought events and response actions. The recount continues with an examination of precipitation and hydrological data during the drought, the resultant drought management outcomes, and the associated economic and environmental impacts of the drought.

RECOGNITION OF THE ONSET OF DROUGHT

The ongoing six-year drought in California began in water year 1987 (October 1, 1986, through September 30, 1987) and has continued for six consecutive years into 1992. It is important to think of drought in terms of water year, which begins three months earlier than a calendar year.

It is also important to differentiate between the definition of the "drought phenomenon" and the definition of the "problem of drought." Typically, three types of drought are distinguished (Dracup 1980) with regard to the drought phenomenon. These include:

- Meteorologic drought; defined based on the deficit of precipitation
- Hydrologic drought; defined based on low streamflow
- Agricultural drought; defined based on soil moisture deficiency

A major difficulty arises when one attempts to define the societal problem of drought. For example, the people of the state of California face the problem of the ongoing six-year drought not only because the precipitation in California has been less than normal, but because there is not, or will not be, enough water to satisfy all the established and new (in-stream and off-stream) uses of water in the state. Therefore the "problem of drought" must be defined from the perspective of adjustments to drought. With respect to off-stream uses, the real issue of the drought problem revolves around the social desirability of securing ample supply of water for all uses at all times. In more general terms, the need and level of drought mitigation (i.e., reducing the adverse consequences of water supply shortages) may be determined by comparing the social, economic, and environmental impacts of drought with and without additional human intervention.

Drought is measured in various ways in California, including total precipitation received, the volume of streamflow or runoff expected, reservoir storage, the Sacramento River Index, and the condition of soil moisture. As mentioned in the previous chapter, the California Department of Water Resources classified 1987 as a critically dry year, based on four drought

indicators: precipitation, runoff, reservoir storage, and the Sacramento River Index as set by the SWRCB. The first year of the drought was characterized by below-average precipitation (61 percent of normal), water year runoff (48 percent), reservoir storage (84 percent), and the Sacramento River Index (50 percent). The Sacramento River Index refers to the sum of unimpaired water year runoff from the Sacramento River near Red Bluff, the Feather River inflow to Oroville, the Yuba River at Smartville, and the American River inflow to Folsom (C-DWR 1991b). The Sacramento River Index is a standard index used to measure water supply conditions in California, and normal flow is reflected by the 50-year average (1941-90) of 18.4 MAF. This index has been classified by C-DWR into five categories: wet, above normal, below normal, dry, and critically dry.

Drought is a creeping phenomenon, and the current California drought really began after a wet 1986 water year. As a result of abundant water supplies in 1986, it was difficult to recognize the onset of drought in water year 1987. This year was critical; a drought year hydrologically, but carry-over was good, and therefore no hardship was experienced in 1987. However, the drought was visible in 1988, and this year marked the establishment of the Drought Information Center at C-DWR.

RETROSPECTIVE DATA ON DROUGHT CONDITIONS

Precipitation and Runoff

Since the onset of drought in 1987, California has experienced at least one month of above-normal precipitation during each water year. For example, the Miracle March in 1991 and a wet February in 1992 assisted in improving water conditions over the short term in the state. However, these precipitation "bursts" were not adequate to overcome water shortages in most parts of the state accumulated during the previous months of the respective water years. The Miracle March doubled the average statewide runoff and precipitation during the period March 1, 1991, to April 1, 1991.

The current drought is extremely close to the severity of the 1929-34 drought experienced in the Sacramento River basin. However, the average annual runoff during the previous drought was lower. In the San Joaquin River drainage basin the 1987-92 drought is the worst six-year period on record. The 1987-92 drought period has been characterized by below-average precipitation varying from a lower limit of 61 percent in 1987 to an upper limit of 86 percent of average in 1989. Water year runoff has varied from 43 to 72 percent of average during the ongoing six-year drought. Reservoir storage has been below 100 percent over the drought period and has averaged 60 percent over the last three years. The Sacramento River Index has not risen above 9.2 MAF (i.e., 50 percent of the 50-year average, 1941-90, of 18.4 MAF) for 5 of the 6 years. These 5 years (1987, 1988, 1990, 1991, and 1992) have been classified as critically dry and the sixth year (1989) as dry. Table IV.1 provides a summary of the statewide precipitation and water year runoff since 1987.

TABLE IV.1

SUMMARY OF STATEWIDE WATER YEAR DATA DURING WATER YEARS 1987-1992 AS OF OCTOBER 1 (In Percent of Average)

	1987	1988	1989	1990	1991	1992
Precipitation	61	82	86	69	76	87
Water year runoff	48	47	72	45	43	43
Reservoir storage	84	66	74	60	61	56
Sacramento River Index (MAF)*	9.2	9.2	14.8	9.2	8.4	8.9
Year type	Critical	Critical	Dry	Critical	Critical	Critical

* The Sacramento River Index is the sum of unimpaired water year runoff from the Sacramento River above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River at Smartville, and American River inflow to Folsom. The 50-year average, 1941-90, is 18.4 MAF.

Source: C-DWR 1991b and personal communication 1992-93.

With the exception of the North Lahontan region, all the hydrologic regions have experienced less-than-average precipitation (less than 100 percent) for at least five of the six drought years. Three of the regions, North Coast, San Francisco Bay, and the Central Coast have been characterized by less than average precipitation during the past six years. The average runoff for nine of the ten hydrologic regions, with the exception of the South Coast, has been below average (less than 100 percent) during the ongoing six-year drought. A description of average annual precipitation and annual runoff for the ten hydrologic regions in California during water years 1987-92 is provided in Figures IV.1 and IV.2.

Surface-Water Storage

California has built extensive reservoir storage facilities to provide sufficient water supplies for a variety of human uses, recreation, and flood prevention in winter. The 1920s and 1930s saw the regional development of water projects followed by construction in the 1960s and 1970s to meet the state's increasing need for power and water. Presently there are 155 major reservoirs in the state with a total storage capacity of almost 38 MAF of water. Table IV.2 shows the total storage for the past six years in California for the 155 major reservoirs including both the SWP and the CVP. A disaggregate breakdown of the surface-water storage according to the ten hydrologic regions in the state is presented in Table IV.3.

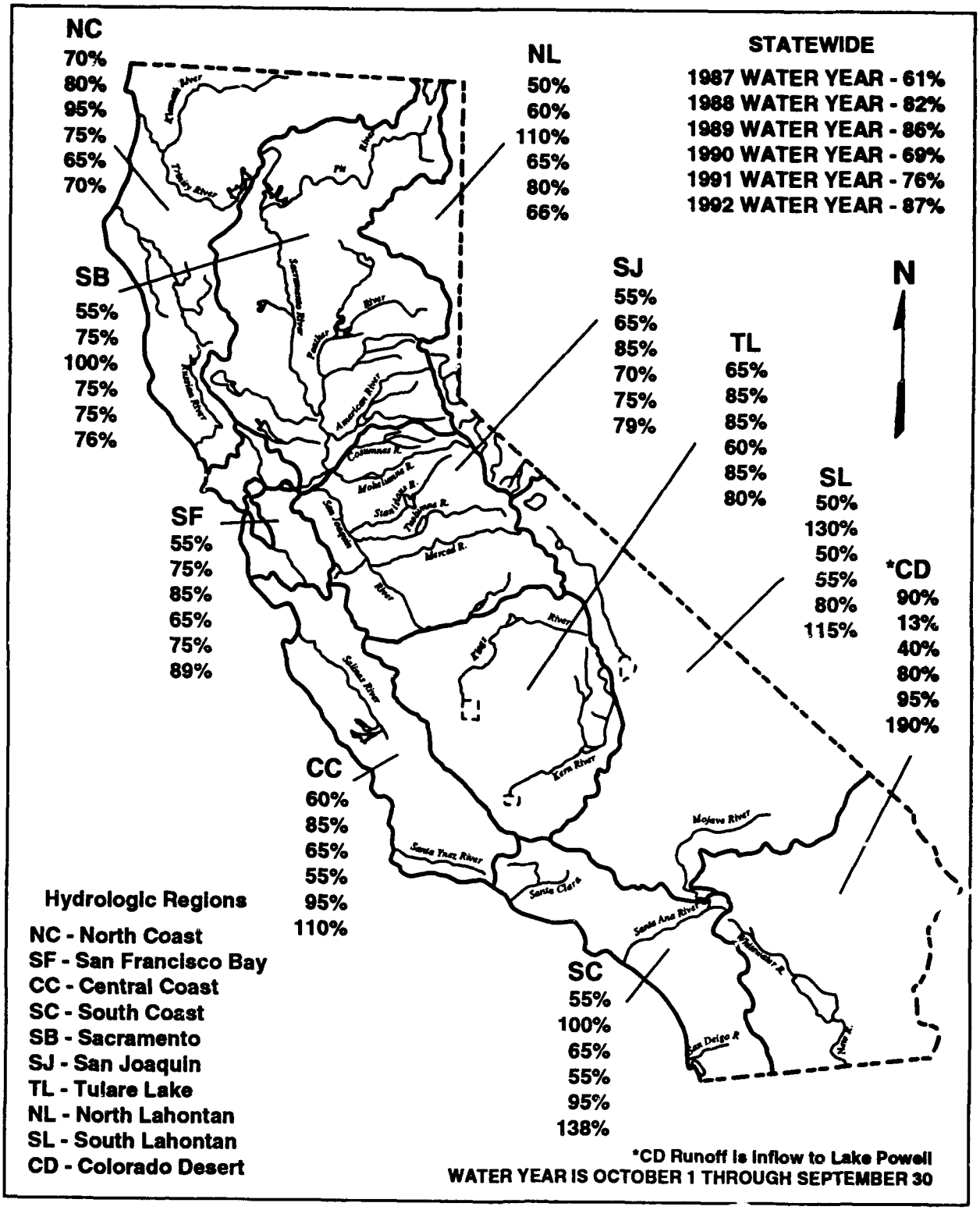

FIGURE IV.1

WATER YEAR PRECIPITATION IN PERCENT OF AVERAGE BY HYDROLOGIC REGIONS, 1987-1992

Source: C-DWR 1991b and personal communication 1992-93.

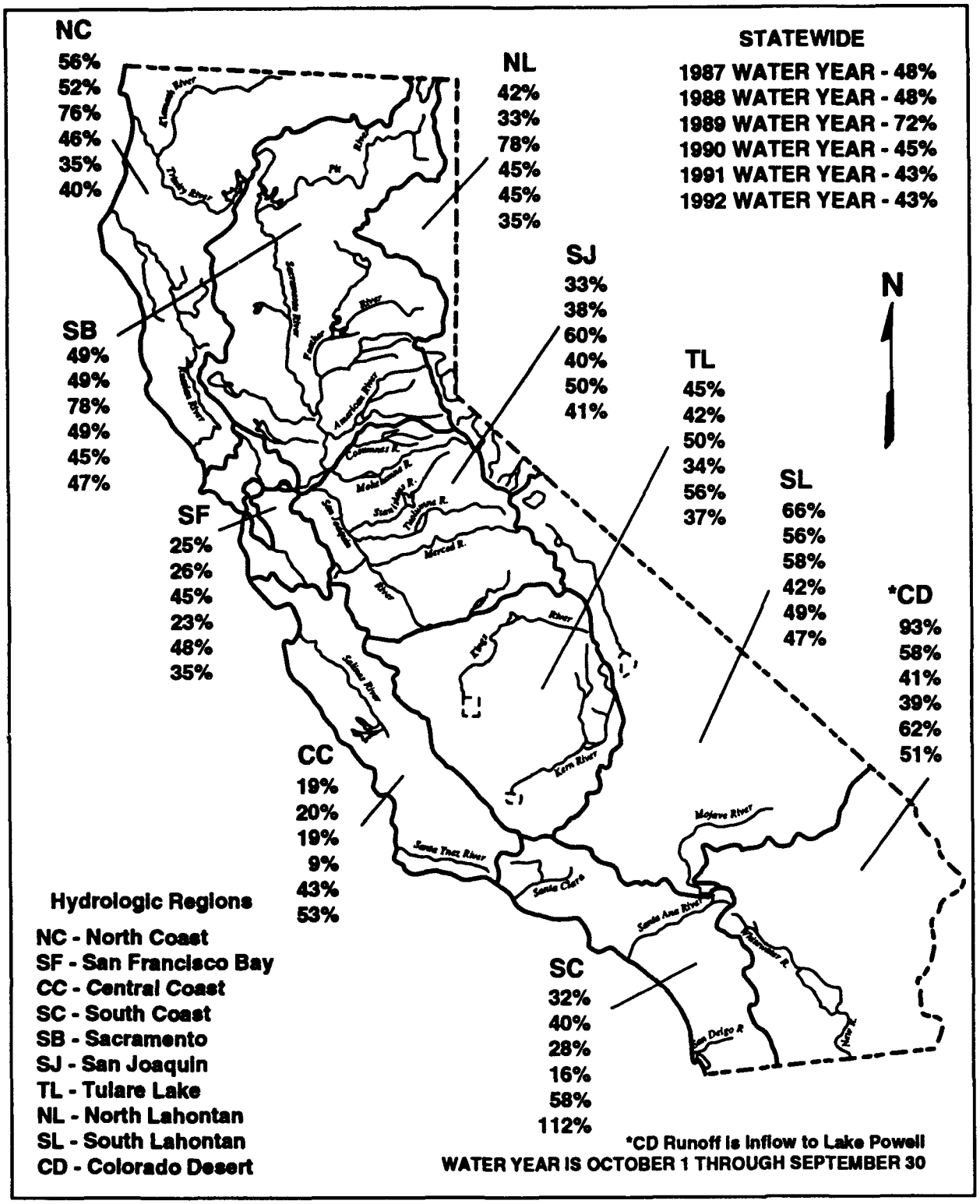

FIGURE IV.2

WATER YEAR RUNOFF IN PERCENT OF AVERAGE
BY HYDROLOGIC REGIONS, 1987-1992

Source: C-DWR 1991b and personal communication 1992-93.

TABLE IV.2

STATEWIDE RESERVOIR STORAGE, 1987-1992
(MAF)

Year			Storage	Percent of Normal
155 major reservoirs				
October 1, 1987			18.9	84
October 1, 1988			14.8	66
October 1, 1989			16.7	74
October 1, 1990			13.6	60
October 1, 1991			13.8	61
October 1, 1992			12.7	56
Total capacity	=	37.7		
Normal (average) storage	=	22.5		
SWP reservoir storage				
October 1, 1987			3.22	85
October 1, 1988			2.64	55
October 1, 1989			3.07	81
October 1, 1990			2.06	54
October 1, 1991			2.59	68
October 1, 1992			2.29	60
Total capacity	=	5.60		
Normal (average) storage	=	3.81		
CVP reservoir storage				
October 1, 1987			6.3	100
October 1, 1988			4.6	73
October 1, 1989			5.1	81
October 1, 1990			4.0	63
October 1, 1991			3.3	52
October 1, 1992			3.1	49
Total capacity	=	11.6		
Normal (average) storage	=	6.3		

Source: C-DWR 1991b and personal communication 1992-93.

TABLE IV.3

REGIONAL SURFACE-WATER STORAGE IN MAJOR RESERVOIRS
(In Thousands of Acre-Feet)

Region	No. of Reservoirs	Total Capacity	Historical Average	Oct. 1 1989	Oct. 1 1990	Oct. 1 1991	Oct. 1 1992
North Coast	7	3,148	2,076	1,684	1,479	1,004	1,187
SF Bay	18	696	397	349	310	333	355
Central Coast	6	947	551	121	93	164	288
South Coast	29	1,978	1,119	1,141	1,201	1,342	1,322
Sacramento	43	16,009	10,306	8,877	6,659	6,664	6,210
San Joaquin	33	11,358	6,470	3,895	3,348	3,660	2,798
Tulare Lake	6	2,045	699	243	170	291	199
North Lahontan	5	1,072	585	221	106	98	91
South Lahontan	8	402	298	200	206	228	223
Colorado River*							
Total	**155**	**37,655**	**22,501**	**16,731**	**13,572**	**13,784**	**12,671**
Percent of average				74	60	61	56

* No in-state reservoirs in this region.
Source: C-DWR 1991b, 1992d and personal communication 1992-93.

Groundwater Storage

Groundwater generally contributes to about 40 percent of California's water supply, but during the current drought water shortages resulted in increased groundwater pumping. As a result, about 60 percent of the state's water during drought was obtained from groundwater. Groundwater basin levels in California vary, and these levels are affected by the rate of recharge, the total number of wells, and the amount of water pumped.

The San Joaquin Valley, California's largest and most productive agricultural region, has been characterized by heavy utilization of groundwater during the ongoing drought. The decline in groundwater storage basin reflects the increased pumpage and inadequate recharge during the past six years. During the fifth year of the drought, it was estimated that groundwater storage in the San Joaquin Valley had been depleted by about 11 MAF (C-DWR 1991b). Groundwater levels in the southern Sacramento Valley had not declined significantly, although declining levels were evident in the northern Sacramento Valley.

A CHRONOLOGY OF DROUGHT EVENTS AND RESPONSE ACTIONS

The background of the drought conditions in the state sets the stage for a discussion of drought events and response actions that occurred during the six-year period. In order to capture the progress of the drought, a chronology of events and actions has been designed. This task involved an intensive review of printed materials. Documentation of the most significant events and response actions has been recorded by exact dates as far as possible. The following is a list of some of the drought events arranged according to water years.

First Year: Water Year 1987 (October 1, 1986-September 30, 1987)

As described earlier, water year 1987 spelled the onset of the six-year drought in California but was not recognized as the first year of drought until 1988.

Second Year: Water Year 1988 (October 1, 1987-September 30, 1988)

Although the survey of public attitude in the state revealed that the adult community was aware of current water shortages, most of them (70 percent) believed that serious shortages would occur in the next decade. San Joaquin County was the first county in the state to declare a drought emergency 19 months after the onset of the hydrologic drought in the state. Around this period, California Governor George Deukmejian urged residents to take voluntary steps to cut water use. The first formal declaration that the state was in a drought was made during this period by David N. Kennedy, California Water Resources Department Director (April 19, 1988). The second year of drought was characterized by conservation actions that included both voluntary (e.g., Metropolitan Water District and San Diego County Water Authority) and mandatory measures (city of Los Angeles). Other events and actions involved interconnections and the easing of federal legislation to facilitate water exchanges and transfers, trucking in water, and the State Water Resources Control Board (SWRCB) hearings on the drought.

January 1988. Fifty-four percent believe there is currently a serious water shortage in California, and 70 percent believe that there will be a serious shortage in ten years. (Survey of California adult attitudes towards water use in the state) (Waterworks Southwest, February 1988)

April 5, 1988. As the snowpack and reservoir levels continue to stay below normal level, San Joaquin County declared a drought emergency. This was the first county in the state to do so. They immediately requested to get cattle feed to dirt brown ranches. (*Bakersfield Californian*, April 8, 1988)

April 16, 1988. California Governor, George Deukmejian, said that he has ordered the Department of Water Resources to draft contingency plans for a "drought emergency" immediately. He urged residents to take voluntary steps to cut water use. The Governor proposed to spend $10.3 million to boost the state's fire fighting forces needed during the current dry conditions. (*Los Angeles Times*, April 17, 1988)

April 19, 1988. California Water Resources Department Director, David N. Kennedy, formally declared a drought in California. This was the first

admission by the state of the fact that California is in a drought. (*Los Angeles Times*, April 20, 1988)

April 27, 1988. City of Los Angeles adopted an ordinance for imposing mandatory conservation measures that included prohibition on serving water in restaurants without customer's request, ban on hosing patio and driveways, immediate repair of leaky faucets. Also, the landlords and businesses were required to install water-saving devices for showers and toilets by October 13, 1988. (*Los Angeles Times*, April 20, 1988)

May 2, 1988. The North Bay Aqueduct, a 24-mile long, $100 million pipeline started serving Solano and Napa Counties. This will provide 42,000 acre-feet to Solano County and 27,000 acre-feet to Napa County residents. (*Vacaville Reporter*, April 26, 1988)

May 10, 1988. MWD of Southern California adopted a water conservation plan to conserve 10 percent of water in response to a statewide drought. Also, for the first time, MWD notified its agricultural customers of likely water rationing if current drought continues through the winter 1988-89. (*Pasadena Star-News*, May 11, 1988)

May 13, 1988. The Colleguas Municipal Water District and the Metropolitan Water District agreed to study a plan to use a pipeline to bring water from Lake Castaic to an underground storage area in mountains between Moorpark and Santa Paula. (*Daily News*, May 14, 1988)

May 1988. Congressman Tony Coelho has introduced emergency legislation that empower the Secretary of Interior to determine if any of the reservoirs of the Bureau of Reclamation has surplus water. Also, the legislation authorizes the Secretary to sell any surplus water of such reservoirs. (*San Francisco Chronicle*, May 25, 1988)

June 3, 1988. San Diego County Water Authority began a voluntary conservation program targeted at residents, government agencies, businesses, and private developers. The Authority will provide information about conservation and a conservation kit. (*San Diego Union*, June 4, 1988)

June 13-14, 1988. State Water Resources Control Board is currently holding hearings on the drought. There were different versions of the water problem in the state. For example, El Dorado Irrigation District believed that the District was in trouble due to the drought, whereas, Coachella Valley Water District felt that they "are able to maintain without a negative impact on the rest of the state." (*San Francisco Chronicle*, June 14, 1988)

June 14, 1988. During a hearing by the State Water Resources Control Board, Mr. Kenneth Roed, Vice President of the California Water Service Co. testified that, during this drought in the state, there has been no unified policy for saving water. Each agency has its own policy and problems. For example, San Francisco Water Department testified that voluntary conservation "was not successful." Therefore, the Department imposed mandatory rationing. However, MWD testified that voluntary conservation measures are effective and get results. (*San Francisco Chronicle*, June 15, 1988)

June 1988. MWD of Southern California and the California Restaurant Association began distributing the water glass pictures. The card will suggest, "if you like a glass of water, just ask." (*Los Angeles Times*, June 16, 1988)

August 11, 1988. Federal Disaster Assistance Act of 1988 (Aid to Water Transfers) was signed into law. This Act authorizes the Secretary of Interior to assist water exchanges and transfers. It authorizes the Secretary "to assist willing buyers to purchase available water supplies from willing sellers, and to redistribute the exchanged water." (Drought Contingency Planning Guidelines for 1989)

1988. City of Willits trucked in water and a temporary pipeline was used to transfer water from Scout Lake. (Drought Contingency Planning Guidelines for 1989)

1988. SWP purchased 122,000 acre-feet from Bullards Bar Reservoir in a "trial transfer" approved by the State Water Resources Control Board. (Drought Contingency Planning Guidelines for 1989)

1988. South San Joaquin Irrigation District (SSJID) purchased 28,000 acre-feet of groundwater produced by 70 wells located near SSJID canals. (Drought Contingency Planning Guidelines for 1989)

Third Year: Water Year 1989 (October 1, 1988-September 30, 1989)

The third year of drought brought Assembly Bill 982 (AB 982) into effect, which expedited procedures for temporary water transfers in California. The southern Sierra Nevada runoff estimates were quite low during the middle of the third year of drought, and the Governor's water awareness week (first week of May) was observed by about 300 public and private agencies in the state. The San Francisco Water Department ended its year-long mandatory water-rationing program, while Los Angeles activated its conservation package program to 100,000 single-family homes. The Los Angeles Department of Water and Power (LADWP) was ordered to temporarily suspend diversions from the environmentally sensitive Mono Lake basin, and CVP water was conveyed by C-DWR for usage at the Kern National Wildlife Refuge.

January 1989. Assembly Bill 982 (AB 982) became effective in the state of California. This legislation establishes new, expedited procedures for temporary water transfers. AB 982 allows State Water Resources Control Board to exempt temporary transfers from the California Environmental Quality Act with a few minor exceptions. (California's Continuing Drought, January 1991)

May 1, 1989. A snow survey indicated that the southern Sierra Nevada runoff estimates are quite low. The Tule River drainage has the region's worst runoff situation with 36 percent of normal. The runoff estimates for the Kern, San Joaquin, and Kings Rivers are 50-60 percent, 54 percent, and 55 percent, respectively. (*Merced Sun Star*, May 4, 1989)

May 1-7, 1989. Governor George Deukmejian proclaimed this week as Water Awareness Week. There are about 300 water agencies in California, both public and private, who will recognize and observe this week. This week is observed to focus everyone's attention on the need of conserving water. The city of Los Angeles unveiled a 280-pound replica of a water faucet at the Music Center plaza during the kick off celebration of this week. (*Los Angeles Herald Examiner*, May 1, 1989)

May 7, 1989. "The drought really isn't over," said Loron Hodge, manager of the Water Association of Kern County. There are no headlines of alarming drought, but nothing much has changed in Kern County as they are "still dependent on imported water supply." (*Bakersfield Californian*, May 7, 1989)

May 10, 1989. Mandatory water rationing imposed on 2.2 million customers of San Francisco and suburban communities about one year ago, officially ended today. The San Francisco Water Department declared that the drought "is over for us." Also the San Francisco Public Utilities Commission dropped the plans to purchase $2 million of water from Yuba County. (*The Orange County Register*, May 10, 1989)

August 2, 1989. Los Angeles Mayor Tom Bradley announced a pilot program to deliver water conservation packages from door-to-door to 100,000 single-family homes. (*Los Angeles Herald Examiner*, August 3, 1989)

August 22, 1989. An El Dorado County judge ordered the Department of Water and Power of the city of Los Angeles to halt all diversions from the environmentally sensitive Mono Lake Basin until March 30, 1990. It is important to note that environmentalists, led by Mono Lake Committee have campaigned against any diversion of water from the lake as it lowers the lake level threatening the survival of nesting and migratory birds and other wildlife. (*Los Angeles Times*, August 23, 1989)

August 31, 1989. C-DWR conveyed 7,200 acre-feet of CVP water for the U.S. Fish and Wildlife Service. The water was conveyed to be used at the Kern National Wildlife Refuge. (Department of Water Resources Bulletin, 132-90)

Fourth Year: Water Year 1990 (October 1, 1989-September 30, 1990)

In this year, there was a distinct emphasis on long-term water supply sources. MWD studied proposals for potential sites for a desalting unit. MWD also purchased 705 acres of land for a possible reservoir site. An increasing number of Canadian firms started competing with each other to supply water to the drought-stricken Santa Barbara and other locations. Meanwhile, Ventura City officials examined the feasibility of transporting icebergs from the polar caps.

This period also saw instances of regional cooperation to supply water to the areas severely affected by drought. This was also a period of extreme distress for some areas, including Santa Barbara and Kern County. Governor Deukmejian proclaimed a state of drought emergency for the county of Santa Barbara. Additionally, Kern County Water Agency declared drought emergency. At the same time, however, Yuba County Water Agency was in a water surplus situation.

Several urban entities in California adopted policies in the past that used constrained water supplies in order to slow down or prevent urban growth. The drought has revived an old controversy about the relationship between the availability of water supply and urban growth. Many respondents gave the example of Santa Barbara to demonstrate a failure of such policies. According to the city of Santa Barbara Public Works Department (personal communication 1992), many inaccurate statements about the drought emergency in Santa Barbara have received wide circulation such that they are believed to be accurate. The Public Works Department indicated that the local community does not believe that constrained water supplies failed to slow down urban growth in the Santa Barbara-Goleta area. Constrained water supplies did not stop growth as some would have wished; but shortage contributed to slowing growth in the area. Additionally, the Public Works Department indicated that the city of Santa Barbara did not put constraints on the expansion of its water supply to sustain a less than 10 percent growth. In the early 1980s, the city adopted the Goleta Overlap Agreement that added 1,000 acre-feet per year of demand, and the environmental review of that agreement documented the need for additional supplies. The remainder of the 1980s was spent trying to add supplies, first by the enlargement of Gibraltar Reservoir and then by the enlargement of Cachuma Reservoir. The city does not share groundwater resources with Goleta Water District.

The desalination alternative seemed to have gained strength in this year as a possible long-term solution to the water shortages. The city of Santa Barbara had examined several water supply proposals and finally decided in favor of building of a desalting plant. The Santa Barbara Public Works Department (personal communication 1992) states that the emergency situation had little to do with the cost of additional supplies. The emergency desalination facility has costs similar to the SWP supplies for the city. Due to the drought, the attitude toward paying for expensive supplies changed. The Public Works Department notes that the city's location makes these supplies expensive. The city of Santa Barbara voters never approved the "critical planning period approach"; it was adopted by the City Council. The city of Santa Barbara signed a contract with Ionics, Inc., for preliminary work on building a reverse-osmosis desalter. In fact, the consensus of a meeting of the Assembly Committee on Economic Development, International

Trade and Technologies favored desalination as an option during drought. Marin Municipal Water District also opened a pilot desalination plant during this year.

The prolonged drought conditions resulted in overpumping of the groundwater in California. In the Central Coast, the farm-rich Salinas Valley faced serious seawater intrusion into its aquifers and the water table dropped an average of 15 feet below sea level during the past three years of dry weather. Also, the city of Los Angeles was blamed for destroying the Owens Valley vegetation due to overpumping of groundwater from its eastern Sierra Nevada properties. Los Angeles stopped pumping groundwater from this region due to the pressures from the Owens Valley ranchers and the Inyo County officials.

The Delta smelt, a three-inch-long fish, attracted much attention when the Fish and Game Commission refused to list it as a threatened species. The Delta smelt remained a major issue between the environmentalists and the state water lobby. Also, in this year, the C-DWR released 30,000 acre-feet to aid outmigration of juvenile chinook salmon.

October and November 1989. C-DWR conveyed 30,000 acre-feet water through Banks Pumping Plant for the Department of Fish and Game. This water was released to aid the outmigration of juvenile chinook salmon. (Department of Water Resources Bulletin, 132-90)

March 1990. SWRCB Division of Water Rights sent notices of curtailment of water use to 88 water right permit or license holders on the San Joaquin River. (California's Continuing Drought, January 1991)

March 1990. Officials of Simi Valley, Thousand Oaks, Moorpark, Camarillo, and Oxnard in eastern Ventura County indicated that they will comply with the request from MWD of Southern California to prepare ordinances that would require reductions in water because of the worsening drought. (*Los Angeles Times*, Ventura County, March 13, 1990)

March 14, 1990. The U.S. 9th Circuit Court of Appeals upheld revisions of the 1902 Reclamation Act that Congress enacted in 1982 providing that farmers could get federally subsidized water to irrigate up to 960 acres of land. The farmers will pay full cost of water on acreage above 960 acres. This decision was a significant blow to large corporate farms such as J.G. Boswell Co. and Southern Pacific Land Co. These corporate farmers got subsidized water even though they controlled land far in excess of the law's original 960 acre limit. (*Los Angeles Times*, March 15, 1990)

March 1990. The State Lands Commission, a government watchdog over state landholdings, agreed to file a legal brief supporting efforts by the National Audubon Society and the Mono Lake Committee to keep in effect a preliminary injunction that has stopped the city of Los Angeles from diverting water from streams feeding the Eastern Sierra Lake since midsummer of 1989. (*Los Angeles Times*, March 29, 1990)

April 1990. City of San Luis Obispo imposed a rationing program to reduce residential use by 30 percent. (Western Water, May/June 1990)

April 1990. Under the pressure from Owens Valley ranchers and Inyo County officials, the city of Los Angeles has agreed to stop pumping groundwater from its Eastern Sierra Nevada properties. This source is one of the city's three largest sources of water. This step has been taken in response to the prolonged drought and the toll it has taken on the Owens Valley vegetation. Inyo County residents had blamed Los Angeles for pumping water and lowering the water levels in private wells and killing vegetation. Inyo County and Los Angeles had battled in court over the pumping. (*Los Angeles Times*, April 4, 1990)

April 23, 1990. The Imperial Irrigation District (IID) approved a plan designed to save up to 70,000 acre-feet of water per year. This plan was designed to ensure that IID does not exceed 3.85 million acre-feet water consumption limit set by the Bureau of

Reclamation. Last year, the county exceeded the limit by 100,000 acre-feet. If IID exceeds its water allocation, the excess use will be deducted from future water allocations. (*Imperial Valley Press*, April 24, 1990)

April 24, 1990. The General Manager of Hetch Hetchy water project, Mr. Andy Moran testified that it faces the worst drought in its seventy years of operating history. The testimony came at a meeting of the San Francisco Public Utilities Commission. (*Placer County Journal*, April 25, 1990)

May 1, 1990. The Demonstration Semitropic Local Element Agreement executed to serve as a prototype for establishing local elements of the Kern Water Bank. (*C-DWR Bulletin 132-90*)

May 1990. Reacting to Mayor Tom Bradley's proposal for mandatory water rationing for the city of Los Angeles, the Apartment Association of Greater Los Angeles has asked how they can get their tenants to cut back on water use when a vast majority of apartments are master-metered. (*Los Angeles Times*, May 13, 1990)

May 1990. The farm-rich Salinas Valley in the Central Coast of California is facing serious seawater intrusion problems due to overpumping from the groundwater aquifers. The ocean water is reported to have seeped as far as five miles into these groundwater aquifers. The aquifers in the valley have dropped an average of 15 feet below sea level in the past three years of dry weather. (*Sacramento Bee*, May 13, 1990)

May 1990. San Diego County voters rank California's water shortage as the number one issue facing the state; higher than crime and drugs, according to a poll conducted for the *San Diego Union*. The survey interviewed 400 registered voters and was conducted May 15-20. (*San Diego Union*, May 24, 1990)

May 24, 1990. Kern County Water Agency directors declared a drought emergency. The declaration allows the agency to execute drought-relief projects without resorting to the time-consuming environmental study and competitive bidding procedures required by state law. (*Bakersfield Californian*, May 25, 1990)

June 1990. Heavy structural losses resulted from a fire that swept down from San Marcos Pass towards Goleta in Santa Barbara County. (California's Continuing Drought, January 1991)

June 1990. Not all in California have been hit by drought. The Yuba County Water Agency has reaped a windfall of $15 million by helping less fortunate regions with its "phenomenal water surplus." This agency captures runoff from one of the most generous watersheds in the state—"a swath of the High Sierra between Donner Summit and the Sierra Buttes." The District has rights to about five times as much water as its irrigation customers use. (*Sacramento Bee*, June 3, 1990)

June 4, 1990. Ventura city officials have decided to study the possibility of transporting icebergs from the polar caps and planting them off the county's shores. The iceberg idea is one focus of a $175,000 research project on possible long-term water supplies approved by the City Council of Ventura. (*Los Angeles Times*, June 6, 1990)

June 1990. A heavy rain in Marin County late in May allowed the directors of the Marin Municipal Water District to call off possible mandatory water rationing. Marin's seven reservoirs gained about 2,300 acre-feet of water from these unexpected heavy rains. (*San Francisco Chronicle*, June 8, 1990)

June 1990. A plan to use the San Gabriel Valley's vast underground water storage basin as a safety valve for the Southland's dry spells is being considered by the MWD of Southern California. (*Star News*, June 12, 1990)

June 12, 1990. A Los Angeles City Council committee recommended a 10 percent mandatory water-rationing plan as water conservation efforts average 5 percent this year. However, the Los Angeles residents have saved an average of 11 percent in the two months of April and May of this year. A full council will consider this proposal next month. (*Daily News*, June 13, 1990)

June 14, 1990. MWD of Southern California approves a $628 million operating budget for fiscal year 1990-91 with key elements of large-scale water conservation programs and construction and expansion of needed water delivery systems for Southern California. The District is offering $10 million worth of incentives to member agencies that are able to cut water use by more than 5 percent this summer. Overall, MWD's spending on conservation

efforts will reach $18.7 million. (*The Californian and The Valley Press*, June 15, 1990)

June 1990. Four years of continuing drought have prompted some interesting water-saving classes and seminars for this summer. Examples include "Drip Irrigation for the Home Gardener" (one-day UCLA extension program) and "Xeriscape: Gardening for a Dry Climate" (meets five days at UCLA). (*Los Angeles Times*, June 24, 1990)

July 13, 1990. The city of Santa Barbara lifted its ban on watering lawns during the drought. A wildfire that destroyed hundreds of homes near Santa Barbara led to lifting of the ban that was imposed last February. These fire-damaged areas had brown lawns and dry vegetation. (The *Sacramento Bee*, July 13, 1990)

July 16, 1990. The City Council of Los Angeles defeated Mayor Tom Bradley's proposal to impose mandatory water rationing this summer. In the event of failure on the part of businesses and residents to voluntarily conserve water use by at least 10 percent any month, then the Council will reconsider imposing water rationing. (*Los Angeles Times*, July 14, 1990)

July 17, 1990. Governor Deukmejian proclaimed a state of drought emergency for the city of Santa Barbara.

August 1990. A Canadian company's proposal to export water by tanker to drought-stricken Santa Barbara is being challenged by an Indian tribe in British Columbia that claims that the plan could damage the environment near its reservation. As the drought in California intensifies, an increasing number of Canadian firms are competing with each other to export water. The city of Santa Barbara is expected to vote on whether to approve the tanker water from Canada or build a desalination plant to supply the city. (*Los Angeles Times*, August 3, 1990)

August 9, 1990. The Assembly of California Legislature adopted Assembly Concurrent Resolution No. 180. It requests C-DWR to submit a report to the legislature by March 15, 1991, containing specified information regarding the availability of water for 1991. (California's Continuing Drought, January 1991)

August 30, 1990. The Fish and Game Commission denied the recommendation of the Department of Fish and Game to list the Delta Smelt as a threatened species under the state's Endangered Species Act. The C-DWR and the water lobby had opposed the recommendation of the Department of Fish and Game. (*Alameda Yodeler*, October 1990)

September 1990. MWD has approved a $500,000 study to determine potential sites for a demonstrating desalting unit. "This planning program will determine the appropriate actions taken by Metropolitan to plan, design, construct, and operate a demonstration seawater desalination plant on the Southern California coastline." (U.S. Water News, September 1990)

September 1990. MWD of Southern California purchased 705 acres of land for possible reservoir site. (*Riverside Press-Enterprise*, September 12, 1990)

September 15, 1990. The level of Lake Tahoe dropped below its natural rim jeopardizing water supplies for the downstream communities for the second time during the four-year drought. (California's Continuing Drought, January 1991)

September 18, 1990. City of Santa Barbara signed a contract with Ionics, Inc. for preliminary work on a proposed 2,500 to 10,000 acre-feet/year capacity reverse-osmosis desalter using seawater. (California's Continuing Drought, January 1991)

September 19, 1990. Imperial Irrigation District (IID) objected to a request from the U.S. Bureau of Reclamation to conserve about 85,000 acre-feet of water by the end of the year for the District. (*Imperial Valley Press*, September 19, 1990)

September 1990. Archbishop Roger Mahoney urged all Catholics in Los Angeles Archdiocese to join in an effort aimed at alleviating the severe drought now plaguing California for the fourth straight year. "Conservation is a form of worship," Mahoney remarked. (*Antelope Valley Press*, September 21, 1990)

September 20, 1990. Desalination as an option during drought was the consensus expressed by scientists, engineers, businessmen, and lawmakers at meeting of the Assembly Committee on Economic Development, International Trade, and Technologies chaired by Assemblyman Richard Polanco. Mr. Polanco compared Southern California's dependence on imported water from the Sacramento Delta and the Colorado River to America's reliance on foreign

energy supplies. (*San Gabriel Valley Tribune*, September 23, 1990)

September 25, 1990. Marin Municipal Water District (MMWD) opened a pilot desalination plant that uses "reverse osmosis." This is the first time when the desalination technology is being used on Bay water. (*Marin County News Pointer*, September 1990)

Fifth Year: Water Year 1991 (October 1, 1990-September 30, 1991)

During the fifth year of drought, Governor Deukmejian declared a state of drought emergency for the county of Santa Barbara. The Standard and Poors reviewed the impact of drought on the credit ratings of eight of the largest water system issuers of bonds. The review showed that the credit rating of at least one was likely to weaken due to the drought, as reduced water resulted in lower revenues. A preliminary report, submitted by Spectrum Economics to California Urban Water Agencies showed that aerospace, defense, computer, and food-processing businesses are increasingly nervous about the expected water shortages in California in the coming decade.

The October-February period of the 1991 water year was marked by an increase in precipitation deficit. This was followed by a very wet March that recorded precipitation up to three times the average for the month. The Miracle March turned a "desperate drought situation into a manageable one" (C-DWR 1991b). The March rains provided only a brief respite to the dry conditions, and 1991 turned out to be the driest of the 1987-91 period.

As the drought intensified, there were instances of cooperation among the water users. Southern California Edison Company, Southern California Gas Company, Metropolitan Water District of Southern California (MWD), and Los Angeles Department of Water and Power formed a water-energy conservation partnership. At the same time, MWD and Imperial Irrigation District (IID) entered into an agreement that would allow 100,000 acre-feet of the IID water allotment to be transferred to MWD. Research, funded through MWD, investigated if alfalfa could be grown with less water in Imperial County. During this year, MWD also agreed to transfer 7,200 acre-feet of emergency water to the water districts in southern Santa Barbara County through Oxnard and Ventura.

During this water year, the MWD started providing cash incentives to its member agencies to conserve water. By the end of the year, this conservation effort created an unexpected water surplus for the MWD. As MWD did not have sufficient storage capacity, they decided to sell the surplus water.

Proposition 128, also known as "Big Green," was rejected by Californians. This proposition included sweeping environmental reforms by providing full protection to fish, shellfish, and their habitat. However, the environmental community rejoiced in the decision of a U.S. District Judge ordering Glenn-Colusa Irrigation District to cut back in river pumping to protect the chinook salmon population. By the end of the water year, the U.S. Fish and Wildlife had recommended to the U.S. Department of Interior to list the Delta smelt as a "threatened," rather than "endangered," species.

In this year, a controversial Katz Bill (Assembly Bill 2090) was initiated to allow farmers to sell water directly to the urban agencies. This bill was opposed by the agricultural sector, who contended that this measure would transform the California farm belt into barren land. Finally, the Senate Agriculture and Water Resource Committee voted against the bill.

The drought seemed never-ending, and the three participants of the Three-Way Process struggled to survive. By the end of this water year, the environmental sector had secured its position as a major player in the water politics of California.

October 1990. California Department of Fish and Game and federal fisheries agencies met with a number of water agencies to begin developing plans for 1990. Operations for minimum flows and temperature control were discussed.

October 2, 1990. Southern California Edison Co., Southern California Gas Co., MWD of Southern California, and Los Angeles Department of Water and Power announced the formation of a water-energy conservation partnership. As a first project, Edison workers will install 16,000 water-saving toilet tank flappers supplied by MWD in low-income homes in the electric utility service area. "Electricity, natural gas, and water have in common the need for conservation. In fact, they are interrelated," remarked John Bryson, CEO of the Edison Co. (*San Gabriel Valley Tribune*, October 3, 1990)

October 1990. San Diegans cut their water use by 10.7 percent for the months June through September. This was achieved through voluntary conservation measures. (*San Diego Union*, October 7, 1990)

October 1990. MWD of Southern California has approved $150,000 to fund research in the Imperial County to see if alfalfa can be grown with less water. Alfalfa is a major crop in this county. The MWD and Imperial Irrigation District (IID) have entered into an agreement that will allow 100,000 acre-feet of water to be transferred from IID's allotment of Colorado River water to MWD. In return, MWD will pay for expensive improvements in the irrigation system, including lining of canals and new reservoir construction. (*Imperial Valley Press*, October 12, 1990)

October 10, 1990. The Metropolitan Water District of Southern California Board of Directors voted to support Proposition 148. This proposition would provide funding for water treatment facilities and supply development, flood control, drought relief, wastewater and contaminated groundwater reclamation, and other such projects. (*Paramount Journal*, October 18, 1990)

October 1990. Berrenda Mesa Water District has proposed selling some of its water from the California Aqueduct to a Southern California developer (Summit Valley Partners) in what could be the first transfer of SWP water out of Kern County. The developer has offered $20 million in exchange for permanent rights to 20,000 acre-feet of water per year. (*Bakersfield Californian*, October 21, 1990)

October 25, 1990. Senator Pete Wilson, R-California, moved to hold the water reclamation bill that would limit the size of farms to 960 acres for being eligible to receive subsidized water. Earlier in August, the *Orange County Register* had examined farm water policy and found that the CVP farmers are using billions of federally subsidized water to grow crops. Some water districts in the Sacramento River Valley pay $1.50/acre-foot of water, whereas MWD in Southern California pays $233/acre-foot of water drawn from the same river delta. (*Orange County Register*, October 26, 1990; *San Diego Union*, October 20, 1990)

October 1990. Importing state water to Santa Barbara County was favored 4 to 1 by county residents surveyed in recent News-Press poll conducted by Richard Hertz consulting firm. (*Santa Barbara News Press*, October 22, 1990)

October 1990. Fitch Investor Service reported on how drought was affecting four hydroelectric projects. Reduced water results in reduced generation and lower revenues that can affect timely payments of debt service on these projects' bonds. The eight large drought-affected issuers monitored by Standard & Poor's have a combined total of $3.6 billion in bonds outstanding. Recently, Standard & Poor's also reviewed the effect of drought on these eight of the largest water-system issuers of bonds and concluded that the credit rating of at least one was

likely to weaken due to the drought situation. (*Sacramento Bee*, November 2, 1990)

October 30, 1990. Kern County Water Agency unveiled their "What if" drought contingency plans at a state Department of Water Resources. (*Bakersfield Californian*, October 31, 1990)

November 1990. A proposed pipeline, called the Inland Feeder, connecting the SWP's east branch aqueduct in San Bernardino County with Metropolitan's Colorado River Aqueduct in Riverside County will be discussed in four community meetings in November 1990. (*Moreno Valley Butterfield Express*, October 21, 1990)

November 1, 1990. The Department of Water and Power (DWP) in Los Angeles announced that its customers had cut down their water usage by only 5.2 percent in October 1990, far short of the 10 percent conservation goal. It was the first time in the six months that the DWP has been measuring conservation efforts that the city of Los Angeles failed to meet its 10 percent goal. At this time, the DWP officials do not see any mandatory rationing of water for the city any time soon. (*Los Angeles Times*, November 2, 1990)

November 13, 1990. Governor Deukmejian proclaimed a state of drought emergency for the county of Santa Barbara.

November 1990. Eastern Municipal Water District is providing area school districts a combination of free information, teacher workshops, in-class presentations, plays, computer programs, and contests to teach students water awareness and conservation. (*Riverside Press-Enterprise*, November 6, 1990)

November 6, 1990. Voters rejected Proposition 128. This proposition included sweeping environmental reforms known as "Big Green." Section 5.7 of Big Green proposition provides a "full protection to and propagation of fish, shellfish, and their habitat in the state marine bay, estuarine, and ocean water." The opponents of this provision believed that it would give priority to fish and game over people and agriculture for their water needs, particularly during this serious drought. (*Los Angeles Times*, November 8, 1990)

November 1990. MWD and Wells Fargo Bank teamed up to bring water conservation message to public through a special water-saving kit prepared by the district. (*San Marino Tribune & News*, November 8, 1990)

November 14, 1990. Sierra Club officials asked the city of Los Angeles to fill a wildlife lake with potable water despite the current drought. They claimed that thousands of migratory birds are passing Sepulveda Basin without stopping. The city officials show reluctance to use potable water as they had faced serious public criticism last year when they put drinking water in the 11 acre lake. The city officials plan to put only the reclaimed water when they receive it from the Tilman sewage treatment plant. (*Orange County Register*, November 15, 1990)

November 16, 1990. U.S. Deputy Regional Forester David M. Jay ruled that propane cannot be sprayed into the winter clouds over the middle fork of the Feather River until the federal agency has reviewed an appeal filed October 29 by a sport fishing organization. The California C-DWR had planned a five-year prototype $2-million project for cloud seeding with a potential increase of 10 percent of the snowpacks and adding 21,000 acre-feet of water to the annual spring runoff into Lake Oroville. (*Bakersfield Californian*, November 18, 1990)

November 1990. Recently, the Association of California Water Agencies (ACWA) presented the vulnerability of the Sacramento-San Joaquin River Delta to a possible major earthquake and resulting disruption of water supply for the state. The opponents of the Peripheral Canal proposal accused ACWA for implicitly attempting to revive the Peripheral Canal proposal as a remedy to the situation. (*Bakersfield Californian*, November 20, 1990)

November 1990. The Association of California Water Agencies (ACWA) has sponsored an 18-month publicity campaign, called "Living on the Edge," to show the desperate situation of the California water supply problem. The cost of the campaign is estimated to be $350,000. (*Bakersfield Californian*, November 21, 1990)

November 20, 1990. Modesto Irrigation District agreed to sell water to San Francisco. The San Francisco Public Utilities Commission still has to approve the offer. (*Modesto Bee*, November 21, 1990)

November 21, 1990. The state C-DWR released its 620-page draft environmental report on its five-year,

$290 million plan to enlarge waterways in the northern Sacramento-San Joaquin Delta. (*Bakersfield Californian*, November 23, 1990)

November 1990. MWD will provide cash incentives to its member agencies to conserve water. (*Madera Tribune*, November 21, 1990)

November 1990. It has been planned to transfer 7,200 acre-feet of emergency State Water Project water through the MWD to Oxnard to Ventura water main. Ventura would then exchange an equal amount of water to Santa Barbara from its supplies at Lake Casitas. (*Ventura County and Coast Report*, November 22, 1990)

November 1990. As MWD faces a cutback in its supply of water of 300,000 acre-feet from the Colorado River next year, it is exploring the possibility to enter into some "temporary" arrangements with water districts such as Imperial Water District, Palo Verde Water District, and Coachella Water District. (*Imperial Valley Press*, November 27, 1990)

December 1990. A 16-inch steel pipe became a part of a three-mile Oxnard-to-Ventura connection to initiate exchanges and transfer to move emergency state water to water districts in southern Santa Barbara County in 1991.

December 11, 1990. The Board of Directors of Metropolitan Water District decided to impose a mandatory water-rationing plan beginning February 1, 1991. This decision was taken in consideration of the impending fifth year of drought. (*Simi Valley Enterprise*, December 12, 1990)

December 1990. The farmers in Ventura County are facing a 20 percent cut for the next year on use of imported water from the Metropolitan Water District. (*Oxnard Press Courier*, December 13, 1990)

December 1990. 12,530 citations for water wasting have been issued since the last seven months when the Drought Buster (drought-coping) program first began. This $1 million-a-year program is part of the anti-drought response of the Los Angeles Department of Water and Power. (*Daily News*, December 23, 1990)

December 19, 1990. The state C-DWR shut off the California Aqueduct deliveries from the Edmonston pumping station to the Los Angeles basin for one week. This action was prompted by the fact that lack of rains have caused the reservoir levels in the north to dip to low levels. (*Press Enterprise*, December 28, 1990; *Los Angeles Times*, December 24, 1990)

December 1990. Governor-elect Pete Wilson named Douglas P. Wheeler, a former Sierra Club director as his Secretary of Resources. Mr. Wheeler pledged to aggressively mediate disputes between the environmental movement and the business community. (*Los Angeles Times*, December 27, 1990)

1990. The Central Valley of Fresno drilled six new wells and is exchanging reclaimed water for Kings River water.

1990. City of Napa purchased 6,500 acre-feet of water from the Yuba County Water Agency's Bullards Bar Reservoir and had it delivered via the SWP North Bay Aqueduct.

1990. Three units of C-DWR's largest power plant were shut down due to low reservoir levels at Lake Oroville requiring the purchase of replacement capacity and energy.

1990. In 1990 alone, it is estimated that 5 billion board feet timber were killed by drought-related causes.

1990. Cities supplied by the CVP were cut back 25 to 50 percent. (C-DWR, January 1991)

1990. SWP cut deliveries to agricultural customers by 50 percent. (C-DWR, January 1991)

1990. According to C-DWR economists, the direct economic cost to California agriculture of the 1990 drought is forecasted to be $455 million (3 percent of 1989 value of California's agricultural output.)

February 15, 1991. Governor Pete Wilson established the Drought Water Bank as a part of a four-point drought plan. (A Retrospective 1991 Emergency Drought Water Bank, March 1992)

February 25, 1991. The Water Districts in southern Santa Barbara County began receiving emergency SWP water deliveries. Emergency transfers were made from C-DWR through MWD to Oxnard to the City of Ventura. An equal amount of metered water is accounted for as "in-lieu" exchanges at Lake Casitas. Water is conveyed from Casitas via

temporary pipelines through the Carpinteria County Water District.

March 1, 1991. SWP deliveries were cut to 10 percent of contractual entitlements for municipal users and were suspended for agricultural users. The First declaration of available CVP supplies was 25 percent of entitlements for agricultural customers, 25 to 50 percent for urban users, and 75 percent for water rights holders in the Sacramento River, and exchange contractors in the San Joaquin River. (Howitt, R, Moore, N, and Smithe R. T., 1992)

March 1, 1991. The city of Los Angeles imposed water rationing requiring the residents to cut water use immediately by 10 percent from 1986 levels and an additional 5 percent by May 1. (*Los Angeles Times*, March 1, 1991)

March 1991. A bill proposing to renew research and development on seawater desalination was introduced in the U.S. Senate by Senator Paul Simon, D-IL. (*Imperial Valley Press*, March 3, 1991)

March 1991. Despite the heavy March rainfall, California's rainfall, snowfall, and runoff for the year are still well below average. (*Los Angeles Times*, March 30, 1991)

March 1991. Heavy March rainfall raises Lake Cachuma (southern Santa Barbara County's principle surface water supply) from 12 percent to 40 percent of capacity thus avoiding drawing the lake down to 3 percent of capacity (approximately 50 percent of the dead storage) during the 1991-92 water year.

April 9, 1991. Santa Barbara city officials lifted a 14-month ban on lawn watering after the March rains. (*Los Angeles Times*, April 10, 1991)

April 1991. Spectrum Economics, energy and natural resources consultants, submitted a preliminary report to California Urban Water Agencies indicating that aerospace, defense, computer, and food-processing businesses are growing increasingly nervous about the expected water shortages in the coming decade that creates corporate bias against plant expansion and location in California. (*Los Angeles Times*, April 23, 1991)

June 4, 1991. California Assembly Committee passed legislation that would make it easier for farmers to sell water to drought-stricken cities. This bill is still a long way from passage. The opponents of this bill charge that this would transform California's farm belt into "another Owens Valley." Owens Valley once a productive agricultural area, had turned into barren land as Los Angeles bought the land and pumped water to the city. (*Los Angeles Times*, June 5, 1991)

June 4, 1991. Santa Barbara County voters approved measures to import water through the State Water Project into the region. The voters also approved building of a desalination plant in an advisory election. (*Los Angeles Times*, June 6, 1991)

June 20, 1991. The House of Representatives overwhelmingly approved a bill that would bar delivery of subsidized water to farms larger than 960 acres. This legislation is designed to plug the loopholes that allow corporate farmers such as J.G. Boswell, Co. to receive subsidized water. (*Mercury News*, San Jose, June 21, 1991)

June 20, 1991. The House of Representatives passed a bill requiring the farmers who use federal irrigation water for growing subsidized crops to pay 100 percent of the delivery costs of the water. (*Star Tribune*, June 22, 1991)

June 26, 1991. The officials attending the California Association of Water Agencies Conference said that the state was still in drought despite heavy March rains. They believe that water rationing is likely to continue. (*Daily News*, June 27, 1991)

July 2, 1991. The California State Assembly approved the legislation that allows more freedom to farmers to sell water rights to the drought-stricken cities. The bill was sent to the state senate after a 46-25 vote. This bill was opposed by several rural legislators. (*Imperial Valley Press*, July 3, 1991)

July 2, 1991. In a 46 to 25 vote, the California Assembly passed legislation that would allow farmers to sell their water without interference from their local irrigation districts. This was a clear victory of the urban interests over the rural in this battle for water. (*Los Angeles Times*, July 3, 1991)

July 1991. MWD of Southern California proposed to build a water bank in the Coachella Valley where it will deposit water in wet years and withdraw it in dry seasons. The Desert Water Agency directors fear a loss of water quality should MWD bank water in the Coachella Valley. (*Riverside Press-Enterprise*, July 17, 1991)

July 16, 1991. Gov. Pete Wilson temporarily withheld the controversial water-sales bill that allows individual farmers to directly sell water to cities. Water Resources Director David Kennedy expressed "serious concerns" with a number of provisions in the bill. (*Los Angeles Times*, July 17, 1991)

July 23, 1991. Two Southern California officials asked the U.S. Senate panel to provide federal funds for desalination research. The Senate Committee is considering legislation that would authorize the Interior Department to fund at least $90 million worth of research during the next five years. (*Los Angeles Times*, July 24, 1991)

August 1991. Gov. Wilson signed legislation by Sen. Don Rogers to add nearly $2.3 million to California Conservation Corps (CCC) for drought-related activities. This will provide extra help to the state C-DWR and local agencies in looking for water leaks, putting in drought-resistant plants and helping with fish and wildlife habitat preservation. (*Bakersfield Californian*, August 7, 1991)

August 6, 1991. The King River Report was released. This indicated that there was a decline of 3 million acre-feet in water beneath the King River Conservation District during the fall of 1986 through the fall of 1990. This drop in underground water has occurred due to the long drought. (*Bakersfield Californian*, August 7, 1981)

August 1991. A congressional agency, Office of Technology Assessment (OTA) dismissed the idea of an undersea 2000-mile pipeline carrying water from Alaska to California. The agency considers this alternative as unnecessary and unfeasible based on its high projected cost and adverse environmental implications. This Alaskan pipeline proposal was earlier advanced by the Alaskan Governor, Walter J. Hickel, and L.A. County Supervisor, Kenneth Hahn. (*Los Angeles Times*, August 13, 1991)

August 1991. Huntington Beach has been tentatively selected as a site for a $60 million experimental ocean-desalting plant, owned by the MWD of Southern California. (The *Orange County Register*, August 13, 1991)

August 16, 1991. A U.S. District Judge ordered the largest water diverter on the Sacramento River, Glenn-Colusa Irrigation District, to cut back in river pumping to protect the population of chinook salmon. Chinook salmon is listed as an endangered species under the federal law. The irrigation district had contended that the cutback would result in a significant crop damage in its area. A temporary restraint order was requested by the National Marine Fisheries Service, an arm of the U.S. Dept. of Commerce. (*Sacramento Bee*, August 17, 1991)

August 17, 1991. The MWD of Southern California board of directors agreed to sell up to 50,000 acre-feet of water to relieve an unexpected surplus of water in local reservoirs. The surplus of water during the drought was created as a result of successful conservation efforts in Southern California. (*Daily News*, August 21, 1991)

August 20, 1991. The Senate Agriculture and Water Resources Committee voted against the Assembly Bill 2090 (Katz Bill) after Governor Pete Wilson refused to support the measure. This bill would have allowed farmers sell water directly to the urban agencies. (*Daily News*, August 21, 1991)

August 20, 1991. MWD of Southern California decided to abandon a multimillion dollar program of water conservation rewards. The MWD has paid out $26 million during the past five months as incentives to agencies for conserving water. These incentive payments will be eliminated as of October 1, 1991. The MWD also decided to reduce the price of some of its water. These steps were taken in view of surplus reservoirs. The MWD has more water than it can comfortably hold as a result of an unexpectedly successful conservation program that includes cash incentives to member agencies for using less water. (*Los Angeles Times*, August 21, 1991)

August 1991. Scientists at the National Oceanic and Atmospheric Administration's Climate Analysis Center in Maryland are tracing a "weak El Niño" in the Pacific Ocean. El Niño, a powerful warm water ocean current, can bring "drought-busting" storms to Southern California this winter. (*Daily News*, August 22, 1991)

August 1991. San Juan Suburban Water District started installing water meters for its customers in northeast Sacramento, California. This is part of a program aimed at increasing water supplies up to 50 percent through conservation. (*Sacramento Bee*, August 30, 1991)

September 3, 1991. The U.S. Environmental Protection Agency told the State Water Resources Control Board that their Water Quality Plan (May

1991) for the Sacramento-San Joaquin Delta is inadequate. The temperature and salt levels adopted in the plan were not sufficient to protect "the ecological health of the estuary." These variables are controlled by varying the release of water in the delta. (*Los Angeles Times*, September 4, 1991)

September 1991. The MWD of Southern California is planning to build a massive reservoir in Riverside County. The proposed Domenigoni Valley reservoir would hold 800,000 acre-feet of water. This will nearly double the existing storage capacity of MWD. This project is being undertaken because during the drought, MWD had to sell water at a bargain price as it did not have enough storage capacity. (*San Gabriel Valley Tribune*, September 8, 1991)

September 10, 1991. The East Bay Municipal Utility District Board voted not to participate in the statewide water pact which called for California cities and suburbs to adopt voluntary conservation measures that could save enough water to supply the residential needs of 2.5 to 5 million Californians. The opponents of this pact think that the District already conserves enough water and does not need any more conservation. (*San Francisco Chronicle*, September 11, 1991)

September 24, 1991. MWD of Southern California decided to break its traditional alliance with the agricultural interests and pursue a free-market policy of buying water wherever it can. Under the existing law, urban agencies are not allowed to buy water directly from farmers. The Katz Bill intended to do this, but was recently defeated. MWD plans to draft its own legislation to effect this change. MWD will need this new legislation to pursue its new strategy. (*Los Angeles Times*, September 25, 1991)

September 27, 1991. The U.S. Fish and Wildlife Service has proposed to list a three-inch long delta smelt of San Joaquin-Sacramento River Delta as a "threatened" rather than "endangered" species under the Endangered Species Act. "Threatened" status is less severe than the "endangered" one in terms of its implications on the curtailment of exports of [illegible]er from the delta. This recommendation will [illegible] considered by the U.S. Department of Inter[illegible] acceptance of the listing. (*Los Angeles Times*, September 27, 1991)

Sixth Year: Water Year 1992 (October 1, 1991-September 30, 1992)

Despite higher rainfall than in previous years in the first half of this year, the drought conditions persisted, with the Sierra runoff staying at below its normal level. California was in a drought for the sixth year. The conservation efforts had paid off by reducing water use and, at the same time, lowering the revenue. The drought proved to be a financial drag for most of the water purveyors. This water year saw an effort by these purveyors to increase the water rates to cover the cost of drought. The Los Angeles Water and Power Commission attempted to increase the water rates, but the Los Angeles City Council rejected the idea. Many water consumers believed that it was a penalty imposed on them for conserving water during drought. The public becomes incensed by being required to pay more for less.

October 1, 1991. The Los Angeles Water and Power Commission voted to seek an 11 percent increase in water rates and to double an emergency surcharge to cover part of a projected $98.8 million deficit caused by the five-year drought. (*Los Angeles Times*, October 2, 1991)

October 15, 1991. Los Angeles Department of Water and Power signed an agreement with the Inyo County Board of Supervisors confirming the city's water rights in Owens Valley and regulating the amount of water that can be pumped out of the area. (*Los Angeles Times*, October 16, 1991)

December 1991. The Los Angeles City Council rejected a proposed 11 percent water rate hike by the Department of Water and Power (DWP). The DWP argued that the rate hike was necessary due to reduced revenues as a result of the city's mandatory rationing. (*Daily News*, December 5, 1991)

December 5, 1991. The Department of Water Resources announced that the farmers in Kern County will at least get 20 percent of their requested SWP water next year. (*Bakersfield Californian*, December 6, 1991)

December 17, 1991. The Sacramento City Council decided to require all new homes to install water meters. (*Sacramento Bee*, December 18, 1991)

January 1992. A U.S. District Judge ordered Glenn-Colusa Irrigation District prohibiting diversion of water from the Sacramento River near Hamilton City from July 15 to November 30 each year. (*Sacramento Bee*, January 10, 1992)

January 1992. The Walnut City Council narrowly rejected a proposal to ban the use of "greywater" to irrigate yards. (*Los Angeles Times*, January 26, 1992)

January 1992. The MWD of Southern California lost $129 million last year due to its aggressive conservation campaign that led to decline in sales revenue. (*Orange County Register*, April 19, 1992)

February 6, 1992. Central Valley Project confirmed that water deliveries to some farmers would be totally cut-off this year. (*Bakersfield Californian*, February 11, 1992)

February 27, 1992. Governor Pete Wilson will seek negotiations with the Bush Administration for takeover of the Federal government's Central Valley Project irrigation system and merge it with the state's water system. (*Los Angeles Times*, February 28, 1992)

March 1992. A study conducted by the Northwest Economics Associates indicated that the San Joaquin Valley's farm economy suffered $545 million loss last year. Nine thousand jobs in this sector were lost and 253,000 acres were left fallow as there was insufficient water available. (*Tribune*, March 20, 1992)

March 20, 1992. The Bureau of Reclamation announced that CVP agricultural contractors will receive 25 percent of their normal water allocations this year. At the same time, State Water Project also announced increase in deliveries to 45 percent of the amount requested by the water agencies. (California Farmer, April 1992)

April 6, 1992. Governor Pete Wilson announced his new long-term water policy that emphasizes marketing and conservation of existing supplies, new storage facilities, and changes in to Sacramento-San Joaquin Delta. The plan for the Delta includes construction of flow control barriers, enlargement of channels and shifting of the pumping of water from the Delta to winter months through use of four new pumps. His plan attempts to appease all three of the participants in the water issue. (*Sacramento Bee*, April 7, 1992)

April 28, 1992. The Chief Hydrologist for the State Department Water Resources confirmed that the state of California is still in the sixth year of drought despite recent high levels of rainfall. The Sierra runoff is below its normal level. (*Bakersfield Californian*, April 29, 1992)

April 28, 1992. The U.S. Bureau of Reclamation opened a new center in Sacramento to teach farmers how to conserve water. (Fresno Bee, April 29, 1992)

May 20, 1992. The state's drought Water Bank announced allocation of 90,970 acre-feet to water-short buyers. More than two-thirds of it (66,400 acre-feet) going to agriculture in the San Joaquin Valley. Department of Fish and Game has received an allocation of 14,570 acre-feet. The rest of the allocation (i.e., 10,000 acre-feet) has been given to Contra Costa Water District. (C-DWR News Release, May 20, 1992)

SUMMARY OF DROUGHT MANAGEMENT OUTCOMES

Water Allocation and Deliveries

The first three years of drought did not prompt any significant cutbacks to water allocation and deliveries in the SWP and CVP entitlements. These are two major projects that supply water to agricultural and municipal water uses, with the SWP accounting for 7.4 percent and the CVP providing 21.7 percent of California's supplies. The fourth year of drought, however, had taken its toll on the drawdown of water in project reservoirs and led to the first cutbacks in CVP and SWP supplies. Thus, in 1990, CVP cut most agricultural users by 50 percent, and similar reductions were made by SWP on agricultural users. Drought conditions worsened in 1991, and by the end of February, statewide precipitation, runoff, and storage reached the lowest levels during the ongoing four-year period. The SWP stopped agricultural deliveries completely and cut municipal users to 35 percent of their contractual entitlements which was further cut in 1992. CVP cutbacks left agricultural customers receiving 25 percent of entitlements, urban users obtaining 25 to 50 percent deliveries, and Sacramento water rights holders and San Joaquin exchange contractors getting 75 percent of their entitlements. Although these statistics on water deliveries were available, it should be noted that statewide statistics on water use during this drought by various water use sectors and water districts were not available during the time of this study. These statistics are expected to be released in January 1995 when the water management plans by various entities will be submitted.

In addition to these adjustments to water allocation and deliveries, the California Department of Water Resources allowed the use of its facilities for wheeling water and encouraged water exchanges. About 20 exchanges had been facilitated by November 1990 involving about 300,000 acre-feet of water (Gleick and Nash 1991). C-DWR was instrumental in effecting transfers under the direction of state laws enacted during the 1980s. Table IV.4 illustrates the individual water transfers facilitated as of December 1, 1991, using the State Water Project (C-DWR 1991b). Many other transfers independent of the SWP also took place. For example, about 60,000 acre-feet of water from four different agencies were transferred to the Department of Fish and Game to help restore fish and wildlife habitat.

SWP Deliveries

State Water Project deliveries are divided into entitlement water and other deliveries (surplus and unscheduled water, other water, and Feather River diversions). Entitlement water to municipal and industrial users showed no significant cutback during the first four years of the drought. However, in 1991 more than 50 percent of the 1987 SWP entitlement was cut back.

Deliveries of SWP entitlements to the agricultural sector remained normal for the first three years of the drought. The fourth year (1990) showed a 32 percent reduction in 1987 deliveries. However, SWP entitlements were drastically cut in 1991, and only 1 percent of the

TABLE IV.4

1991 WATER BANK TRANSFERS
(As of December 1, 1991)

Title of Transfer	Source Agency	Destination Agency	Amount of Transfer (AF)	SWRCB Action?	SWP Wheeling?	Oroville Storage?	CVP Wheeling?	Status
Dept. of Water Resources (C-DWR) Water Bank	350 contracts	Water Bank	831,403[2,3]	Yes[4]	Yes	Yes	Yes	Approx. 99% of contracts approved
Placer County Water Agency (PCWA)/San Francisco (SF)	PCWA	SF	20,000[1,2]	Yes	Yes	Yes 6,000 for DFG	No	SWRCB Approved
Placer County (PCWA)/Santa Clara Valley Water District (SCVWD)	PCWA	SCVWD	15,000[1,2]	Yes	Yes	No	No	SWRCB Approved
Kern County Water Agency (KCWA)/West-lands Water District (WWD)	KCWA	WWD	45,000	Yes	Yes	No	No	SWRCB Approved
Yuba County Water Agency (YCWA)/Four Agencies (N)	YCWA	N	7,500[2]	Yes	Yes	No	No	SWRCB Approved
Yuba County Water Agency (YCWA)/DFG	YCWA	YC	30,000[5]	Yes	No	Yes	No	SWRCB Approved

1 Approximately 20 percent allocated to Delta carriage water.
2 Refill impacts.
3 Approximately 15 percent allocated to Delta carriage water.
4 137,200 acre-feet subject to State Water Resources Control Board (SWRCB) jurisdiction (127,200 AF YWCA; 10,000 AF OWID).
5 For supplemental Yuba River fish flows, if necessary.
Source: C-DWR 1991b.

1987 entitlement was delivered to the agricultural sector. Total SWP deliveries (entitlement and other deliveries) in 1991 were 47 percent of the 1987 deliveries (Table IV.5).

CVP Deliveries

Central Valley Project water deliveries are divided into four categories: water rights water, project agricultural water, project municipal and industrial water, and waterfowl conservation water. The drought did not significantly affect deliveries to water rights holders. However, agricultural project water was cut by about 36 percent in 1990 and 58 percent in 1991, in comparison with 1987 deliveries. Municipal and industrial project water showed increased deliveries in 1988-90. However, in 1991 deliveries were reduced by about 30 percent from 1987 deliveries. Waterfowl conservation deliveries during the drought showed an increase of 1987 project water in order to reduce drought impacts on waterfowl populations (Table IV.6).

A more detailed breakdown of CVP contractual entitlements and drought shortages (CVP Contracts 1992) is provided in Table IV.7. Water rights holders are not permitted to receive more than 25 percent reductions in deliveries and therefore did not experience severe hardships during the drought. The total annual CVP contractual entitlements are 6.7 MAF. Project water makes up 55 percent, while water rights quantities make up 45 percent of the total.

The State Drought Emergency Water Bank of 1991

The fifth year of drought led to progressively greater water shortages, and on February 1, 1991, the Governor signed Executive Order No. W-3-91 that established the Drought Action Team. Besides representing the Governor, the team was to assist on a local and state level in handling the drought. On February 15, Governor Wilson announced a four-point drought plan. His plan can be summarized as follows:

- Establish a State Drought Emergency Water Bank (Water Bank) to meet critical water needs.
- Communities should adopt rationing plans with up to 50 percent cutbacks in water use.
- The California Department of Fish and Game must work with the U.S. Fish and Wildlife Service to protect natural habitat.
- Establish a $100 million Drought Action Fund to assist with conservation, water supply augmentation, and other drought mitigation activities. (Howitt, Moore, and Smith 1992).

C-DWR was responsible for operating the Water Bank, which was established to meet four critical needs: municipal and industrial uses, agricultural uses, protection of fish and

TABLE IV.5

TOTAL AMOUNTS OF WATER DELIVERED BY STATE WATER PROJECT, 1962-1991

	Water Delivered (Acre-feet)								
	Entitlement Water[a]			Other Deliveries Surplus and Unscheduled					
Year	Municipal and Industrial (1)	Agri-cultural (2)	Total (3)	Municipal and Industrial (4)	Agri-cultural (5)	Other Water[b] (6)	Feather River Diversions[c] (7)	Total Deliveries[d] (8)	Recreation Supported (Recreation days)[e] (9)
1962						18,289		18,289	30,000
1963						22,456		22,456	105,000
1964						32,507		32,507	331,600
1965						44,105		44,105	449,800
1966						67,928		67,928	482,700
1967	5,747	5,791	11,538	0	0	53,605		65,143	455,200
1968	46,472	125,237	171,709	10,000	111,534	14,777	866,926	1,174,946	931,300
1969	34,434	158,586	193,020	0	72,397	18,829	794,374	1,078,620	1,554,800
1970	47,996	185,997	233,993	0	133,024	38,080	759,759	1,164,856	1,804,800
1971	85,286	272,054	357,340	2,400	293,619	44,127	778,362	1,475,848	2,085,900
1972	181,066	430,735	611,801	22,205	401,759	73,127	817,398	1,926,290	1,971,200
1973	293,824	400,564	694,388	3,161	293,255	43,666	800,743	1,835,213	2,502,000
1974	418,521	455,556	874,077	4,753	412,923	48,342	911,613	2,251,708	4,073,600
1975	641,621	582,369	1,223,990	21,043	601,859	67,170	862,218	2,776,280	4,189,300
1976	818,588	554,414	1,373,002	32,488	547,622	116,962	946,440	3,016,514	4,239,600
1977	280,919	293,236	574,155	0	0	390,176	581,994	1,546,325	3,951,900
1978	742,385	710,314	1,452,699	3,566	13,348	122,916	786,517	2,379,046	5,773,700
1979	690,659	969,237	1,659,896	66,081	582,308	189,396	882,549	3,380,230	5,298,700
1980	730,545	799,204	1,529,749	19,722	384,835	48,590	875,045	2,857,941	5,701,900
1981	1,057,273	852,289	1,909,562	12,000	896,428	283,849	838,557	3,940,396	6,017,800
1982	928,721	821,303	1,750,024	0	215,873	159,528	776,330	2,901,755	6,187,700
1983	483,499	701,370	1,184,869	0	13,019	189,302	602,905	1,990,095	5,838,200
1984	725,925	862,694	1,588,619	3,663	259,254	388,064	832,332	3,071,932	6,273,100
1985	992,538	1,002,915	1,995,453	9,638	298,034	408,875	870,008	3,582,008	6,639,800
1986	998,611	997,025	1,995,636	2,595	34,025	197,471	791,737	3,021,464	6,966,039
1987	1,096,368	1,033,718	2,130,086	6,949	107,958	385,264	831,947	3,462,204	7,228,815
1988	1,316,820	1,068,302	2,385,122	0	0	521,370	794,834	3,701,326	6,854,300
1989	1,602,454	1,251,293	2,853,747[f]	0	0	495,702	809,250	4,158,699	6,738,300
1990	1,876,072	706,079	2,582,151	0	90	466,578	851,247	3,900,066	6,060,100
1991	536,672	12,444	549,116	3,521	0	538,987	546,931	1,638,555	N/A
1992[g]	1,172,800	559,135	1,731,935	4,221	N/A	N/A	N/A	1,736,156	N/A

a Entitlement and advance entitlement deliveries.

b Includes amounts of preconsolidation repayment, emergency relief, and regulated delivery of local supply water; non-SWP water delivered to Napa County Flood Control and Water Conservation District and the city of San Francisco through SWP facilities; CVP water conveyed (including Decision 1485 and recreation and fish and wildlife water); 1990 Ground Water Demonstration Program, recreation and exchange water; and water purchased from Yuba County Water District.

c Feather River diversions to Joint Water Districts Board and Western Canal Water District.

d Percent change in total deliveries relative to 1987: 1988 (+6.9); 1989 (+20.1); 1990 (12.6); 1991 (-52.7); 1992 (-49.9).

e A recreation day is the visit of one person to a recreation area for any part of one day.

f Includes SWP share of generation from Hyatt-Thermalito, Gianelli, Devil Canyon, Warne, Alamo, Castaic, Reid Gardner Unit No. 4, and Bottle Rock power plants.

g 1992 data are projected and preliminary for entitlement water only.

Source: C-DWR, State Water Project 1992g.

TABLE IV.6

CENTRAL VALLEY PROJECT WATER DELIVERIES
(Historic 1987, 1988, 1989, 1990, and Projected 1991)

	Historic				Projected 75/100/25
	1987	1988	1989	1990	1991
Water rights water					
Sacramento River	1,549,000	1,407,000	1,379,000	1,349,000	1,375,000
Exchange Contractors	853,000	853,000	834,000	781,000	658,000
American River/All others	172,000	138,000	148,000	136,000	148,000
Total water rights	**2,574,000**	**2,398,000**	**2,361,000**	**2,266,000**	**2,181,000**
Percent change from 1987		-6.8	-8.3	-12.0	-15.3
Project agricultural water					
Sacramento River	370,000	385,000	341,000	277,000	293,000
DMC/SLC	1,932,000	1,931,000	1,691,000	1,218,000	436,000
Friant Division	843,000	697,000	716,000	538,000	736,000
TCC/Corning/All others	662,000	610,000	614,000	422,000	143,000
Total project agric.	**3,807,000**	**3,623,000**	**3,362,000**	**2,455,000**	**1,608,000**
Percent change from 1987		-4.8	-11.7	-35.5	-57.8
Project M&I					
American River	80,000	109,000	90,000	79,000	14,000
San Felipe Division	21,000	75,000	112,000	65,000	32,000
Contra Costa	142,000	126,000	122,000	125,000	97,000
All others	100,000	88,000	78,000	77,000	98,000
Total M&I	**343,000**	**398,000**	**402,000**	**346,000**	**241,000**
Percent change from 1987		+16.0	+17.2	+0.9	-29.7
Waterfowl conservation	**130,000**	**179,000**	**238,000**	**205,000**	**200,000**
Percent change from 1987		+37.7	+83.1	+57.7	+53.8
Grand totals	**6,854,000**	**6,598,000**	**6,363,000**	**5,272,000**	**4,230,000**
Percent change from 1987		-3.7	-7.2	-23.1	-38.3

Note: Projected deliveries for 1992 are approximately same as 1991.
Source: California Central Valley Project Operations Office 1992.

TABLE IV.7

CVP CONTRACTUAL ENTITLEMENTS AND DROUGHT SHORTAGES, 1992

Facility/Description		Contractual Quantities Water Rights	Project	Total	Shortage 25%	50%	75%
Sacramento River							
Settlement contracts							
Agriusers		1,800,335	371,651	2,171,986	1,628,990	1,628,990	1,628,990
M&I		1,110	585	1,695	1,271	1,271	1,271
City of West Sacto	(W0187)	13,920	9,680	23,600	17,700	11,800	5,900
City of Redding	(5272A)	14,110	2,490	16,600	12,450	12,450	12,450
Colusa Drain MWC	(W0693)		57,637	57,637	43,228	28,819	14,409
Sutter Butte MWC	(W0862)		17,700	17,700	13,275	8,850	4,425
Butte Slough ID	(W0863)		4,200	4,200	3,150	2,100	1,050
Feather River			20,000	20,000	15,000	10,000	5,000
Tehama-Colusa Canal			356,300	356,300	267,225	178,150	89,075
Black Butte		430	3,165	3,595	2,696	1,798	900
Corning Canal			43,800	43,800	32,850	21,900	10,950
Shasta Lake			14,250	14,250	12,224	8,660	5,099
Trinity River Division			40,800	40,800	30,600	20,400	10,200
Sacramento River total		**1,829,905**	**942,258**	**2,772,163**	**2,080,659**	**1,935,188**	**1,789,719**
American River							
Folsom Lake		59,000	50,750	109,750	97,063	84,375	71,688
Folsom South Canal		25,000	210,000	235,000	30,000	30,000	30,000
City of Sacramento		140,000	90,000	230,000	60,000	60,000	60,000
Placer County		120,000	35,000	155,000	8,000	8,000	8,000
American River total		**344,000**	**385,750**	**729,750**	**195,063**	**182,375**	**169,688**

TABLE IV.7 (Continued)

CVP CONTRACTUAL ENTITLEMENTS AND DROUGHT SHORTAGES, 1992

Facility/Description	Contractual Quantities Water Rights	Project	Total	Shortage 25%	50%	75%
Delta						
Contra Costa Canal		195,000	195,000	195,000	146,250	97,500
Delta total		**195,000**	**195,000**	**195,000**	**146,250**	**97,500**
Delta export						
Cross Valley Canal		128,300	128,300	96,226	64,150	32,077
Delta-Mendota Canal	887,277	453,758	1,341,035	1,026,862	910,921	793,586
Delta-Mendota/San Luis		279,160	279,160	209,370	139,580	69,790
San Luis Unit	6,000	1,116,500	1,122,500	845,750	566,625	287,500
San Felipe		196,300	196,300	147,225	98,150	49,075
Delta export total	**893,277**	**2,174,018**	**3,067,295**	**2,325,433**	**1,779,426**	**1,232,028**
Grand CVP total	**3,067,182**	**3,697,026**	**6,764,208**	**4,796,155**	**4,043,239**	**3,288,935**
Other not affecting CVP						
Friant Unit						
Class 1		800,000	800,000	680,000		
Class 2		1,400,000	1,400,000	0		
Sly Park			23,000			
Sugar Pine			4,400			

Note: Water rights holders are not cut by more than 25 percent. Therefore figures for water rights holders in the last two columns do not reflect 50 percent and 75 percent shortages.

Source: CVP Contracts 1992.

wildlife, and carry-over storage for 1992 (C-DWR 1992a). C-DWR was to purchase water from willing sellers and sell it to users with critical needs. Water for the bank was acquired from three sources:

- Fallowing or idling of farmland and utilizing conserved irrigation water in the Water Bank.
- Using groundwater instead of surface water.
- Transferring surplus surface water from local reservoirs to the Water Bank.

Purchase agreements were activated in early April, and by early June, more than 300 contracts were developed. Table IV.8 summarizes the 351 contracts signed by the Water Bank. A statewide total of 820,805 acre-feet were purchased by the Water Bank, with fallowing contributing to 51 percent; groundwater, 32 percent; and surface water, 17 percent. A detailed list of crops fallowed, and those planted but not irrigated are provided in Table IV.9. A large percentage of the Delta corn acreage was fallowed. About one-third of the acres fallowed took place in San Joaquin County, followed by Yolo County, which contributed to one-quarter of the acres fallowed for the Water Bank.

The Water Bank paid $125 per acre-foot for water from all sellers. During more favorable water supply-and-demand conditions late in the year, SWP negotiated contracts at $30 and $50 per acre-foot. Most of the Water Bank water was delivered through SWP facilities. Water from various sources was transferred and stored in the SWP-CVP system until the time of delivery. Water was sold at $175 per acre-foot, and this cost pertained to water delivered as far as the SWP Delta Pumping Plant. Additional costs were charged for conveying water to final destinations, and costs varied for SWP and non-SWP contractors purchasing water from the Water Bank.

The Water Bank allocations as of October 10, 1991, are shown in Table IV.10. MWD received the largest allocation (215,000 acre-feet), followed by Kern County Water Agency (53,979 acre-feet) and the city of San Francisco (50,000 acre-feet). A general critique of 1991 Water Bank operations and processes (Howitt, Moore, and Smith 1992) revealed that the Water Bank was a success and a significant achievement in California water policy. The bank's operations were handled very efficiently, and this water trading was an economic boost for both agriculture and economy in the state. The Water Bank's operations, however, created potential effects on the local economics of water-exporting regions. Howitt, Moore, and Smith (1992) state that these effects were geographically diverse and small compared with overall gains. The Water Bank has been criticized, because it was less successful in addressing the negative environmental impacts of the ongoing drought. However, through an acquisition funded by Assembly Bill 12 (AB 12), signed into law by Governor Wilson in mid-October 1991, C-DWR acquired 28,000 acre-feet for the state Department of Fish and Game. In general, the direct environmental benefits of the bank were marginal compared to the benefits received by the buyers and sellers.

TABLE IV.8

DROUGHT WATER BANK PURCHASE SUMMARY

Region	Category	Acre-feet	Percent of Total
Delta	Fallowing	333,723	40.7
	Groundwater	2,529	0.3
	Stored water	2,576	0.3
Sacramento River	Fallowing	36,652	4.5
	Groundwater	46,787	5.7
Yolo	Fallowing	34,463	4.2
	Groundwater	27,308	3.3
Yuba/Feather/elsewhere	Fallowing	15,226	1.9
	Groundwater	182,341	22.2
	Stored water	139,200	17.0
		820,805	
Statewide totals	Fallowing	420,064	51.2
	Groundwater	258,965	31.5
	Stored water	141,776	17.3
		820,805	**100**
Total number of contracts: 351			

Source: C-DWR 1992a.

The State Drought Emergency Water Bank of 1992

In March 1992, the C-DWR initiated the 1992 Water Bank when the ongoing drought entered its sixth consecutive year. The same guiding principles and objectives of the 1991 Water Bank were followed in establishing the 1992 effort. However, there were some significant modifications in the implementation of the Water Bank during the sixth year of drought.

Prior to the rain in February 1992 that filled many of the reservoirs in Southern California, initial estimates of critical needs were about 500,000 acre-feet. However, in March 1992, critical need demands were approximately 100,000 acre-feet. Allocations from the Water

TABLE IV.9

DROUGHT WATER BANK CROP SUMMARY BY COUNTY
(Acres Fallowed)

Crops	Butte County	Colusa County	Contra Costa County	Sacramento County	San Joaquin County	Shasta County	Solano County	Stanislaus County	Sutter County	Tehama County	Yolo County	Total
Alfalfa*			678.0	996.5	3,795.2	521.9	913.8				3,313.6	10,219.0
Asparagus					1,277.4							1,277.4
Barley*				175.6	412.6		79.2				53.9	721.3
Corn			6,500.0	9,014.3	24,958.3		5,471.7	136.0	1,589.4		11,606.6	59,276.3
Dichondra*											27.4	27.4
Dry beans	458.5			243.9	959.1		387.5				1,187.1	3,236.1
Grapes*				198.0							56.2	254.2
Melons									167.0			167.0
Milo			40.0		188.9							228.9
Misc. truck			18.0	58.9	462.7							539.6
Pasture*			1,482.0	1,783.9	591.7	3,258.1	3,208.5			390.0	5,473.3	16,187.5
Rice	1,158.0	2,231.0		798.0		577.6			2,557.8		857.8	8,180.2
Safflower*				1,034.8	24.6		325.7				3,013.2	4,398.3
Seed grass*							74.4				488.1	526.5
Sudan*				131.6								131.6
Sugar beets		92.2		1,323.7	3,699.0		1,206.5		923.8		2,705.4	9,950.6
Sunflowers			518.0	862.1	383.7		572.4		166.1		267.1	2,769.4
Tomatoes				125.6	1,216.4		451.6				2,553.4	4,347.0
Turnips						35.4						35.4
Wheat*	1,455.7		1,344.2	11,927.1	14,288.5	50.5	5,859.9		55.0		8,602.9	43,583.8
Subtotal	**3,072.2**	**2,323.2**	**10,580.2**	**28,674.0**	**52,258.1**	**4,443.5**	**18,551.2**	**136.0**	**5,459.1**	**390.0**	**40,206.0**	**166,093.5**

Several contracts were negotiated in which the method of conserving water was left to the discretion of the water district. These contracts may represent some additional fallowing; however, the amounts cannot be quantified.

*Crops noted were planted but not irrigated, rather than fallowed.

Source: C-DWR 1992a.

TABLE IV.10

WATER BANK ALLOCATIONS
(As of October 10, 1991)

Agency	Acre-feet	Cost
Alameda Co. Water District	14,800	$ 2,590,000
Alameda County - Zone 7	500	87,500
American Canyon Co. Water District	370	64,750
Contra Costa Water District	6,717	1,175,475
Crestline-Lake Arrowhead	236	41,300
Dudley Ridge Water District	13,805	2,415,875
Kern Co. Water District	53,979	9,446,325
Metropolitan Water District of Southern California	215,000	37,625,000
Oak Flat Water District	975	170,625
San Francisco	50,000	8,750,000
Santa Clara Valley Water District	19,750	3,456,250
Westlands Water District	13,820	2,418,500
Total	**389,952**	**$68,241,600**

Source: Department of Water Resources in Howitt, Moore, and Smith 1992.

Bank, as of October 23, totaled 154,250 acre-feet (C-DWR 1992a). Agricultural purchases represented about 62 percent of total Water Bank allocations. Although twelve agricultural water districts participated in the 1992 Water Bank, about 87 percent of all agricultural purchases was made up of Tulare Lake Basin Water Service District and Westlands Water District. The remaining purchases were made up of municipal and industrial demands (25 percent) and the state Department of Fish and Game (13 percent).

Groundwater and conservation represented about 150,000 acre-feet of the water purchased by the Water Bank as of October 23, 1992. The balance came from direct surface water contracts (C-DWR 1992a). About 31,000 acre-feet had to be reserved to meet Delta water quality requirements. The 1992 Water Bank sellers and purchasers are presented in Table IV.11. The C-DWR purchased water from the 1992 Water Bank at $50/acre-foot. The selling price was $72/acre-foot, including the additional costs for administration purposes and Delta requirements.

The 1992 Water Bank differed from the 1991 Water Bank in several key aspects. The major modifications to the 1992 Water Bank were:

- It was substantially smaller in volume and less costly to buy and sell than the 1991 Water Bank.
- It was primarily an agricultural water supply bank.
- The Water Bank was completely underwritten by buyers.
- The fallowing of land as a source was not permitted in the 1992 Water Bank.
- The Water Bank instituted a system of pools for allocating supplies.
- It used Option and Purchase Deposits for water.
- Water needs for wildlife interests were a key purpose of the 1992 Water Bank

LEGISLATION CONCERNING DROUGHT AND WATER CONSERVATION

Drought Legislation

During the drought, a number of agencies identified drought legislation that would assist in managing the water shortage. An informative description of the 23 bills considered in both the California legislature and the U.S. Congress addressing drought issues as of December 1, 1991, was prepared by C-DWR (1991b) and is contained in Appendix A. A listing of state and federal drought legislation incorporating strategic and tactical measures as of December 1991 is provided in Table IV.12.

TABLE IV.11

1992 DROUGHT WATER BANK: SELLERS AND PURCHASERS
(In Acre-Feet as of October 23, 1992)

Contractor/Purchaser	Amount	Percent
Sellers to the Water Bank		
Alhambra Pacific Joint Venture	5,000	2.8
Browns Valley Irrigation District	4,600	2.6
Conaway Conservancy	17,500	9.9
Davis Ranches	4,000	2.3
East Contra Costa ID	2,500	1.4
Los Rios Farms	15,000	8.4
Merced Irrigation District	15,000	8.4
Oakdale ID/South San Joaquin ID	50,000	28.2
Oroville-Wyandotte ID	10,000	5.6
Pelger Mutual Water Co.	1,500	0.8
Upper Swanston	995	0.6
West Sact./RD 900	1,500	0.8
Western Canal Water District	50,000	28.2
Total	**177,595**	**100.0**
Purchasers from the Water Bank		
Allocation to agricultural demands		
Broadview Water District	255	0.2
Del Puerto Water District	300	0.2
Foothill Water District	900	0.6
Hospital Water District	200	0.1
Kern County Water Agency	8,170	5.3
Orestimba Water District	75	0.05
Panoche Water District	2,000	1.3
Quinto Water District	100	0.05
Solado Water District	300	0.2
Sunflower Water District	400	0.3
Tulare Lake Basin Water Service District	31,550	20.4
Westlands Water District	51,000	33.0
Total agricultural uses	**95,250**	**61.7**
Allocation to fish and wildlife demands		
Department of Fish and Game	**20,000**	**13.0**
Allocation to urban demands		
City and County of San Francisco	19,000	12.3
Contra Costa Water District	10,000	6.5
Metropolitan Water District of Southern California	10,000	6.5
Total urban uses	**39,000**	**25.3**
Total allocations for all uses	**154,250**	**100.0**

Source: C-DWR 1992f.

TABLE IV.12

1991 DROUGHT LEGISLATION
(Refer Also to Appendix A)

Issues	Number of bills
State legislation	
Water transfers	2
Urban water management plan	2
Fish and game protection	1
Forestry and fire protection	1
Water reclamation projects	1
Drought emergencies and drought assistance	6
Agriculture	3
Water appropriation	1
Water supply development projects	1
Safe drinking water and drought relief bonds	1
Total	19
Federal legislation	
Drought relief	1
Drought emergency	1
Drought management and assistance	1
Drought response	1
Total	4

Water Conservation Legislation Memorandum of Understanding

A Memorandum of Understanding Regarding Urban Water Conservation in California (MOU) was signed on December 11, 1991. Its signers now number 150, of which 105 are urban water suppliers who serve over 80 percent of the state population. The MOU (1991) states a commitment by water agencies to implement 16 conservation measures known as Best Management Practices (BMPs) over the next 10 years. The MOU also created the California Urban Water Conservation Council which is charged with oversight and annual reporting on implementation progress of the BMPs. This MOU focused on urban water conservation in California and was an agreement among urban water suppliers, public advocacy organizations, and other interested groups. The BMPs (listed in Table IV.13) were intended to reduce long-term urban demands from what they would have been without the implementation of these urban water conservation practices. These BMPs are in addition to short-term tactical programs that may be instituted during water supply shortages.

TABLE IV.13

BEST MANAGEMENT PRACTICES (BMPs)

1. Interior and exterior water audits and incentive programs for single-family residential, multifamily residential, and governmental/institutional customers

2. Plumbing, new and retrofit

   a. Enforcement of water-conserving plumbing fixture standards including requirement for ultralow-flush (ULF) toilets in all new construction beginning January 1, 1992

   b. Support of state and federal legislation prohibiting sale of toilets using more than 1.6 gallons per flush

   c. Plumbing retrofit

3. Distribution system water audits, leak detection, and repair

4. Metering with commodity rates for all new connections and retrofit of existing connections

5. Large landscape water audits and incentives

6. Landscape water conservation requirements for new and existing commercial, industrial institutional, governmental, and multifamily development

7. Public information

8. School education

9. Commercial and industrial water conservation

10. New commercial and industrial water use review

11. Conserving pricing

12. Landscape water conservation for new and existing single-family homes

13. Water waste prohibition

14. Water conservation coordinator

15. Financial incentives

16. Ultralow-flush toilet replacement

Source: Adapted from Memorandum of Understanding 1991.

WATER CONSERVATION DURING THE ONGOING DROUGHT

The discussion on water conservation for the state of California is based on information gathered from newspaper articles and available publications covering the current drought. The discussion focuses mainly on demand management measures adopted by some agencies in California during the 1987-92 drought.

First Year (Water Year 1987)

Even before the onset of drought in 1987, the MWD sponsored ongoing annual education programs in 1983 based on various water issues, particularly conservation targeted at fourth and sixth grades in schools. The cost of the program was predicted to average $300,000 per year.

Second Year (Water Year 1988)

During the second year of drought, the state urged wholesalers of state-supplied water to cut back consumption by 10 to 15 percent. According to the *Sacramento Bee* (April 21, 1989), reaction to the state's appeal was mixed. Urban wholesalers such as the MWD agreed to cooperate with the request. The Director of Kern County Water Agency (KCWA) described the request as "impractical." He contended that farmers were using water very efficiently in the San Joaquin Valley, and a large savings in water use could not be achieved in a short period of time without the loss of crops and money.

Examples of conservation efforts in the state among some agencies (Table IV.14) can be summarized as follows:

- San Francisco Water Department (SFWD) imposed 25 percent mandatory conservation on its 2.1 million customers in the city and suburban areas.

- MWD requested a 10 percent voluntary conservation and launched a $12 million public information campaign featuring celebrities to get its message across to its 14 million customers.

- San Diego Water Authority (SDWA) launched its conservation program called "Water Conservation, a San Diego Way of Life" (*San Diego Union*, May 20, 1988). The agency also instituted a public information campaign of $180,000 (funded by both MWD and the city of San Diego) on conservation tips and water-saving equipment.

- The Los Angeles Department of Water and Power (LADWP) introduced a 9.9 percent water rate increase with a new policy that required special low-flow devices to be fitted to all the city's showers and toilets. Mandatory conservation

TABLE IV.14

EXAMPLES OF CONSERVATION DURING THE SECOND YEAR OF DROUGHT

	A	B	C	D	E	F	G	H	I	J	K
San Francisco Water Department (SFWD)				X (25)							
Metropolitan Water District (MWD)		X (10)						X			
Los Altos Hills (San Francisco Peninsula)		X (15)	X (25)								
San Diego Water Authority (SDWA)		X (10)									
Los Angeles Department of Water and Power (LADWP)		X		X		X		X			
East Bay Municipal Utilities Department (EBMUD)					X (25)						
City of Haywood				X							
Santa Clara Valley Water District				X (25)							
Purisima Hills District				X (45)							

A = Education
B = Voluntary Conservation
C = Extreme Voluntary Conservation
D = Mandatory Conservation
E = Mandatory Metered Rationing
F = Increasing Rates or Surcharges
G = Direct Economic Incentives
H = Distribution of Water-Saving Devices
I = Public Information Campaign
J = Waste Patrols and Citations
K = Enforce by Fines and Meter Discs

Sources: *Los Angeles Times*, April 28, 1988; *San Francisco Chronicle*, June 2 and June 15, 1988; *San Diego Union*, May 20, 1988.

Note: Figures in parentheses denote percent voluntary/mandatory conservation.

was instituted, covering restaurants, cleaning driveways, and shutting down some fountains.

- East Bay Municipal Utilities District (EBMUD) imposed 25 percent mandatory conservation and increased water rates for residents using more than 400 gallons of water a day.

- Other examples of mandatory conservation included Los Altos Hills (25 percent), the city of Hayward, Santa Clara Valley Water District (25 percent), and Purisima Hills District (45 percent).

Third Year (Water Year 1989)

The third year proved to be a wetter year than the first two years, but this did not spell the end of the drought. Some examples of conservation efforts in the third year (Table IV.15) were as follows.

- The Tri-Cities Municipal Water District asked construction crews to cut its water use by 50 percent and residents and businesses by 20 percent.

- SFWD replaced mandatory conservation with appeals for voluntary conservation.

- MWD and Santa Clara Valley Water District continued with mandatory conservation measures.

- LADWP ended its mandatory conservation.

- EBMUD reduced its mandatory conservation from 25 percent to 15 percent.

- Marin Municipal Water District imposed water rationing on March 1 and ended it after the spring rains.

- Kern County Water Agency urged its residents to practice water conservation by watering their lawns only 3 times a week.

Fourth Year (Water Year 1990)

Water conservation was firmly embedded on a statewide basis during the fourth year of drought. Efforts were made by some local governments in Southern California in furthering conservation and preparing for water shortages. Water conservation efforts and other programs to cope with water shortages among local governments in Southern California were identified based on the results of a survey of local governments in Southern California, conducted by the *Los Angeles Times* (April 1, 1990). Voluntary conservation programs were identified among

TABLE IV.15

EXAMPLES OF CONSERVATION DURING THE THIRD YEAR OF DROUGHT

	A	B	C	D	E	F	G	H	I	J	K
Tri-Cities Municipal Water District		X									
San Francisco Water Department (SFWD)		X									
Metropolitan Water District (MWD)				X							
Los Angeles Department of Water and Power (LADWP)		X				X		X			
East Bay Municipal Utilities Department (EBMUD)				X (15)							
Santa Clara Valley Water District				X (25)							
Marin Municipal Water District				X							
Kern County Water Agency (KCWA)		X									

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K = Enforce by Fines and Meter Discs

Sources: Orange Co. Register, August 16, 1989; *Bakersfield Californian*, May 7, 1989.
Note: Figures in parentheses denote percent voluntary/mandatory conservation.

45 local communities in the sample survey in Southern California. Mandatory conservation was active among 17 communities in the Southern California area. Other conservation programs and steps toward preparing for water shortages include:

- Direct economic incentives
- Distribution of water-saving devices
- Waste patrols and citations
- Water monitoring
- Installing meters
- Water reclamation
- Conservation in public uses
- Drought-tolerant landscaping
- Supply augmentation

The following extract compiled by the *Los Angeles Times* from the *Public Affairs Clipsheet*, Metropolitan Water District, March 14, 1991 (Vol. 5), illustrates the "Los Angeles March to Water Rationing" during the fourth year of drought.

- **March 21** The Metropolitan Water District warns Southland water agencies, including the Los Angeles Department of Water and Power (LADWP), to restrict water use.

- **March 23** Mayor Tom Bradley asks the LADWP to draw up a blueprint with tough penalties.

- **March 31** Bradley vows to seek mandatory water rationing within 60 days if consumption is not voluntarily reduced by 10 percent during the next month.

- **April 4** Los Angeles agrees to stop pumping groundwater for a year from Owens Valley, one of the city's three largest sources of water.

- **April 17** A MWD committee recommends paying millions of dollars in rebates to water agencies that get customers to cut use by more than 5 percent between June and September.

- **April 27** LADWP announces programs that include a team of roving "drought busters" looking for water waste.

- **April 30** At a news conference, Bradley challenges Los Angeles to voluntarily cut water use by 10 percent or face water rationing within 60 days.

- **May 3** Mayor unveils mandatory water-rationing plan.

- **May 30** The council's Commerce, Energy, and Natural Resources Committee gives conditional approval to the mayor's plan while calling for a report on the effectiveness of ongoing voluntary conservation.

- **June 28** Council tentatively approves mandatory rationing plan but throws in amendments that will delay final vote for several weeks.

- **July 10** MWD reports that water use in many Southern California cities dropped from 8 to 16 percent under voluntary programs.

- **July 11** New figures showing a strong conservation effort by residents prompt some lawmakers to change their minds about backing the mayor's proposed mandatory water-rationing plan.

- **July 14** By a 10-2 vote, council votes down mandatory water cuts.

- **July 25** Council approves voluntary water rationing and includes the city's first fines for flagrant water wasters.

- **August 3** Los Angeles residents cut water use by only 9.8 percent in July and are warned that mandatory water rationing may be imposed.

- **September 5** Los Angeles residents cut water use by 13 percent in August and push back the possibility of rationing at least until October.

Source: *Public Affairs Clipsheet*, Metropolitan Water District, March 14, 1991 (vol. 5).

Fifth Year (Water Year 1991)

As the drought progressed into the fifth year, the Miracle March rains and the success of the Water Bank assisted most communities in coping with their water shortages. As a result, some communities reduced their conservation goals from more than 45 percent to 25 percent and lower. However, communities in Southern California, for example, those served by the MWD, continued to pursue an aggressive conservation program. In May 1991, a survey was conducted to provide California Urban Water Agencies (CUWA) with updated information on what its eleven member agencies were doing to deal with urban water demands of the summer and fall during the fifth year. The results of this survey are presented in Table IV.16. The conservation programs undertaken by the member agencies vary both in terms of water use reduction goals and measures adopted. Water use reduction goals varied from a low of 10 percent for LADWP to a high of 31 percent for MWD. The conservation measures adopted are similar to the demand management measures described in the earlier years of the drought.

TABLE IV.16

1991 CONSERVATION MEASURES TAKEN BY CUWA MEMBER AGENCIES TO MEET URBAN WATER DEMANDS

	Percent Reduction Goals	A	B	C	D	E	F	G	H	I	J
Alameda Co. WD	18		X		X		X	X	X		
Contra Costa WD	26	X		X	X		X	X	X		X
East Bay MUD	15	X	X		X	X	X	X	X		
LA Dept. of W&P	10	X	X		X	X	X	X	X	X	X
MWD of Southern CA	31				X	X		X			
MWD of Orange Co.	20		X	X	X	X	X	X	X	X	
Orange Co. WD	20			X		X		X	X		
San Diego Co. Water Auth.	20	X	X	X	X	X	X	X	X	X	X
City of San Diego WUD	20			X			X	X	X	X	
San Francisco PUC	25	X	X		X		X	X	X		X
Santa Clara Valley WD	25	X	X		X			X	X	X	X

A = Mandatory Metered Rationing
B = Mandatory Conservation
C = Extreme Voluntary Conservation
D = Increasing Rate or Surcharges
E = Direct Economic Incentives
F = Distribution of Water-Saving Devices
G = Media Public Information
H = Mailed Public Information
I = Waste Patrols and Citations
J = Enforcement by Fines or Meter Disks

Source: California Urban Water Agencies (CUWA), June 1991.

Sixth Year (Water Year 1992)

The progress of the drought into the sixth year was accompanied by continued water conservation programs. A survey of the CUWA member agencies was completed in May 1992 in order to update the 1991 survey. The survey demonstrated that all agencies recognize the importance of demand management measures. Southern California had above-normal local supplies in 1992, allowing relaxation of water restrictions. Drought continued, however, in the major Northern California import sources, thus impacting availability of supply. Accordingly, the demand management programs pursued by the CUWA member agencies and their goals differed according to their water supply situation. However, all eleven member agencies continued with their mailing of public information. More than 80 percent of the agencies pursued their media public information programs and the distribution of water-saving devices (Table IV.17). One important development at the end of the fifth year of drought (September 1991) was the signing of the Best Management Practices (BMPs) statewide agreement monitored by the California Urban Water Conservation Council. The conservation program followed by the water agencies in the sixth year included some of the 16 BMPs advocated in the Memorandum of Understanding (MOU) agreement. For example, MWD designed its commercial and industrial program according to the BMP requirements for those sectors. Components of this program include publications, technical workshops, business conferences, training courses, water use surveys, water management studies, and a telephone hotline.

ECONOMIC AND ENVIRONMENTAL IMPACTS OF THE DROUGHT

The economic effects of the drought were not felt immediately, but the environment was impacted since the first dry weather in 1987. Quantitative assessments of economic losses of the six-year drought are difficult to ascertain because limited data are available regarding the analysis of drought impacts. The discussion that follows describes the impacts of the drought on agriculture, industry, other economic sectors, and the environment.

Economic Losses in Agriculture

Irrigated agriculture was little impacted during the first three years of the drought, as the use of stored water was allowed. There were local water project shortages in 1988, although water deliveries to agricultural users were not reduced until 1990. In 1990 the overall impacts to agriculture were minimal (Cannon 1990; CDOC 1990; Gleick and Nash 1991). In contrast to minimal impacts of irrigated agriculture early in the drought, dry-farm agriculture and native produce were impacted the first year of the drought - 1987. Despite the onset of the drought in 1987, cash receipts from farm marketings in California reached a record of $18.3 billion in 1990, reflecting a $0.8 billion increase from 1989 (C-DWR 1991b, Gleick and Nash 1991.)

TABLE IV.17

1992 CONSERVATION MEASURES TAKEN BY CUWA MEMBER AGENCIES TO MEET URBAN WATER DEMANDS

	Percent Reduction Goals	A	B	C	D	E	F	G	H	I	J
Alameda Co. WD	15			X	X		X	X	X		
Contra Costa WD	15						X	X	X		
East Bay MUD	15	X	X		X	X	X		X		X
LA Dept. of W&P	10			X	X	X	X	X	X		
MWD of Southern CA	10				X	X	X	X	X		
MWD of Orange Co.	20				X		X	X	X		
Orange Co. WD	10			X		X		X	X		
San Diego Co. Water Auth.	10					X	X	X	X		
City of San Diego WUD	20			X			X	X	X	X	
San Francisco PUC	25	X	X		X		X	X	X		X
Santa Clara Valley WD	15	X	X		X			X	X	X	X

A = Mandatory Metered Rationing
B = Mandatory Conservation
C = Extreme Voluntary Conservation
D = Increasing Rate or Surcharges
E = Direct Economic Incentives
F = Distribution of Water-Saving Devices
G = Media Public Information
H = Mailed Public Information
I = Waste Patrols and Citations
J = Enforcement by Fines or Meter Disks

Source: California Urban Water Agencies (CUWA), May 1992.

Agriculture was impacted during the fifth year of drought (1991), but the Water Bank had a significant effect on the agricultural sector. According to Howitt et al. (1992), the Water Bank allocations generated economic gains in the regions importing water in 1991. Howitt et al. (1992) indicate that the importing agricultural regions gained in employment by 1,153 jobs, and this increase exceeded the 162 estimated job losses experienced in exporting regions. Agriculture in importing regions enjoyed an increase of $45 million in income, surpassing the estimated loss of county income in exporting regions ($13 million).

Statewide economic impacts on agriculture during the fifth year of drought were estimated by C-DWR (C-DWR 1992c). C-DWR estimated that the drought idled about 347,000 "net" acres with a loss of gross receipts of about $252 million in 1991. Net acres reflect not only the decrease in acres caused by the drought, but also the increase in some crops related to crop-shifting in response to the drought. Another estimate of drought indicated that irrigation costs to growers in the San Joaquin Valley alone were estimated to have increased by about $160 million (Northwest Economic Associates 1992).

Agricultural impacts were concentrated in a few regions, especially the southern San Joaquin Valley and the Central Coast region. Scarce groundwater supplies impacted the southern San Joaquin Valley, while extensive dryland pasture and a high dependence on groundwater made conditions difficult in the Central Coast. Irrigation districts that predicted agricultural impacts during the fifth year include Kern County Water Agency (KCWA) and Westlands Water District (in San Joaquin Valley) and Glenn-Colusa Irrigation District (in the Sacramento Valley).

For example, KCWA funded a study in early 1991 to estimate economic impacts of proposed water delivery cutbacks on five water districts depending solely on SWP entitlements. The study estimated that gross output would decline by $221 million if no water was available to produce annual crops (Northwest Economic Associates 1991). Furthermore, lost wages and salaries, both direct and indirect, would amount to $113 million.

Reduced surface supplies and increased groundwater pumpage impacted planted acreage in the Westlands Water District during the drought. The district forecast decreases of approximately 140,000 acres in planted acreage in 1991. Subsequently, based on available data, the district forecast a decline in income of $1400 per acre, for a total predicted income loss of about $200 million (Westlands Water District 1991).

A summary of the estimates and forecasts (both local and statewide) of economic impacts on the agricultural sector is shown in Table IV.18. Some farmers faced increasing costs and declining revenues, and some local communities suffered from reduced activity (Gleick and Nash 1991).

Any prediction of drought impacts obviously reflects assumptions of surface water supply, groundwater use, water costs, and water distribution. The 1987-1992 drought demonstrated that the ability to shift among water users is crucial (Howitt 1991). Howitt pointed out that if irrigation water can be readily moved from low values to high value uses within agriculture, the total impacts on farmers, urban areas, and food consumers will be greatly reduced.

TABLE IV.18

SUMMARY OF ESTIMATES OF ECONOMIC IMPACTS ON THE AGRICULTURAL SECTOR IN 1991

Study	Loss	Comments
Statewide	**Estimated Loss**	
C-DWR 1992	$252 million (gross receipts)	Drought idled about 347,000 "net" acres.
Regional	**Estimated or Predicted Loss**	
Northwest Economic Associates 1991	$221 million (gross) predicted for Kern County alone in 1991	Assumed no production of annual crops and permanent destruction of some tree crops. (now appears an overly harsh scenario).
Westlands Water District 1991	$200 million (gross) predicted within the Westlands Water District for 1991	Overestimate of fallowing and Overestimates of per acre value.
Northwest Economic Associates 1992	$160 million estimated cost in San Joaquin Valley	Increases in irrigation costs to growers only

Economic Losses in Industry and Manufacturing

The California economy was worth more than $760 billion in 1992. Other than agriculture and recreation, industries dependent on reliable water supplies in California include refining, food processing, semiconductor manufacturing, and services. According to Spectrum Economics (1991), seven of California's major industrial sectors increased production during drought, although they reduced their water use by 3 to 10 percent annually. These seven industrial sectors include fruit and vegetable processing, paperboard and box production, refining, concrete, communications, and motor vehicle production (Gleick and Nash 1991).

The industries dependent on reliable water supplies have taken steps to reduce their water requirements during the drought. The petroleum refineries that used nearly 230,000 acre-feet in the early 1980s (C-DWR 1982) have been planning to recycle and reuse refinery process water. The food industry, utilizing over 100,000 acre-feet of water per year (C-DWR 1982), has also reduced its water requirements through recycling, improved equipment, and changes in operations. As a result of this proactive planning for drought and flexible rationing programs (exemptions granted for businesses facing serious consequences), these industries have not suffered much economic losses during the drought. The semiconductor industry has implemented conservation measures, but Yamane et al. (1991) predicted that increasing industrial cutbacks during the ongoing drought might lead to increased costs or force companies to rely more heavily on out-of-state production facilities. A survey of 836 executives in the state,

conducted for the California business round table, revealed that two-thirds of companies favored increasing the state's water supply (*Riverside Press-Enterprise*, February 5, 1991). The housing and construction industry has been impacted by the drought, and some communities in California imposed interim regulations on new development. This measure required developers to apply for a building permit for any new development, and the applicant would have to ensure that new projects would mitigate and offset water usage. In this way existing community water resources, already impacted by the drought, would be safeguarded from additional impacts by new users. One positive outcome of this restriction on new development has been an increase in the use of water-saving devices during the construction process (Gleick and Nash 1991). Other industries have also benefited from the drought, and these include well drillers, who have prospered during this six-year period.

Economic Impacts on Other Sectors

The impacts of the drought affected other economic sectors including municipalities, energy, and the "green industry." The discussion of impacts on the first two sectors is based largely on material presented by Gleick and Nash (1991). The impact on municipalities in the state led to five counties declaring emergency drought conditions in 1990: Santa Barbara, San Benito, Kings, Madera, and San Luis Obispo. Five other counties, Mendocino, Tulare, Sutter, Glenn, and Colusa, declared drought emergency in the spring of 1991. Most districts, such as MWD and Marin County, announced plans to invest capital in ongoing water conservation programs. For example, MWD planned to spend $30 million per year for water conservation programs and $378 million to line irrigation canals and improve aqueduct control systems. This was in return for about 200,000 acre-feet of water from Imperial Valley irrigation projects and the All American Canal. Residential conservation programs were widely implemented in the state, and reductions varying from 15 to 50 percent in water use were achieved, especially during the fourth and fifth years of the drought. For instance, Santa Clara County achieved 20 percent voluntary reduction in 1989 and 1990, and per capita use dropped 24 percent.

In addition to conservation techniques such as voluntary and mandatory rationing and retrofit programs, the use of reclaimed water has increased in the state. During the drought, the city of Irvine became the first in the nation to use reclaimed water for toilet flushing in commercial buildings (C-DWR 1991b). Furthermore, the cities of Santa Barbara and Montecito used reclaimed water for public landscaping.

Another sector impacted by the drought is hydroelectric generation, which normally provides about 20 percent of the state's total electrical energy supply and represents more than 30 percent of electricity produced by California utilities. Hydroelectric generation declined to about 12 percent of total generation and 18 percent of in-state generation during the first four years of the drought (Gleick and Nash 1991). This decline has been made up mainly by burning more costly natural gas and importing power from out-of-state sources. Gleick and Nash (1991) claim that the decline in hydroelectric generation has cost California rate payers $2.4 billion during this period.

There are widely varying estimates of the impact to the "green industry," owing to the problems of defining and knowing the baseline conditions and extracting other factors. Preliminary estimates indicate that the California "green industry" experienced drought-induced direct losses of equivalent full-time jobs totalling about 5,630 (C-DWR 1992e). This figure excludes job losses in the "green industry" due to recession. Additionally, drought impacts forced some "green industry" employees to work fewer hours in 1991. Declines in revenues suffered by the "green industry" due solely to drought were about 7 percent in 1990 (C-DWR 1992e). It should be noted that the "green industry" suffered an even greater decline in business in 1991 due to other factors such as recession and increased water costs.

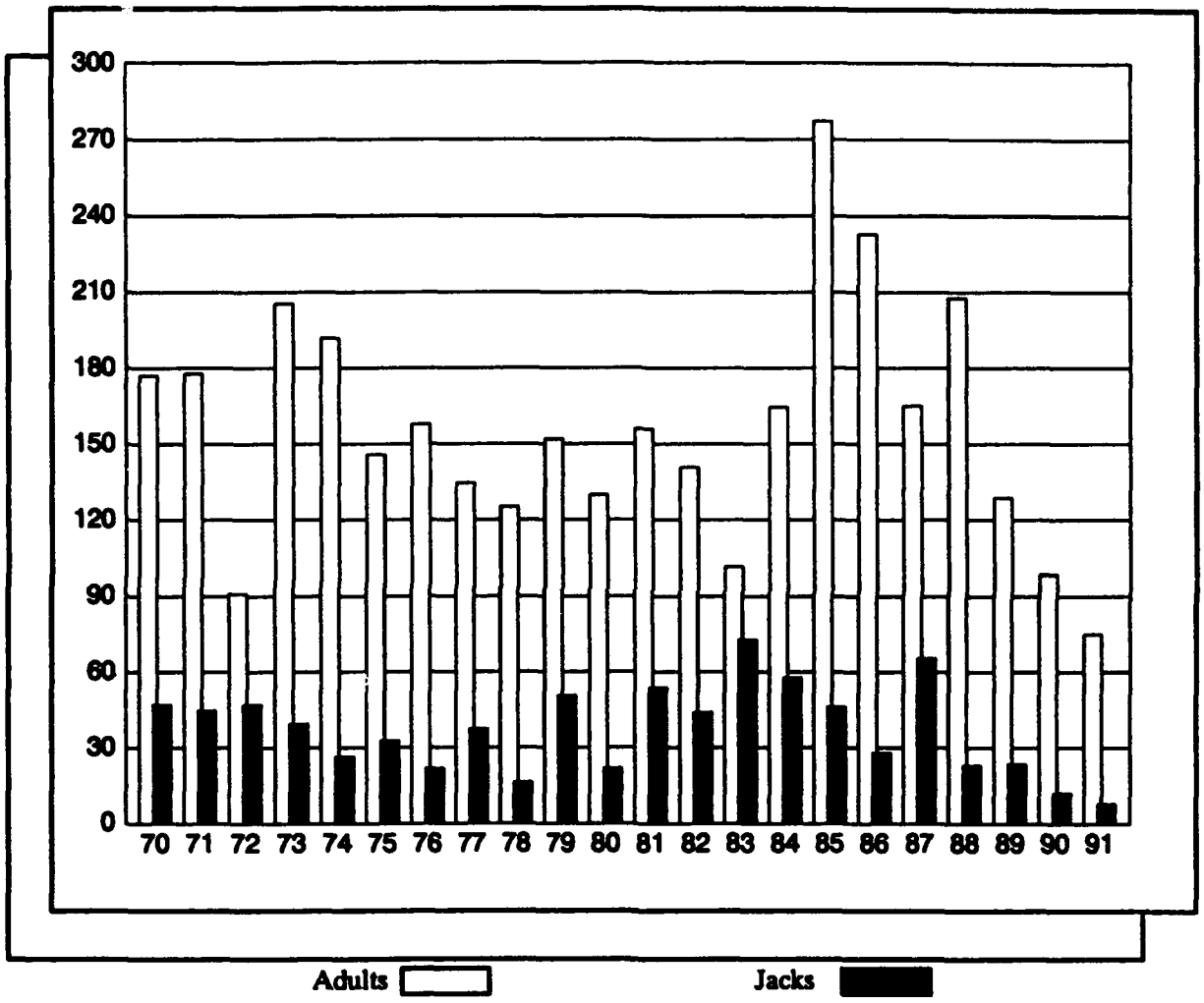
ENVIRONMENTAL IMPACTS

Fish and Wildlife

According to C-DWR (1991b), it is possible that the most severe impacts of the drought have been on the environment and the fish and wildlife that depend on the rivers for their sustenance. The environment was impacted immediately with the onset of drought in 1987. Impacts were pronounced on fisheries and aquatic resources, particularly species such as salmon, which shows a good correlation to flow (USFWS 1987; Gleick and Nash 1991). This relationship has since been refined to show that water temperature, Delta exports, and percent river flow diverted at the Delta Cross Channel and Georgianna Slough explain the relationship better. The following discussion on impacts of the drought to fish is based on information contained in C-DWR (1991b) and the Pacific Fishery Management Council publication, *Review of 1991 Ocean Salmon Fisheries* (PFMC 1992). However, the extent that the environment has been impacted by drought and low flows has not been established. There are several major factors in addition to flow, such as toxics, introduced species, and overfishing that have impacted the environmental resources, but these losses have not been assessed. Other important environmental impacts include increases in upstream temperature, winter-run chinook salmon habitat, cumulative impacts, longfin smelt, Sacramento splittail, April 1991 Delta operations, violation of Delta standards in 1991 and 1992, and unmitigated water transfer impacts.

The fall-run chinook salmon represents the major facet of California's commercial and sport fisheries. Figure IV.3 reveals that the population of the fall-run chinook salmon had declined to its lowest numbers in the last two decades despite consistent hatchery production. Counts of adult salmon show a consistent decline from about 232,000 in 1986 to about 96,000 in 1990. The counts of two-year-old immature jack salmon showed a continued decline since the outset of the drought in 1987 (from about 70 jacks in 1987 to about 11 jacks in 1990). According to C-DWR (1991b), several generations may be needed to restore these populations once precipitation returns to normal.

The drought also impacted the striped bass and adult populations declines to an estimated all-time low of 515,000 in 1990 (C-DWR 1991b). Figure IV.4 illustrates the California Central Valley striped bass young-of-the-year index, which demonstrates that the spawning success decreased substantially during the drought. In 1986 the population level index of the 1.5-inch

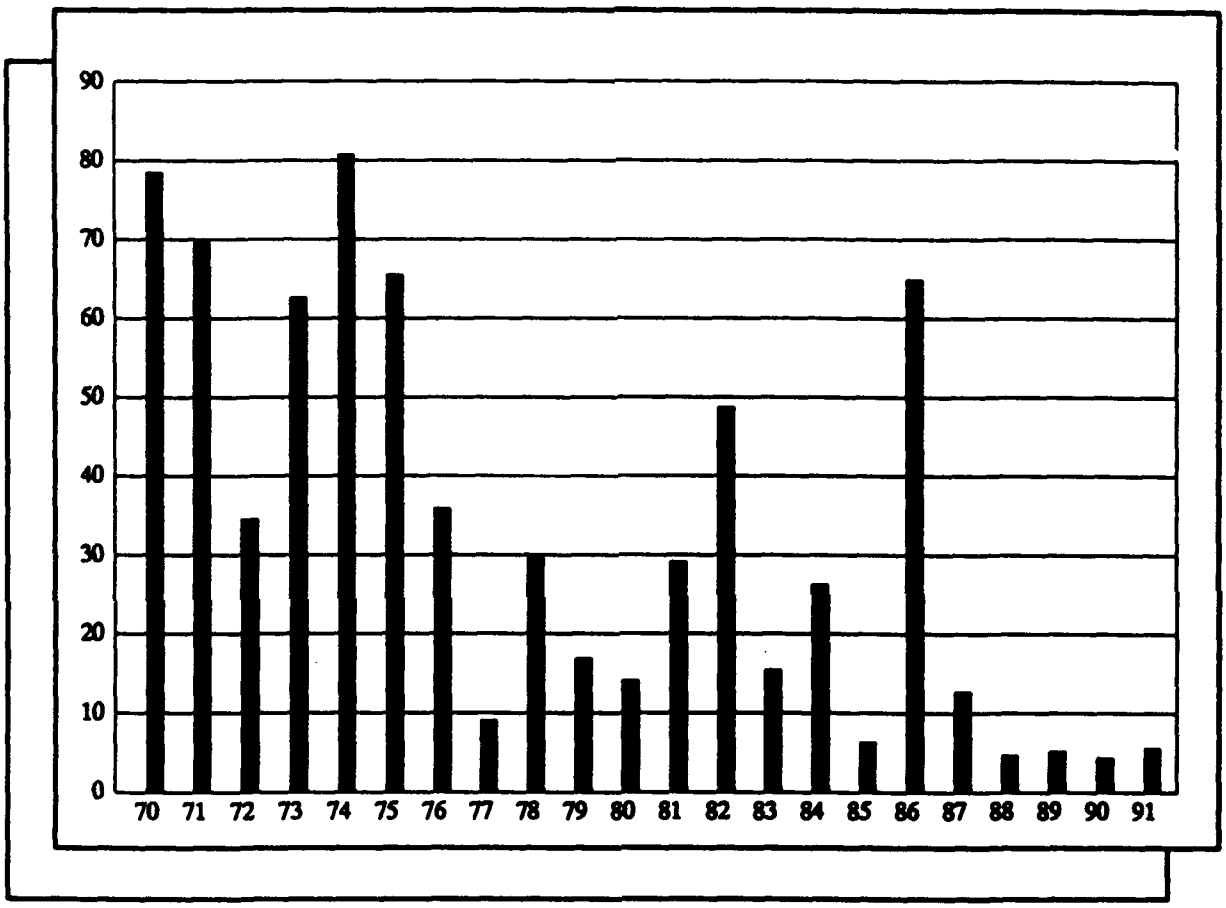


1 Upper Sacramento River jack estimates based on Red Bluff Diversion Dam samples. All other estimates generally are based on carcass surveys. Adult and jack numbers generally are based on a 24-inch fork length cut-off (unpublished CDFG data). Figures for 1987 through 1990 are preliminary; figures for 1991 are preliminary estimates.

FIGURE IV.3

CALIFORNIA CENTRAL VALLEY NATURAL FALL-RUN CHINOOK SPAWNING SALMON (In Thousands of Fish, 1970-1991)[1]

Source: C-DWR 1991b.

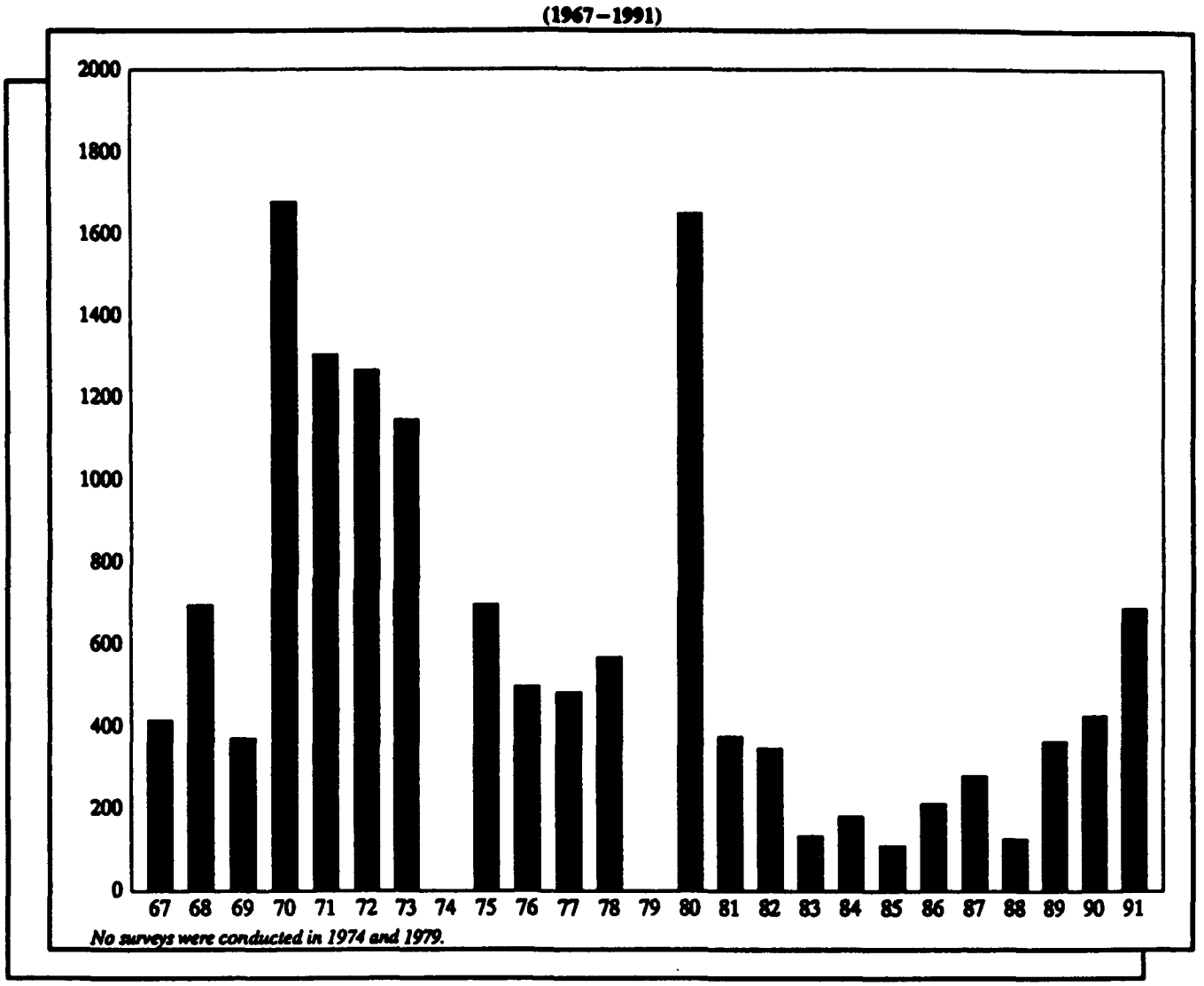


[1] Relative number that compares, by sampling, the population levels of 1.5–inch striped bass between years.

FIGURE IV.4

CALIFORNIA CENTRAL VALLEY STRIPED BASS YOUNG-OF-THE-YEAR INDEX[1]

Source: C-DWR 1991b.



[1] Relative number that compares population levels from year to year based on fall sampling, when adults are susceptible to sampling nets.

FIGURE IV.5

INDEX OF FALL ABUNDANCE OF DELTA SMELT BY YEAR[1]

Source: C-DWR 1991b.

striped bass was about 65, decreasing to about 12 in 1987 and to about 6 in 1991 (C-DWR 1991b). Besides the salmon and the striped bass, other species were also impacted, including the Delta smelt. Figure IV.5 deficits the annual index of fall abundance of Delta smelt from 1967 to 1991. The Delta smelt index was lowest during the mid-1980s, and although it has been increasing since 1989, the annual index was well below 1,000 in 1991 (C-DWR 1991b). However, 1992 trends reveal that this promising increasing trend has largely reversed.

Wildlife has been impacted by the ongoing drought, as shown by drastic declines in the wintering waterfowl in the Central Valley of California during the last decade. Most waterfowl do not breed in California. During the 1980s, the waterfowl suffered from drought experienced in the north. Drought affected the winter habitat and the condition of birds returning north to breed. The 1990 population was estimated at about 2 million as compared with about 10-12 million in 1980 (testimony of John Turner, Director, U.S. Fish and Wildlife, noted in Gleick and Nash 1991). The authors maintained that although waterfowl populations are affected by several factors, the water shortage has intensified these losses by reducing the quantity and quality of wetlands habitat in the Central Valley.

Forestry

The current drought has impacted California's forests. The California Department of Forestry and Fire Protection (CDF) is responsible for the largest area of forest, about 34 million acres, in California (Gleick and Nash 1991). The impacts of the drought on the CDF and the citizens of California are long-term and are predicted to continue into the next generation (C-DWR 1991b). By the fifth year, the drought intensified the buildup of dead fuels on 25 percent of the lands that the CDF protects. Three years of the current drought (1987, 1988, and 1990) were among the worst fire seasons experienced in the state. Based on acreage burned in the 1986 season, there was a six-fold increase in 1987, and acreage burned almost doubled during the 1988 and 1990 fire seasons. Yosemite National Park for the first time in its history closed down in 1990 (Gleick and Nash 1991). Additionally, the death rate of timber has continued to increase during the drought. Since its onset in 1987, the drought has destroyed 18 billion board feet of the state's merchantable timber. This is equivalent to building about 1.8 million homes (C-DWR 1991b).

Other Sectors

Environmental impacts also impacted the recreation and tourist sector. The water shortage led to increased operating costs in many of the state's parks. These increased costs are due to several factors that include (C-DWR 1991b):

- Need for new wells or deeper wells
- Trucking of water supplies in severe cases

- Installation of water conservation equipment such as drip irrigation and self-closing faucets

- Construction of boat ramp extensions to reach lower water levels

By the fifth year of the drought, water use at state parks was about 10 gallons per capita per day (gpcd) in comparison with 14 gallons gpcd during the 1976-77 drought (C-DWR 1991b).

In the tourist sector, the ski resort business in the state declined as the drought progressed and snow conditions deteriorated in the mountains. Estimates from the California ski industry indicated that "skier visits" had declined from 7.1 million in the 1988-89 season to 6.1 million in 1989-90 and 4.1 million in 1990-91 (Gleick and Nash 1991). The authors estimated that the ski resort industry lost about $85 million during the 1990-91 winter season, and employment levels fell to about 50 percent of normal during this time.

SUMMARY

This chapter described the progress of the drought from its onset in 1987 to its present-day status. The story of the drought has been described in detail so as to give the reader a summary of the precipitation and hydrological conditions during the six-year period, the actions taken during drought, and the economic and environmental impacts of the drought.

With this established knowledge base, the research team proceeded to search for learned lessons through interviews with representatives of agencies and organizations that control or influence water management. The reaction of these participants to what happened during the drought was expected to uncover prescriptive insights about what to do and what not to do during future drought episodes. The next chapter presents the interview findings.

V. SURVEY RESULTS: GENERAL PERCEPTIONS

This chapter summarizes the contents of the interviews pertaining to four general aspects of the drought: (1) critical drought impacts; (2) communication and cooperation; (3) the role and responsibilities of the media; and (4) response of the general public and water users to the drought.

The following opinions were presented during the interviews. They are not intended to represent the views of the U.S. Army Corps of Engineers or the authors of this report. The views have not been modified by the report authors. Participants interviewed in the study were given the opportunity to review draft versions of this report in order to both comment on the overall results of the study as well as to comment on perceptions specific to them. Two workshops were also held to review the document in a communal setting. We encourage reading of this section in the spirit of identifying a wide spectrum of varying perceptions that comprise water and drought management philosophy in California.

PERCEPTIONS OF DROUGHT IMPACTS

Major droughts, such as the 1987-92 drought in California, may have substantial adverse impacts on the economy, political system, environment, and society as a whole. Because less water is available during drought, some human activities become constrained, and the objectives possible with a plentiful water supply cannot be achieved. Also, the competition for water among various economic activities may leave the environmental uses of water at a disadvantage causing significant environmental impacts.

Investigations of drought usually concentrate on its adverse consequences. However, droughts also have positive impacts as well. One such effect is the subject of this study, namely, the lessons for water management.

The survey respondents named a large number of negative impacts of the drought but generally were able to quantify very few. Table V.1 shows a roster of the impacts of the 1987-92 drought in California that were mentioned by the survey participants. These impacts are grouped under four broad categories: environment, agriculture, urban economies, and other. The following sections describe the most critical impacts in each category.

Environmental Impacts

Almost all survey respondents agreed that the greatest impact of the 1987-92 drought fell on the state's environmental resources. The environmental community pointed out that the natural ecosystems in California have been diminished and weakened because of population

TABLE V.1

IMPACTS OF THE 1987-1992 DROUGHT IN CALIFORNIA AS CITED BY INTERVIEW PARTICIPANTS

I. ENVIRONMENTAL IMPACTS

- Reduced abundance and harvest of freshwater and anadromous fish
- Penetration of salt water into the Sacramento-San Joaquin Delta
- Forest damage from pests and fire
- Decline in the quality of wildlife habitat due to reduced water deliveries to California's wetlands
- Decline in populations of threatened and endangered species of plants and animals
- Increase of fossil fuel generation impacted air quality

II. IMPACTS ON AGRICULTURE

- Drought-related idling of farmland (especially in the acreage of rice, wheat, and cotton)
- Reduced agricultural income
- Increased agricultural cost
- Reduced herd sizes in some parts of the state
- Erosion of grazing areas due to overgrazing
- Increased capital investment by farmers on pumps and wells
- Overdrafting of groundwater aquifers
- Impacted industries producing goods to farmers
- Crop shift impact has been detrimental to the vegetable industry
- Demonstrated ingenuity of the farmers

III. IMPACTS ON URBAN ECONOMIES

- Increased expenditures on emergency water conservation programs
- Losses of plant materials on urban landscapes
- Increased costs of water treatment due to lower water quality
- Positive and negative criticism from customers
- Increased volume of work in urban water agencies

IV. OTHER IMPACTS

- Increased costs for fossil fuel energy to replace lost hydropower
- Income losses of the ski industry due to bad snow conditions
- Reduced houseboating activity due to low reservoir levels
- Increased emissions of carbon dioxide due to the burning of extra fossil fuels
- Increased expenditures for fire protection, fire control, staffing, and operational expenses
- Reduced visitor attendance at parks and facilities
- Social hardships
- Consumer inconvenience and lifestyle changes
- Industrial production and wage-earning-hours reduction
- Devaluation of California as a desirable industrial location

pressures and that their continued survival requires careful management and control. The drought has exacerbated the existing environmental problems.

Some environmental impacts of the drought occurred outside the water management systems in the sense that no human actions could prevent the damages. For example, the shortage of precipitation has caused very high tree mortality due to increased vulnerabilities to insect infestations and other forest diseases. At the end of 1991 as mentioned earlier, the damage assessment by the California Department of Forestry and Fire Protection estimated that since 1987, the drought has killed 18 billion board feet of merchantable timber (i.e., enough timber to build 1.8 million normal-size homes). Only a fraction of the dead timber can be recovered.

The impacts of drought on aquatic and riparian resources were evident throughout the water management system of the state. Respondents representing the state and federal natural resources agencies were aware of the drought-related problems. They expressed some frustration with the lack of understanding of the environmental needs by the public and the off-stream users of water. Many of them thought that society has to decide whether environmental uses should have priority. Some respondents suggested that there should be a referendum (or a popular vote) on this issue. They indicated that once the society "makes up its mind" and puts high priority on protecting ecological resources of the state, they will "gladly oblige." The environmental managers know what needs to be done and how to do it. Actually, the society did force water managers to give high priority to protecting the threatened and endangered species. The protection of species in the Sacramento River has resulted in forcing the operations of the water projects for environmental enhancement.

The participants from the environmental community believed that the operators of the water projects are clearly to blame for some environmental impacts. Aquatic resources were stressed because of the cumulative impact caused by minimum flows that persisted since 1987. Agriculture and urban areas received full allocations of the stored water during the first three or even four years at the expense of carry-over storage. Then when the drought continued, the projects wanted to have more carry-over storage by cutting down the minimum-flow requirements for protecting the aquatic resources. (It should be noted, however, that according to C-DWR, in 1989 it was not possible to carry over more water at Folsom and Oroville reservoirs, as this would encroach into flood use storage.) If the cutbacks were introduced earlier, then the SWP and CVP would be in a better position to protect the ecological resources. There would be more water to enhance flows and mitigate high water temperature impacts.

Impacts on Agriculture

Respondents from agricultural water districts gave many examples of negative impacts of the drought on agriculture. Because the major projects reduced water deliveries to agriculture, the respondents seemed compelled to let everyone know that these cutbacks caused major hardships. Significant amounts of agricultural land were left idle, and the cost of water went up. Many respondents acknowledged that the economic impacts were not great because of the availability of groundwater, changes in cropping patterns, and on-farm water conservation

practices. The impact of greater concern to them was the change in attitudes of the general public toward the agricultural sector. They resented the "farmer bashing" that was present in the media, especially during the fifth year of the drought. Some respondents viewed "farmer bashing" as a sign of future problems for agriculture in the state. Because of the change in public attitudes, next time it will be more difficult for agriculture to obtain water supplies or even maintain their current supplies. On the positive side, some respondents believed that the impacts of the drought had been mitigated tremendously on the farms by the farmers. They said that there were a million acres of farmland surviving with only a 25 percent water supply, and due to the ingenuity of the farmers, agriculture was not greatly impacted economically.

A majority of all other survey participants sympathized with farmers but were concerned more with the social impacts of water shortages on the rural communities than with the statewide impact of drought on income of the agribusiness sector of the state economy. The estimated losses in farm sales of $0.5 billion were often viewed by the other respondents as important but not as critical as the environmental impacts. This view was influenced, at least in part, by the realization that total farm sales represent a very small fraction of the state gross regional product (approximately $20 billion out of $700 billion or less than 3 percent) and that the highest farm sales year of 1990 was the third year of drought.

Respondents from the environmental community viewed the impacts on California's agriculture as being greatly softened because of the existing water management system, which protected off-stream uses of water against drought. Some statements seemed to imply that this protection comes at the expense of the environment.

Impacts on Urban Economies

The impact urban water users most frequently mentioned was conserving water and adjusting their lifestyles in order to do it. Although all survey participants praised the conservation effort of urban water users, their views on the level of hardship and the economic consequences of water-rationing programs were often deeply divided.

The participants whose responsibilities involve the development and administration of urban water demand management programs, both long-term and short-term, tended to view the negative impacts of rationing programs as negligible or minimal. They praised the consumers for great cooperation and quoted the achieved water savings as evidence of the success of the rationing programs. Because these participants work diligently to promote water conservation at all times, they viewed the drought as an opportunity to increase the public awareness of water use and achieve significant improvements in the efficiency of water use. Consumer inconvenience or economic hardship of businesses and industries was less of a concern.

The participants who deal with operations of water supply systems and those who perform long-term planning activities were concerned about the consequences of water rationing. As one respondent put it: "When you propose a rationing plan at 45 percent of what people are used to having, you must deal with a lot of angry people because this has a serious impact on people's lives and businesses." Another respondent called the conservation programs "irrational

rationing," indicating that because of strict water-rationing provisions, some electronics firms in Silicon Valley had to spend a lot of money on water conservation to avoid large employee layoffs. They paid up to $30,000 per acre-foot for water conserved, while farmers were very willing to give up much of their water at $125 per acre-foot or less. However, this comparison has to be interpreted cautiously, since the $30,000 per acre-foot is for a permanent effect (not one-time, like the $125 per acre-foot), and was primarily expended to avoid extremely high effluent discharge costs. Other respondents in the group often mentioned the difficulties involved in designing, implementing, and enforcing rationing programs, as well as their negative impacts on water utility revenue. Some saw the revenue losses caused by the rationing to be setbacks for their long-term conservation programs. In order to balance revenues, many retail water agencies had to increase water rates. The *Los Angeles Times* ran the headline "No Good Deed Goes Unpunished" in response to the proposed rate hike in Los Angeles.

The participants representing the urban "green industry" of landscapers and nurseries voiced numerous complaints against water-rationing programs, especially against total bans on outdoor watering. They lost a number of business accounts for landscape maintenance, because the owners had to let the landscapes die. Outright bans on landscaping use "until the drought is over" often paralyzed landscape businesses in many communities. Landscapers can work with very little water to beautify and maintain urban landscapes, but they cannot work without water. The landscape contractors pointed out that they represent a major industry in California, with the value of products and services that they estimate between $10 and $12 billion annually, almost two-thirds of the total value of farm product sales in the state.

Other Impacts of the Drought

Although environment, agriculture, and urban economies account for the majority of adverse impacts of drought, other sectors and activities also had their share of negative effects of drought. These other impacts are characterized here under the categories of water quality, recreation, energy, administration, and water policy.

Impacts on Water Quality

The six-year drought has impacted the state of the California water resources in terms of both their quantity and quality. Groundwater reserves have been depleted in many areas, causing accelerated seawater intrusion in coastal regions and subsidence in the San Joaquin Valley. The survey respondents voiced some concerns about the impacts on water quality. The availability of water to dilute the pollutants continues to be an important element of water quality protection. For example, higher salinity of water in the Delta combined with higher organic content of inflowing freshwater causes elevated levels of THMs (trihalomethanes) in public water supplies using the Delta water.

Impacts on Recreation and Tourism

Nearly $50 billion is spent annually in California on recreation and tourism activities (Gleick and Nash 1991). The drought had major impacts on tourist activities such as skiing in the Sierra Nevada, houseboating on reservoirs, and fishing for salmon and striped bass. For example, the number of recreation days on the State Water Project lakes has dropped from 7.2 million in 1987 to about 6 million in 1990, a 17 percent decrease. Visits to urban areas also dropped. The city of Santa Barbara estimated that they lost $30 million in tourism in 1990 due to publicity about drought and fires (Reinhold 1991).

The respondents who mentioned the impacts of drought on tourism often acknowledged the difficulty in estimating such impacts. Some decline in tourism and recreation was attributed to the economic recession. Others felt that the importance of these impacts easily fades away in comparison with the potentially irreversible impacts on the state's ecological resources.

Impacts on Energy Production

Hydroelectric power provides approximately 20 percent of the California's total electric energy supply and represents about one-third of the electricity produced by utilities located within the state. Because the amount of hydroelectricity produced is directly related to the amount of water in storage, the production of hydropower dropped to about two-thirds of normal during the drought. The representatives of the energy industry reported that the first four years of the drought have cost ratepayers an extra $2.4 billion because of the extra oil and natural gas burned to replace hydroelectricity. This has also caused an estimated 25 percent increase in the emissions of carbon dioxide.

The respondents from the energy industry voiced few complaints about the loss of hydropower. They tended to believe that during drought, water has more important uses than the production of hydropower. Some simply acknowledged the current situation in which their generating stations are operated according to an "environmental dispatch," instead of the traditional "economic dispatch." The advantages of hydropower as an inexpensive and flexible source of power are not sufficient to give it high priority during drought.

Impacts on Administrative Management

Almost all respondents from government agencies indicated that the drought has significantly increased their workloads as well as the level of difficulty in discharging their responsibilities. The SWRCB had to investigate an unusually high number of complaints. Also, there were a large number of permit applications filed by water users with critical needs for water who waited until the last moment to make requests. In other agencies, the respondents had to attend meetings more frequently than normal, and some had to devote considerable amounts of time to dealing with the media.

Impacts on Water Policy

One of the most significant impacts of the drought occurred in the state's political arena. The declining reservoir storage, drawdown, groundwater overdrafting, and water conservation execution allowed the state, regional, and local water agencies to delay hard choices in shaping new water policy. In 1991, the situation became very difficult. As one respondent stated: "Things got too bad and politicians stepped in. For politicians everything is very simple, [they] do not understand the complexity of the system." Thus water management moved up to the political agenda of Governor Pete Wilson. On February 1, 1991, the Governor signed Executive Order No. W-3-91 which established the Drought Action Team. In two weeks, the team recommended the creation of an emergency drought Water Bank. The 1991 Drought Water Bank was viewed by many respondents as a very positive outcome of the drought. Some praised the leadership of Governor Wilson, stating that before he stepped in, the state's drought policy could be characterized as mostly "doing very little and praying for rain."

A majority of respondents indicated that the Water Bank represented an important milestone in formulating an effective water management policy in California. The bank allowed water to move to high-value uses simply because of the raw power of market forces in allocating scarce resources.

Relative Importance of Drought Impacts

The information on impacts and economic costs of the drought is of critical importance to the formulation of adequate drought response plans. By comparing the various impacts, policymakers should be able to adjust the allocation of dwindling water resources so that the most severe impacts are minimized. The survey respondents were well aware of the implications of quantified impacts on water policy. Those whose water supplies were curtailed gave a detailed description of all impacts and attached a dollar value of losses wherever possible. At the same time, they were careful not to minimize or discount hardships and economic losses suffered by others.

In general, the respondents were fully cognizant of the difficulties in measuring drought impacts as well as the dangers involved in comparing the economic losses suffered by various economic sectors. They recognized the tendency of impact evaluation studies to be focused on impacts that can easily be quantified in dollar terms while undercounting those impacts that cannot be easily assessed in dollar terms. Many respondents agreed that the quantifiable economic impacts have occurred but were not critical because there was enough water to get by. Greater economic impacts would very likely occur if the drought continued or deepened. Although the economic impacts were of more immediate concern to people, because they often translate into lost jobs, there was almost a common opinion that the most severe effects of the drought fell on the ecological resources of the state. Objections to this view were raised by representatives of the agricultural sector. Some members of the agricultural community held the opinion that the environmental damages were exaggerated by the resources management agencies and the environmental community in order to take away water from agriculture.

Conclusions Concerning Drought Impacts

The results of the interviews lend support to two general conclusions pertaining to the impacts of drought. These conclusions can be summarized as follows:

- **Measurement and valuation of drought impacts is very difficult.** Attributing changes in economic performance and environmental resources to drought is not a simple task. Attaching dollar values to these changes is even more difficult and almost impossible in the case of impacts on the environment. Because of these difficulties, there is a tendency to focus only on impacts that can be measured and valued in monetary terms (e.g., loss of production of hydroelectricity). Many other impacts with potentially higher economic losses are usually described in qualitative terms only.

- **Anecdotal evidence and speculations about drought impacts influence drought response decisions.** During drought there is insufficient time to study the impacts carefully and make accurate predictions of potential impacts. As a result, qualitative statements about the impacts influence drought response decisions of water agencies. The mass media play a large role in disseminating anecdotal evidence about various impacts, often focusing on some impacts and overlooking others.

COOPERATION AND COMMUNICATION

The survey participants were almost unanimous in their opinion that the drought brought about a great improvement in cooperation among the agencies at various governmental levels as well as across the functional agencies at the same level. Also, the controllers and influencers of water management in the state were willing to communicate and compromise for the common purpose of coping with the drought. The drought seemed to have brought at least a partial and temporary peace among normally opposing interests. The following are some examples of good faith, cooperation, and communication that developed in the water management arena during drought.

The Memorandum of Understanding

As part of the ongoing proceedings on the allocation of water rights in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, the Department of Water Resources and the State Water Conservation Coalition (a cooperative project of the Northern California-based Committee for Water Policy Consensus and the Southern California Water Committee) brought interested parties together to develop a consensus on reasonable long-term conservation measures and achievable savings for urban areas. These measures became known as Urban Water Conservation Best Management Practices (BMPs). On December 11, 1991, the parties signed

a Memorandum of Understanding (MOU) that described the BMPs and set forth the obligations of all signatories. The participating urban water agencies agreed to aggressively implement the BMPs and monitor the success of implementation programs through an organization called California Urban Water Conservation Council. In return, they received assurances from the environmental community that they would accept the projected water-savings estimates of the BMPs and support the need to develop more reliable urban water supplies in the state.

The drought provided an impetus for signing the MOU. Some respondents pointed to the MOU as an example of good cooperation during drought. The significance of MOU, however, goes beyond the Bay/Delta issues. For the first time, the urban and environmental interests in California reached a consensus and influenced the balance of power among the urban, agricultural, and environmental sectors. The existence of such an imbalance brought agricultural sector to the negotiating table as well.

The Three-Way Process

Some respondents pointed out the Three-Way Process as an example of good cooperation and communication during the drought. In December 1990, representatives of the agricultural, urban, and environmental sectors began discussion on resolving the critical issues in the existing water management system in California to advance their common interests.

An opinion expressed during the interviews was that before the Three-Way Process began, some thought that any one of the three interest groups (i.e., agricultural, urban, and environmental) had enough political power to block any solutions to California water problems that were seen as mostly benefiting one or both of the other two sectors. This balance of power ("veto power") created a stalemate in water development for a period of more than 20 years.

The Three-Way Process aimed at achieving a consensus in which all three sides recognized that each sector has legitimate water needs. They sought to develop a phased approach to solving water problems that would be linked to simultaneous benefits for all sectors. They also agreed that the state needs an integrated package of water supply solutions to meet the most important needs of all three sectors. The Three-Way group was composed mainly of water professionals and activists who had a good understanding of water issues and of the views and positions of their constituencies. The Three-Way group saw itself as a resource whose conclusions and consensus views would be offered to the policymakers and politicians for their actions. However, at the end of the sixth year of drought, the expectations of success of the Three-Way Process had been lowered significantly. Apparently the willingness of the participating parties to compromise had diminished. Several participants of the workshops held in December 1992 expressed some doubts about the possibility of reaching a consensus.

Other Examples of Cooperation

The spirit of cooperation is not new to Californians. During the drought crisis of 1977, the communities in need could count on the help of not only their neighbors but also all other entities in the state. Long-standing animosities were put aside in order to help. For example, Metropolitan Water District of Southern California cooperated with the SWP and several other agencies in order to get water to Marin County and other districts in Northern and Central California. During the 1987-92 drought, water was provided to Santa Barbara using a sequence of exchanges and arrangements to transfer water from the north. Many other exchanges between neighboring districts also took place.

Another example was the public and private cooperation in implementing water conservation programs. In Southern California, Metropolitan Water District discovered a new marketing tool for the distribution of water conservation devices whereby the local fast food chains and grocery stores volunteered to set up device pickup points and distribute conservation kits to their patrons. This method of device distribution saved Metropolitan a lot of money while allowing the participating businesses to demonstrate their concern for the community and benefit by drawing more customers to their places of business.

There were many more examples of good cooperation and communication during the drought. One or more examples were given during each interview. Members of the environmental community indicated they had access and could talk to anybody in the state. State agencies could get cooperation of other agencies without any delays. Individual urban water users were more than willing to avert the crisis and readily responded to requests for conservation.

Conclusions Concerning Cooperation and Communication

The observations pertaining to cooperation and communication during drought are not new. Research on natural hazards has shown that disasters bring people together. Old animosities are abandoned in order to unite against the external forces. Water planners have known from previous experiences with droughts that during a drought they can accomplish more because there is more "readiness to help."

The C-DWR Drought Information Center has provided the hub of communication regarding the current drought since its establishment in 1988. The center is staffed by a team of public information officers and drought specialists, and it serves as the Department's clearinghouse for all inquiries regarding the drought's statewide impact. The personnel at the Drought Information Center responds to numerous calls and correspondence on a daily basis from news reporters, water agencies, lawmakers, and the general public.

Three conclusions can be drawn from the experiences of the survey participants:

- **Plans for improvements in infrastructure and efficiency of water use are easier to sell during drought.** Because the public attention is focused on water problems during drought, it is easier to communicate to the public the needs for long-term water conservation or improvements in reliability of supply and gain the public approval for proposed solutions.

- **Bureaucracies give high priority to cooperation during drought.** For many water institutions the drought is a real test of their performance. Officials and administration make extra efforts to perform well and are willing to cut "red tape" in order to speed up the administrative process wherever possible.

- **The C-DWR Drought Information Center has stimulated communication.** The Center has stimulated communication during the drought by arranging media interviews with various Department experts, preparing news releases and reports, assisting water agencies with financial and technical expertise, briefing local and foreign dignitaries, and replying to letters suggesting solutions to water shortages or requesting information on various topics.

ROLE OF THE MEDIA

The California drought of 1987-92 has been a continuing major news story. The newsworthiness of the drought created an opportunity to focus public attention on California's water issues. A majority of the survey participants recognized the importance of the mass media in influencing the drought management decisions. Many respondents criticized the media for not being very helpful. We summarize the views on the role of the media from the perspectives of the media, water controllers, and water influencers.

The Media Perspective

The media saw their role during the drought as informing the public on how supply allocations were made and on the consequences of the allocations and related decisions. In the media's view, people care about water when it does not come out of their tap or when it comes under their front door, that is, only during the periods of drought or flood. Although the primary objective was to cover the breaking news on drought, some media, especially the major newspapers, tried to bring into the picture water supply issues from a broader statewide perspective. Reporters asked, "Why are we in this crisis?" And the answer often required an extended inquiry and a role of a watchdog. Reporters tend to dig up reports on lessons learned and recommendations from previous droughts and find out whether the recommendations were implemented. They also want to see where the rhetoric is not matching reality, and whether any laws are broken. To them newsworthiness is present "when somebody is falling down on a job." When actions are done well and everything works as expected, there is no news.

The media, in their inquiries, want answers to the questions of the general public. During drought, what people want to know is, how much water is it prudent to use? Or how much water is it prudent to save? The public also wants to make sure that water agencies are not asking them for unnecessary sacrifices.

The Perspective of Water Controllers

Survey participants who represented water agencies generally gave the media good marks for their performance during the drought. They recognized that the press is probably the most important influence on public opinion. Various respondents gave one or more examples of things that the media should do in order to help. Accordingly, the media should:

- Inform the public about the trade-offs between various purposes of water use
- Play a bigger role in educating the public on water issues
- Pay more attention to the drought impacts on agriculture
- Give more credit to state and federal agencies for their role in the drought
- Expose the full spectrum of impacts and not focus exclusively on environmental impacts
- Maintain public responsibility and objectivity

Some water managers, however, were more critical of the media than other respondents. Most of them had to learn, on the job, how to deal with the press. Some believed that the media are completely "out of control" and all too often "make a mountain out of a molehill."

The Perspective of Water Influencers

Environmental community and regulatory agencies had more favorable opinion of the media's performance than water managers. One respondent believed that the great success of urban water conservation was primarily a result of the media constantly harping on the drought problem. The newsworthiness of drought resulted in an unusually large amount of print space and air time devoted to the drought. The public had no reason to doubt that they are in a drought crisis. Also, thanks to the mass media the public now has a better overall picture of water management than before the drought. The newspapers have good and vigorous writers of the water subject, even though they are not always complimentary of the operations and decisions of water management institutions. The influencers tended to agree that the criticism of the media by water managers is mostly unjustified because the media's primary role is to report on events and not to manage water resources. In cases where there were problems, the blame for poor communication has to be put on water agencies themselves.

Conclusions Concerning the Mass Media

The results of the interviews point to the following conclusions about the role of the media during drought:

- **The role of the media is not well understood by water managers.** The media are governed by their own rules of objective reporting, newsworthiness, and their perceptions of what the public wants to know. They cannot be managed by water agencies. If they were they would not be able to sell news. The questions like, Are we in a drought? or Is the drought over? are not silly questions from the media's point of view. Reporters understand the thinking modes and perceptions of the general public much better than water professionals. For them, once the water supply situation is called a drought, it automatically implies that behavior has to be changed from normal behavior to crisis behavior. Such a change is newsworthy.

- **Media cannot improve on imprecise and ambiguous messages.** Media reporters cannot improve on the clarity of the messages that they receive from water managers. More likely the statements will become even more confusing after they are reported in the press. Only unambiguous and complete answers to questions that are asked by the press can be communicated clearly to the public.

- **Media cannot explain complex water management issues.** What is very interesting to water professionals is usually "too dry" for newspapers, radio, and television. Long feature articles on water issues do not sell newspapers, but timely, well-written articles during a drought emergency will be read by concerned people.

RESPONSE OF THE PUBLIC

Survey respondents were unanimously in agreement that the public response to drought, in terms of cutting back on their water use, was very good. There were some differences of opinion with respect to the reasons for such a good response, as well as the problem of unfair treatment of those who conserved water by raising rates to make up for the lost revenue.

Reasons behind Public Cooperation

Some respondents expressed the view that urban users of water are the only group with significant potential for exercising water conservation. On a short notice they can change their water use behavior (by watering their yards less, flushing toilets less frequently, not cleaning their sidewalks with hoses) or use water-saving technology (such as toilet inserts, low-flow showers, and other devices). Farmers, on the other hand, have very few options for an

instantaneous adjustment in their water use. They use water for only one purpose, which is watering crops. Water needs are determined by weather, type of crop, and the growth stage. Once the seeds are in the soil, the only short-term option the farmers has is to let the crop die. Only some farmers can turn to pumping groundwater or reduce the use of water for leaching out salt buildup. Finally, environmental uses have no options at all. Water in the stream for fish or dilution has no substitutes. Although this reasoning had some simple appeal, the opinion that urban dwellers should save water simply because they can was not shared by all respondents.

The cooperative public response was partially summarized by one respondent as "people do the right thing if they have to do it." Another respondent expanded upon this statement indicating that people will conserve water if they are convinced that the drought is serious and when they believe that their actions matter and that what they are asked to do is fair. The public responded so well to the appeals for water conservation because these seemingly prerequisite conditions were present. Media's constant attention to drought convinced people that the drought was real. Mandatory rationing with enforcement further impressed the public about the seriousness of the situation. Rationing plans were designed with a purpose of making the required reductions in water use fair to all residents. Finally, information on changes (i.e., reductions) in water use provided the necessary feedback to water users to convince them that their efforts made a difference.

The survey respondents believed that water conservation efforts tended to be uniform throughout the state. Because the majority of urban residents share the same ultimate water supply sources, there is a reason for distant communities to share in the conservation effort. People in Southern California saved significant amounts of water even though one of their sources, the Colorado River water, was not affected by the drought. In some isolated areas with ample local supplies people did not reduce water use because they did not have to. In other areas reductions were more than was necessary.

Response to Fiscal Problems

The success of rationing programs often translated into fiscal problems for urban water utilities. In most water agencies, almost 80 percent of water supply cost is fixed (overhead, debt service, etc.). Reduced water use resulted in revenue shortfalls because water rates were usually not adjusted before rationing programs were put in place. Those customers who conserved had their water bills reduced. Approximately 80 percent of the combined reductions in water bills resulted in a shortfall of the agency's revenue, because of the prevailing cost structure.

Agencies with substantial revenue shortfalls caused by reduced water use as well as increased cost of operations during drought had to increase water rates. From the public's point of view, this was unfair. It seemed their reward for good behavior in conserving water was higher water rates. Rate hikes meet strong public objections during periods without drought, and there is no reason to expect public support for rate increases during or shortly after a drought. The press was not supportive either and, as in most rate hikes they were likely to blame the mismanagement of water utilities for cost increases. The outcome of this dilemma is undermined confidence of the public in their water agencies and possible reluctance to

conserve water in the future. The survey respondents described several cases of fiscal problems. Some blamed the media and the public for not understanding their cost structure and rate setting procedures.

Public Support for Long-Term Solutions

Survey participants had some difficulty in interpreting the implications of the excellent cooperation of the residents of California during the drought, with regards to public support for alternative solutions to the California's water supply problems. Generally, two opposing views were present during the interviews: an optimistic proconservation view and a pessimistic conservation outlook.

The optimistic proconservation view interpreted the public response to demand reduction programs as demonstrated readiness to conserve during future droughts. Those who shared this view maintained that the drought demonstrated a significant potential for water conservation in urban areas. People can and will save water during future droughts, and urban water suppliers can build in firm drought contingency savings of 20 percent or more into their long-term water supply plans. Furthermore, during the drought, people learned how to conserve water and changed their old wasteful habits to permanently use less water.

The pessimistic conservation outlook employed a very cautious interpretation of the public behavior during the drought. Those who shared this view maintained that if the urban public assumed the behaviors that are appropriate for crisis conditions and helped water agencies to get out of the crisis by making the necessary sacrifices, most water savings (except those resulting from installation of ULV toilets and low-flow showerheads) will disappear once the crisis is over. People are not likely to look forward to having to suffer the same hardships during future droughts. They will find out why they got into the crisis in the first place. If there is anything they can do to avoid a similar crisis in the future, they will pursue it. In other words, people will support additional water development and other permanent solutions. Several examples were given to support the pessimistic conservation outlook. First, some respondents maintained that if Californians had to vote on Proposition 9 (the construction of the Peripheral Canal in the Delta) in 1992 as opposed to the actual vote in 1982, the proposition would pass by a wide margin. Other respondents used the example of actions taken by the city of Santa Barbara. According to them, the hardships suffered by water users in Santa Barbara swayed the public's vote to approve the extension of the State Water Project Coastal Branch and the desalination plant. There was not enough time to look for least-cost solutions. Now Santa Barbara has the most costly source of water in the state, although SWP supplies and desalination were the least-cost feasible supply options for the South Coast. The cost of water from the desalting plant is about $2,000 per acre-foot if the plant operates full-time, but higher if it generates only during water shortage periods as is likely. The cost of water from SWP Coastal Branch will be between $1,200 and $1,300 per acre foot. In comparison, before the drought the city of San Diego used to be mentioned as paying the highest cost for water supply in the state. That cost was about $600 per acre-foot. The higher cost of water supply and other drought-related expenses more than doubled normal water rates in Santa Barbara.

Conclusions Concerning Public Response

The current drought demonstrated that urban water users can cut back on water use, and this confirms the experiences of the 1976-77 drought. Residential and commercial users in urban areas are willing to curtail their normal water use during a crisis. They have a number of options for achieving water conservation because water is used for many purposes, some of which are less essential than others and can be stopped or reduced. The following conclusions can be drawn from the results of the interviews:

- **People are willing to conserve if certain conditions exist.** The fact that urban dwellers can conserve water does not automatically mean that they will. Urban households and businesses took actions to conserve water because they believed that (1) there was a severe drought, (2) their conservation efforts helped mitigate the adverse consequences of the drought, (3) all members of their community were asked to conserve and made sincere conservation efforts, (4) their personal actions furthering group welfare rather than self-interest would have desirable long-term consequences for their community, and (5) their efforts involved only a reasonable level of personal cost and inconvenience.

- **Drought focused public attention on water supply.** When there is no drought, people tend to get involved in water management only when there is a rate increase. During the drought they focused on other issues related to water supply and were more willing to support solutions and investments in improvements of water use efficiency and water supply reliability.

VI. SURVEY RESULTS: WATER MANAGEMENT ISSUES

This chapter summarizes the results of the interviews that pertain to four major aspects of water management during drought: (1) new developments and innovative approaches; (2) critical legislation; (3) timing of drought response actions; and (4) performance of water institutions.

NEW DEVELOPMENTS AND INNOVATIVE APPROACHES

The 1987-92 drought forced Californians to look for innovative solutions to both the immediate and long-term water supply problems. A number of new developments and innovative approaches surfaced during the interviews. Probably the most important development of the drought was the creation of the Water Bank. Other important developments mentioned by the respondents included: (1) the Three-Way Process negotiations; (2) signing of Memorandum of Understanding; (3) rescheduling of annual deliveries by CVP; (4) purchase of water for in-stream purposes by the Department of Fish and Game; and (5) new knowledge about the needs of aquatic life. In addition, several innovative approaches were tried in the following areas: (1) urban water conservation; (2) agricultural water conservation; (3) ricelands/wetlands conjunctive water use project; (4) groundwater management; and (5) unconventional supply alternatives (desalination and off-stream storage).

The Three-Way Process and Memorandum of Understanding were described in Chapter V under the heading of Cooperation and Communication. The opinions of the survey participants regarding the Water Bank, rescheduling of water deliveries, purchase of water for in-stream purposes, and new knowledge about aquatic life are described below.

Views on the 1991 Drought Water Bank

Many respondents indicated that the creation of the Water Bank during the drought was a new development with very important implications for future water policy in the state. The success of the bank was so great that many institutions sought to take at least partial credit for its conception. Actually, the bank was masterminded by no more than a dozen professionals under the direction of the Director of C-DWR, David N. Kennedy, and Deputy Director Robert G. Potter. The impetus for bringing the bank to existence on short notice was provided by the Governor of California, Pete Wilson.

Water transfers and banking are not necessarily new ideas in California. Some exchanges and banks existed before the drought, and there has been a lot of discussion about the need for a statewide Water Bank. The 1991 bank can be considered a new development, because, as one respondent put it, "they (C-DWR) actually did it." The creators of the bank had to cut through considerable red tape to make it happen. The C-DWR submitted to the SWRCB an operations

plan for the Water Bank that defined the legal boundaries of water transfers. The Board gave a tentative approval to the plan so that if the proposed transfers were within the legal permissible boundaries, then it was fairly easy to proceed with timely approval of the Water Bank transfers. According to the SWRCB, the transfers were well thought out and executed to meet the critical needs of the buyers and provide extra environmental benefits.

The praises for the Water Bank and interpretation of its implications for future water management took several forms. One respondent stated that the success of the bank exploded the old "farmers will never sell" myth. In reality, farmers were very willing to sell, and bank purchases had to be halted after buying 850,000 acre-feet of water from willing sellers. Other respondents expressed similar opinions, stating that the bank taught the California's water community that water markets, however limited by geographies and constrained by laws and regulations, can work. It demonstrated the "raw power of market forces." Although mostly serving as a clearinghouse for water transfers, the bank was very quick to respond to the needs of water supply agencies. Many respondents believed that the 1991 Water Bank should also be reinstated in 1992.

A significant fraction of California's future water needs can be met by letting water move from lower- to higher-value uses, especially during future droughts. This is the major implication of the success of the bank for future water policy in the state. As long as there are adequate facilities to store and move water throughout the state, urban water agencies as well as agricultural districts can plan for future droughts while counting on the availability of water for purchase from a future Water Bank. Because of this option there will be less pressure by off-stream users to develop more water. Continued use of the Water Bank is very much dependent on available groundwater in the transferring areas. Further, it is largely a conjunctive use program (if the necessary recharge is achieved), otherwise it is a "mining" program.

Some respondents said that to establish a properly functioning Water Bank, it would be necessary to make improvements in water storage and transmission facilities and to change the existing water laws in order to protect water rights of willing sellers and better deal with the issues of third-party effects. The first requirement is mainly related to the Delta problems. The Delta is a focal point for California plumbing. Most water exports (and exchanges) either go through or affect the conditions in the Delta. Improvements have to be made to move water across the Delta in a way that satisfies water purveyors and environmental groups while protecting resources in the Delta. Additional storage for making more efficient use of the existing canals and aqueducts will also be needed. At the receiving end, water districts will have to build interconnections to the major distribution systems of SWP, CVP, and other aqueducts.

With respect to the legal requirements, those who sell water have to be assured that they will not lose their water rights. For example, Yuba County Water Agency, which had supported transfers during the drought, was sued and challenged about its water rights during hearings by the State Board. Note that efforts to ensure in-stream flow on the Yuba River preceded the drought. The California Department of Fish and Game has not opposed Yuba County's sales, but has recommended mitigation. The SWRCB has not threatened their rights. Also, in case of riparian rights, "sales" of water by one riparian may affect the rights of others. Technically, the riparians did not "sell" their water to the Water Bank. They were paid not to use it. The SWP was able to pick it up in the Delta by "virtue" of its obligation to meet water quality

standards by reservoir releases during controlled flow conditions. Some participants from the agricultural sector expressed concerns about the effects of large-scale water transfers on the state's agriculture. Also, they were concerned that water shortages to off-stream users may be created by allocating more water for environmental purposes and forcing the SWP contractors to pay for water purchased through the bank in order to replace cutbacks in normal deliveries. To make it fair, water for the bank should be bought with public funds and released for environmental uses, while protecting the existing contracts for water delivery. As it stands now, SWP contractors have to pay the fixed cost (some 80 percent or normal cost for water delivered) without receiving any contract water. They pay extra for water purchased from the Water Bank.

One additional economic effect of water transfers was that farmers actually made money by selling water and forfeiting agricultural production. Some respondents indicated that this procedure may have long-term impacts on the food production industry and the consumer: potential unemployment and higher prices. The extent of these losses depends upon the frequency and magnitude of water sales.

In summary, the Water Bank was seen by survey participants as the most important new development of the drought. Many hoped that the bank would continue until the drought ends and would be organized again during future droughts. The economic impacts must be studied to determine future operating rules so that the bank can avoid or minimize undesired economic repercussions.

Other New Developments

Under California water law, one cannot hold water rights for in-stream use. During the drought, the California Department of Fish and Game (DFG) was given permission to engage in purchasing water for wetlands and for supplementing river flows to protect fisheries. DFG owns a considerable amount of land. Some land has pre-1914 water rights. The Department also has rights to develop groundwater, engage in conjunctive use of water, and generate water credits in storage. In 1992, DFG set a precedent by purchasing water rights for in-stream use purposes. The (Bradley) Reclamation Drought Act of 1991 and the (Seymour) Drought Response Bill address the mitigation of drought effects and financing drought relief activities. More will be said about these bills in the next section on critical legislation.

Another new development was welcomed by agricultural water districts. The CVP changed its water-contracting and delivery procedures to allow "rescheduling" of water deliveries from one year to another. This new policy introduced the element of flexibility in deliveries and allowed users to keep water in storage to prepare for future upcoming shortages.

Finally, some new developments have altered CVP procedure to safeguard salmon numbers, In 1992, almost 300,000 acre-feet of irrigation water were stored behind Shasta Dam to lower the upper-river water temperature after the winter run had spawned. Salmon need cool water, not exceeding 56°F, to spawn. A 6°F increase to 62°F represents 100 percent mortality of incubating salmon eggs.

Innovative Approaches

The survey participants had some difficulty deciding which approaches were innovative in coping with drought. Most methods, devices, and practices have been known and used during past droughts. This drought has brought about increased use of these approaches. Below are brief summaries of new techniques used in several areas.

Urban Water Conservation

Urban water suppliers set percent water use reduction goals for each year of drought. For 1991, these goals ranged from 15 percent in East Bay MWD to 31 percent in the Metropolitan Water District of Southern California. Note, however, that with reference to MWD's delivery cuts (which had to match supplies), the local agencies had other supplies. The real deficiency seems to have been 15 to 20 percent and was helped a great deal by a very mild (cool) summer. For example, between June and August 1992, usage of surface water was 38 percent greater than the same time in 1991. Goals ranging from 10 to 25 percent were set for 1992. To achieve these goals water agencies implemented one or more water demand management programs. These included mandatory metered rationing, steeply inclined (increasing) commodity rates, distribution of water-saving devices, and enforcement by water-waste patrols and citations or by meter disks and fines.

Although almost all conservation techniques have been used before, some innovative implementation methods appeared during the drought. At the retail level, water purveyors used direct payments to customers for installing retrofit ULV toilets that would not have been installed otherwise. For distributing and installing retrofit kits (i.e., showerheads and toilet inserts), water agencies usually had to spend large sums of money to hire contractors to conduct home visits and deliver the devices. An innovative approach used during the drought succeeded in Southern California, where kits were distributed free by grocery and fast food chains.

At the regional level, joint multiagency advertising campaigns took advantage of the "news shed" phenomenon. These campaigns were designed to advise water users about conservation and covered a large region rather than merely local entities. The campaigns resulted in cost savings to individual agencies and resolved water users' confusion as to the applicability of conservation requests to their service area.

Some innovative implementation methods were used by wholesale water agencies to encourage demand reduction by retail agencies. For example, Metropolitan Water District devised the Incremental Interruption and Conservation Plan consisting of stages of severity reaching 90 percent of "nonfirm deliveries" and 30 percent of "firm deliveries." The program had incentives and penalties linked to the level of compliance. Agencies using less than their target quantity received an incentive payment of $99 per acre-foot of extra conservation. Any agency that did not meet its target quantity had to pay a penalty charge of $394 per acre-foot of the excess use.

Agricultural Water Conservation

Survey participants representing agricultural water districts gave many examples of water conservation efforts taken both by water districts and by individual farmers. They stated that because of drought there is more drip irrigation, more sprinkler irrigation, and more laser leveling of fields than there used to be.

Some participants interviewed in the agricultural sector referred to irrigation efficiency techniques and other quantitative scientific methods used in agriculture to promote water conservation. One agricultural District (Westlands Water District) indicated that it had practiced the Water Conservation and Drainage Reduction Program during the first two years of the current drought. This program provided funding to advise farmers on how to improve on-farm irrigation efficiency. To attain irrigation efficiency, the farmers were advised to improve their existing irrigation systems and their irrigation practices (Robb and Slavin 1990).

One group of participants commented that agriculture has to communicate to the public and policymakers the methods of water utilization on the farm. As a result of poor communication regarding agricultural water use methods, the following criticism has been levelled at agriculture:

- Farmers put water on the wrong crops.
- Agriculturalists are not good stewards of the resource.
- Farmers do not practice good irrigation techniques.
- Farmers could easily conserve and transfer 10 percent of their normal supplies (the "10 percent solution").

The drought had created a greater awareness among the farming community of the need to educate the public and policymakers about water-saving techniques used on the farm.

Ricelands/Wetlands Conjunctive Use Project

Survey respondents representing the environmental community as well as other sectors often referred to the declining water levels in California's wetlands, particularly in the Central Valley. The impacts of reduced deliveries of developed water to agriculture revealed that in many areas, environmental resources are critically dependent on water deliveries to the state's irrigated agriculture. Many wetlands in the Central Valley are maintained by return flows from irrigation. These wetlands received very little water as farmers reduced water application rates and irrigated acreage. The drought also highlighted to resource managers, the fact that the flooded rice paddies in the Sacramento Valley provide a critical support to waterfowl. The Central Valley provides winter habitat for 20 percent of all ducks counted in the United States and 50 percent of all mid-winter water fowl in the Pacific Flyway (California Rice Industry

Association [CRIA] 1992). Because almost 90 percent of the valley's original wetlands have been lost, only 60,000 acres of protected wetlands support waterfowl. Additional habitat is provided by some 600,000 acres of rice paddies that in 1991 were reduced to 300,000 acres due to low water supplies. Therefore, the reduced rice production had an adverse effect on wildlife habitat.

The new knowledge about the interdependence between rice production and waterfowl habitat led the Nature Conservancy of California (established by CRIA) to the development of a "ricelands/wetlands conjunctive use project." The project would:

- Create upward of 100,000 acres of winter wetland habitat by flooding rice paddies in winter
- Provide nearly 300,000 acre-feet of off-stream storage capacity
- Provide for aquatic biodegradation of rice stubble (rather than burning stubble which creates air pollution problems
- Sustain the communities and economies that have become dependent on rice production

The proposed conjunctive use concept plans to set aside eventually possibly hundreds of thousands of acres of winter-fallow rice grounds for managed wetlands and off-stream storage purposes (CRIA 1992). The flooded acreage (up to a depth of six to eighteen inches) would begin in October or early November. The project would provide abundant high quality wetland food and habitat for migratory species of ducks and geese and also nongame wetland birds. When waterfowl populations begin to migrate back north by mid-February, the project would have the option of raising water levels from two to five feet on some lands for the additional purpose of off-stream storage. The SWP, CVP, and local water districts may be interested in utilizing this storage facility. Carry-over capacity of existing reservoirs can also be increased by using off-stream storage. If significant off-stream capacity is made available by the project, big mainstream reservoirs such as Shasta and Oroville could be relieved of some of their flood control responsibilities. In other words, the project would provide an alternative means of storing flood water which may allow for greater carry-over capacity in Shasta Dam. This would also keep Shasta water colder for a longer period of time because the water depth would be greater. Additionally, greater capacity and lower temperatures at Shasta would benefit spawning and out-migrating salmon. The ricelands/wetlands conjunctive use project represents an innovative strategy in water resource management in California, triggered by the 1987-92 drought.

Wastewater Reclamation and Groundwater Recharge

The drought has brought increased attention to wastewater reclamation. In Southern California there were 43 existing and/or under construction reclamation projects as of 1988. These projects will deliver about 200,000 acre-feet/year of reclaimed water to more than 100

sites. Some respondents have indicated that water reclamation is increasing, because the drought created more demand for reclaimed water. A major reclamation project is being considered for the wastewater produced in the San Francisco Bay area and its recharge into the overdrafted aquifer in the San Jose area.

Unconventional Supply Alternatives

Desalination is the extraction of potable water from seawater or brackish groundwater. Desalination of seawater became a more viable alternative during the drought. The city of Santa Barbara has completed the first half of a 7.5 mgd reverse osmosis (RO) plant. The city of Moro Bay completed the construction of a 300,000 gpd plant in 1991. Several cities and water districts actively pursue desalination projects. Because the cost of desalinated seawater is very high (up to $2,500 per acre-foot for base supply operation), in most cases this water cannot be used as a base urban water supply or agricultural supply. The desalination plants are likely to be used as insurance against water shortages and operated intermittently. Costs for brackish groundwater desalination are dependent on the capacity of the extraction system as well as the feedwater quality (range of total dissolved solids [TDS] level in saline brackish groundwater). Systems can be designed for individual wells or combined flows from several wells. Generally, desalination of brackish groundwater is a very reliable source of water supply unless the feedwater contains specific constituents causing problems in the desalination process. There was also an increase in weather modification projects operating in the state. Finally, unconventional water development, such as off-stream storage, received support from the environmental community.

Overall, the survey participants seemed to pay very little attention to unconventional supply alternatives. A better management of the existing supply and water allocation issues seemed by far more important to them than technological innovations.

Conclusions Concerning New Developments

The drought forced water agencies and water professionals to seek creative solutions to water shortage problems. However, very few radical solutions were implemented. Instead, there was a greater diffusion of known technologies, and only solutions that were judged to have a fair chance of succeeding have been implemented. The Water Bank is a good example of the latter. Water transfers had been tried before, and there was a very good chance that the bank would work. Untried solutions, such as bringing water by tankers to Santa Barbara, were less likely to be implemented. Therefore, the conclusions pertaining to new developments and innovative approaches can be summarized as follows:

- **Known and tried solutions prevailed over innovative but untested approaches.** Development of technological innovations takes time, and more innovations are likely to be developed in the wake of the California drought. However, known and tried technologies and solutions were likely to be implemented by more water users and agencies during drought.

- **New approaches to water management were more important than technological innovations.** The Water Bank and water transfers were at the forefront of new developments during the drought. New knowledge about physical systems and environmental response was gained because of the transfers. Also, new knowledge about the linkages between some agricultural water uses (e.g., rice production) and environmental resources revealed opportunities for improved management of environmental resources.

CRITICAL LEGISLATION

The present drought in California revealed various inadequacies of the existing legal system and stimulated more activity in the legal process. During the interviews, participants voiced their opinions on existing legislation, invariably expressing the critical need for legislation to open up the water management process in the state. Critical legislation pertaining to water management had been introduced during the drought at federal and state levels of government. The environmental sector influenced additional legislative action. The drought also brought issues such as water reclamation and groundwater management into focus.

Federal Legislation

Many interviewed water professionals indicated a need for flexibility in the water management process. The infamous Warren Act was referred to by many interviewees when they commented on the restrictive nature of certain federal legislation. As a result of the Warren Act, the Bureau of Reclamation could not transfer nonproject water through their facilities. In a time when the Water Bank had made its mark in meeting the water needs of the state, it seemed ironic that the Warren Act was still in existence. One respondent described it as a "shameful hypocrisy." The restrictions of the Warren Act were clearly demonstrated by its effect on the San Francisco Water Department (SFWD). A respondent indicated that almost all the water bought from the Water Bank gets stored in the San Luis Reservoir, and conditions in the Delta determine the releases from the San Luis Reservoir. The Santa Clara Water District could take its state project water through the federal aqueduct directly from San Luis. Then the South Bay would have extra capacity, and water coming in from the Delta could be diverted to San Francisco, thus facilitating the exchange. At the time of the interview, there were restrictions on making these transfers viable. Recently the Warren Act has been repealed bringing operational compatibility to the SWP and CVP.

The drought also spurred some flexibility in the USBR policy concerning CVP deliveries to water districts. At the beginning of the drought, the "use it or lose it" policy prevailed. According to this old policy, the district had to use the water within 12 months. Participants from one agricultural district stated that the USBR has allowed rescheduling of water since 1989. This policy allows the district to use water that was stored from the previous year. During times of drought this "extra" water becomes most useful especially during times of excessive shortage.

Most respondents referred to the Miller, Seymour (S. 711) and Bradley (S. 586) bills as critical legislation. These bills were initiated because of the present drought and had been referred to the Senate Committee on Energy and Natural Resources. The Seymour Bill would provide the Secretary of the Interior with authorization to respond to the drought. For example, the Secretary would be able to make loans to water users for drought response activities--to study measures for water conservation, augmentation and efficient use and to prepare cooperative drought contingency plans. Additionally, this bill would authorize the Secretary of the Interior to establish a $10 million "Reclamation Drought Response Fund" to finance drought relief activities authorized by the act. With regard to the (Bradley) Reclamation Drought Act of 1991, the USBR, after consulting with governors of affected states, would be authorized:

- To alleviate temporary drought conditions through management and conservation activities
- To provide assistance to willing buyers and sellers of water
- To prepare drought contingency plans for federal reclamation projects
- To contract for storage and conveyance of project and nonproject water

There was much negotiation and consolidation of these parallel pieces of legislation, which were eventually incorporated into the Miller-Bradley Bill. This bill, previously referred to as H.R. 429, contains 40 separate titles providing for water resource projects throughout the West. It is known as the Central Valley Project Improvement Act (Title 34 of Public Law 102-575) and was signed by the President on October 30, 1992. This bill protects, restores, and enhances fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California. The provisions of this bill are summarized in Appendix A (p. A-8).

State Legislation

The drought provided a stimulus for a number of state legislative proposals dealing with water management. One respondent stated that during the sixth year of the drought, there were about 60 or more proposed state laws that were "out of control." More specifically, by the fifth year (December 1, 1991), there were 19 state bills introduced dealing with drought. These bills focused on issues such as drought contingency plans, drought management activities affecting the environment, water appropriation, development projects, safe drinking water, and drought relief and assistance.

Assembly Bill 11x (AB 11x) was a most significant piece of drought legislation introduced in the California State Legislature on March 21, 1991. It required all urban agencies in California (serving more than 3,000 customers or 3,000 acre-feet) to submit drought contingency plans to C-DWR by January 31, 1992. Some respondents stated that AB 11x should have been implemented earlier, by the second year of the drought and not during the sixth year. Drought contingency planning should be introduced at all levels in California and should become a part of the state and federal system. Some respondents perceived that AB 797 (Urban Water Management Planning Act of 1983) and AB 11x had increased the ability for public participation. They stated that agricultural communities have to do this too, since some water agencies in rural areas were unprepared to cope with the drought. However, in 1986, the legislature passed the Agricultural Water Management Planning Act. It requires "every agricultural water retailer supplying more than 50,000 acre-feet of water, if not covered by water conservation requirements of state and federal agencies, to report to C-DWR by December 31, 1989, how its water is managed" (C-DWR 1987).

The most critical form of state legislation involved water transfers and marketing that helped facilitate the operation of the Water Bank. Although there were differing points of view regarding "emergency legislation," most respondents agreed that new legislation and cooperation were essential ingredients to facilitate water transfers and marketing. Although none of the Water Bank transfers were disapproved, the drought revealed that there are too many institutional barriers to water transfers. Others stated that the normal process of water transfers is hindered by the impact of bureaucracy, which has too many agencies administratively involved in any one transfer and this makes the transfer process difficult. Most respondents complained about the amount of "red tape" involved in transfers. Various pieces of legislation were referenced by interviewees pertaining to water transfers: Katz Bill, Seymour Bill, Johnston Bill, and the Bradley Bill. Some respondents stated that the Katz Bill was good for the sale and transfer of water, and in terms of economics future legislative action should pass this bill. Others commented that the Katz Bill authorized the transfer of riparian water rights, and that it was progressive, since it allowed an individual to transfer water.

One respondent believed that the normal process of water transfers will not work and added that the Water Bank worked by going around the system. It was stated that the ability to transfer water was limited by the Delta, since there are restraints placed by the California Environmental Protection Act. Reference was made to the Yuba County Water Agency, which had supported transfers during the drought, and was sued and challenged about its water rights at State Board hearings. This county was not going to sell anymore water in the future. One respondent stated that there is a 60 percent tax on the transfer per acre-foot of water delivered from Northern to Southern California. This 60 percent was made up of 30 percent of carriage water loss in the Delta and 30 percent extortion loss to operate the river in local basins. Therefore, water marketing is not a solution for the future. Further comments indicated that this process ignores water infrastructure and third-party problems, exposes the seller to great risks, makes it expensive for the buyer, and is not a realistic policy. It was added that if water marketing was going to work, many institutional barriers would have to be removed. However, it was pointed out that these barriers were necessary to protect interests, to protect water rights, to protect third parties, and to protect competitors.

A number of respondents referred to the question of water rights and stated that if the Water Bank was going to continue, then someone had to have more control over it. Other respondents referred to the disputes that occurred during the drought over water rights issues and control of water. For example, certain agricultural users contested the rights that the district has over the water apportioned to farmers.

Environmental Legislation

The drought highlighted the fact that California needs a more equitable system for recognizing beneficial uses of water. In the view of the environmental community, while protracted debates over water transfers took place during the period, no environmental legislation (or other executive or administrative action for environmental protection) was implemented in California in response to the drought. Indeed, this is a very significant lesson of the drought—the impacts of the drought have fallen most heavily on the environment. These impacts are largely a function of water management policies and actions before and during the drought as opposed to the drought itself. The dramatic declines in water-dependent ecosystems and species during the drought graphically demonstrate the need for fundamental policy and management reforms to improve both equity and efficiency among all water use sectors, including the environment.

The perceptions and insights shared by environmental groups interviewed, regarding the need for critical environmental legislation, are summarized in the discussion that follows. They stressed that the environment does not have a fallback position, and that baseline standards were inadequate to mitigate environmental impacts. The environmental sector was always low in allocation priorities, and the environmentalists wanted equity and fairness. Some participants stated that the drought proved to be a refreshing change, because the bureaucratic top-down approach for sharing water among in-stream and off-stream users was being reexamined.

Water law should allow in-stream water rights that are not present now. One can work within the existing system of laws, but they are not sufficient, because the laws were developed as the western frontier developed for the use of water out of the river. In-stream water uses (in the river) were never part of this development, and this bias cannot be justified. It would help to develop the proposed water fund to purchase water for the environment and also help to have water rights associated with it. Furthermore, there is a need for new water laws. Changes in existing laws were critical because there is a need to fix the institutions in the long term. Otherwise, the benefits of improvement in the water management system, structural and nonstructural, may not be realized. The Department of Fish and Game was most enthusiastic about the legislation that would recognize in-stream water rights, thus allowing the department to become a participant in water allocation and management of water for fish and wildlife. One of the stated keynotes for the 1990s, in addition to goodwill and professionalism, was supportive legislation to enhance environmental quality. As mentioned, important pending legislation related to fish and wildlife during the drought included the Seymour Bill, the Bradley Bill, the Miller Bill, and the Dooley Bill. These were consolidated into the Central Valley Project Improvement Act.

The Endangered Species Act (ESA) evoked varying points of view among respondents interviewed. Some stated that the ESA was instituted to protect the endangered aquatic and other species. On the other hand, most respondents echoed frustration when referring to the ESA. Some perceived the ESA as the "most significant problem that the state faces," one that has to be modified. The act approaches the problem species by species. It needs to look at the environment as a whole. Some participants believed that the ESA will magnify and extend the current drought. Through the ESA, some agriculturalists stated that not only were fisheries equated to farmers, but agriculturalists were told how to control their operations, whether or not it benefits the fish. They felt that certain amendments and changes were needed in the ESA to allow for better management for water supplies. Some questioned why fishing was being permitted off the coast and in the Sacramento River when the numbers of fish were so greatly diminished. It was also mentioned that environmental acts such as ESA, the Wild and Scenic Act, and forestry acts inhibit water development in mountain areas where the good water is. This water needed to be utilized in order to build up reliable supplies.

Groundwater Management

The drought had increased groundwater pumpage in the state, and it was generally perceived that groundwater had to be managed carefully. Some respondents indicated that within the CVP service area, groundwater overdrafts of 1.5 MAF took place during the fifth year of the drought. They stated that it was difficult to control water use in the San Joaquin Valley, since the situation differs from one region to another. Some have surface supply, others have groundwater supply, and effects fall unevenly on various areas. The respondents said that state legislation has been proposed to construct a plan that affects only critically overdrafted areas. Another group stated that there was a need for the large groundwater basins in the San Joaquin Valley to have mandatory groundwater management plans, with water use being monitored. The group indicated that only political action could avoid lengthy adjudication. Respondents generally perceived that statewide groundwater management was not a viable solution. At that time, water rights holders were permitted to pump water out of the basin for beneficial use. However, groundwater mining and degradation of groundwater quality could not continue indefinitely. One group indicated that the Katz Bill and Bill 486 had put restrictions on waste disposal. The legislation process would have to consider a groundwater protection policy that will include such programs as groundwater mapping, groundwater recharge, and conjunctive use.

Other Legislative Issues

The interviews also identified legislation addressing other issues. Many respondents stated that water reclamation projects were increasing in California. The legislative process had introduced AB 15x (Kelley) reclamation projects appropriating emergency state financial assistance of $10 million from the General Fund to the SWRCB. These loans and grants were to assist local water suppliers for water reclamation projects that could be completed and provide reclaimed water by June 30, 1992. Besides reclamation, respondents also mentioned other legislation related to various plumbing codes (e.g., BMPs) and water quality.

Conclusions Concerning Critical Legislation

- **Drought provided a test of the adequacy of existing laws and regulations.** The drought has demonstrated how the existing laws and regulations really work. Inadequacies were revealed, especially those pertaining to the legality of certain drought response actions. The drought precipitated the resolution of longstanding efforts to pass environmental legislation.

- **Drought brought a danger for passing bad laws.** Although drought emergency legislation was critical to the ability of water agencies and individuals to cope with water shortages, some permanent laws can be passed without sufficient public debate. Hearings on new laws also can be very contentious and can polarize major sectors of users, thus adversely affecting their cooperation in dealing with the crisis at hand.

TIMING OF DROUGHT RESPONSE ACTIONS

The success of coping with drought is critically dependent on the timing of drought response actions. Water controllers do not want to make unwarranted changes in normal operations of water supplies. At the same time, they may take some risks and postpone the declaration of shortages and thus the hardships of water rationing as far into the future as possible.

The survey participants were asked their opinions about the timing of actions taken in response to the drought. The participants' views indicate that the timing of response actions of the majority of water agencies throughout the state is geared to the declarations and announcements made by the Department of Water Resources and the Central Valley Project. The first important decision involves the answer to the question, Are we in a drought? The answer is important to the public because they will eventually carry the burden and costs of dealing with water shortages.

During the second year of drought, Director Kennedy of C-DWR stated that if there are two consecutive critically dry years in the Sacramento River basin (as measured by Sacramento River Index), then one may call the situation a drought. Both 1987 and 1988 water years were critical, and the drought became official. This criterion for declaring drought suggests that SWP is confident about its ability to withstand two consecutive critically dry years. This drought indicator is derived from the experience of the 1976-77 drought, which represented two consecutive critically dry water years.

Calling a given weather anomaly a drought is not as difficult as determining whether the drought is over. The response actions must rely more on the expectation about the continuation of the drought during the next water year (as well as subsequent years) than on the water in storage and the severity of drought during previous years. In hindsight, the Director's prediction

was accurate in the sense that the two dry years signaled a sustained multiyear drought in the state.

Once a drought is recognized, the response actions are tied to the February 15 report on water supply outlook. Around the first of February SWP and CVP take first snow surveys and prepare estimates of water supply in the coming year. The estimate of water supply is the trigger for deciding whether any reductions in water delivery will be made. Actually, it takes more than one estimate to make final decisions. Again, what is known is the amount of water at hand. Expectations about precipitation in the following year must be taken into account as well. However, once the announcement about reductions in water deliveries is made, it triggers actions for all affected districts and greatly influences the decisions of suppliers outside the SWP and CVP systems.

The survey participants devoted significant amount of time to criticizing or supporting the timing of the actions made by the major water agencies. In the following sections we summarize the views on timing under the headings "too late," "too soon," and "right timing."

Criticism of Actions Being Too Late

Environmental groups criticized the actions of C-DWR to curtail deliveries as being too late. They maintained that while ecological resources began suffering during the first year of drought, SWP made full deliveries during the first three years of drought. The major cuts in water deliveries came too late. The SWP elected taking a higher risk decision to lower the reservoirs to take out water for urban and agricultural users. By doing so, it exacerbated the environmental impacts of the drought. By the fifth year, there was not much water left for agricultural and urban users and not enough to protect aquatic resources.

Another type of complaint about the actions of SWP and CVP being too late was voiced by agricultural users. Farmers need to know well in advance how much water they will have next year. A large number of farmers are "farm operators" who lease land to grow crops. They have to make leasing arrangements and secure bank loans for seed, fertilizer, water and other costs no later than in December of the previous calendar year. Announcements about water availability made in March are too late for them. Also, increases beyond planned deliveries made in May only increase their frustration, because they may not have more use for that water.

Very few participants representing urban water suppliers criticized SWP for delays in instituting cutbacks in deliveries. The late arrival of the Water Bank was more likely the subject of their criticism.

Criticism of Response Actions Being Too Soon

No criticisms of drought response actions taken too soon were brought up during the interviews. The timing of the actions taken clearly indicates that the California water controllers did not plan for a dry water year in 1989 to follow the previous two critically dry years. Remember, however, that C-DWR did anticipate the possibility since the Drought Center opened in 1988. Also, reports and public meetings were held in the fall of 1989 to examine the status of supplies and develop plans for handling drought needs.

Support for Right Timing

In terms of the right timing of response actions, urban agencies clearly won. Both controllers and influencers praised urban water districts for their timely response to drought. The majority of urban areas called for voluntary conservation or introduced rationing programs as early as the spring of 1988. Most of the districts maintained restrictions throughout the entire period of drought, adjusting their conservation targets to fit the conditions in local and external supply sources. It seems that urban agencies worried very little about prematurely calling the situation a drought. They knew they had to declare drought in order to get the cooperation of their customers, and they also seemed to remember well the lessons of the 1976-77 drought.

While there was universal support for the timing of urban response actions, the SWP decisions were supported only by participants from the state agencies (both controllers and influencers). In their opinion C-DWR Director Kennedy "did what he had to do and when he had to do it." He should be commended for being able to maintain full deliveries during the first three years of the drought and using the Water Bank to make up for deficits during the latter years. Some participants resented the interference in C-DWR decisions by the politicians.

Monitoring of Drought Conditions

Many survey participants praised C-DWR for their monitoring and timely dissemination of information on drought conditions. Publication of bimonthly reports on the status of water supply conditions and forecast updates was seen as very useful. Local water districts could supplement this information with data on their local conditions and make informed decisions about the need for action.

Conclusions Regarding Timing of Response Actions

Several conclusions can be drawn from the discussions on the timing of drought response actions. These can be summarized as follows:

- **Early actions were justified.** The 1987-92 drought demonstrated that droughts in California are truly unpredictable. In hindsight, taking earlier actions would have been warranted during both California droughts. The lesson of the 1976-77 drought was not lost on urban water providers. They made no bets on the drought to be over soon.

- **Timing of cutbacks in water exports affected user sectors differently.** No timing of cutbacks would satisfy all users of the CVP and SWP water at the same time. Early cutbacks to agriculture translate to certain economic impacts. Late cutbacks increase the risks to urban areas and preempt future options for protecting against environmental damages. Farmers want maximum delivery during a given drought year, and some are willing to receive no supplies next year. Urban areas would like to leave more water in storage to prevent deep cutbacks in deliveries at later, more critical, stages of drought.

- **Timely information on water supply conditions was invaluable to all.** Timely publication of the California Cooperative Snow Surveys Bulletin 120-91 was one of the best investments among all drought-coping measures. It allowed water districts to use their own discretion in making the timely and necessary adjustments.

PERFORMANCE OF WATER INSTITUTIONS

The institutions who control and influence water management in California are the main component of the state's water management system. During the interviews, opinions were collected from the respondents on the performance of federal, state, regional, and local institutions--both those who control water supplies and those who influence the decisions of controllers. Again, the aim was to identify lessons of the drought regarding the institutions. Below are summaries of the views of survey participants directed at specific organizations.

California Department of Water Resources

C-DWR criticisms came primarily from the environmental community. The criticisms pertaining to the delayed cutbacks in water deliveries were described in the previous section. Additional critical comments pertaining to the C-DWR decision making process came from the media and the SWP contractors.

Decision-Making Process

C-DWR (together with other mammoth agencies like CVP) was accused of "playing God" in deciding on who will suffer and how much. The Department was perceived to have a lot of

autonomy because it does not have to consult with the public in making important decisions. Such decisions are made behind closed doors, and only a filtered version of the debate and ultimate decisions are given to the public. One respondent wondered how it could be that if an individual wants to put a grocery store in a lot, his/her permit application is subject to public debate, but when decisions of the superagencies are affecting most of the state population, they are made behind closed doors. By the fifth year of drought, the public was beginning to understand the role and the power of the superagencies.

State Water Project contractors also criticized C-DWR for excluding them from the debate about the allocation of deficiencies and many other decisions that affected them. They would like to have some say in establishing charges for water reallocated for environmental purposes and other decisions.

Organizational Structure

Another criticism of C-DWR pertained to its mission as the steward of the state's water resources. Environmental community criticized C-DWR for having confusing and contradictory roles. They maintained that the State Water Project overwhelmed the functions of C-DWR, pulling more staff and financial resources to SWP operations at the expense of taking care of all water resources in California. It is difficult to understand how good stewards of the state's water resources can have their loyalties with the SWP contractors and be astute water developers. The SWP operations take care of the contractors first, and the function of C-DWR in the area of managing water resources for all purposes (including protection of in-stream uses) is lost.

Several participants suggested that SWP should be managed separately. At least the C-DWR should be divided into two subagencies (or two parts): one would be a water supply agency overlooking operations of the State Water Project, the other would be a state water resources agency planning and managing water resources all over California. Some suggested that SWP should be separated from the state government altogether and transformed into a quasi-governmental agency (or a corporation) to clarify its water policy and achieve more efficient management of the SWP water. If SWP were an independent agency, the state budget problems would not affect water delivery. Also, the state's lengthy procurement process would go away, and the necessary work could be done much faster.

C-DWR Perspective

Participants representing C-DWR tended to have a balanced view of their performance during drought. Some conveyed an impression that their hands were tied, and some decisions were taken away by politicians. Others felt that given that their long-term plans have not been fully implemented (i.e., the SWP facilities are not completed), they had to perform miracles to keep the state economy afloat during the drought. The C-DWR provided a liaison or a vital link in the water management hierarchy and among controllers and influencers of water in California.

The C-DWR could only perform this task by adopting an objective and independent stance in handling water shortages. The C-DWR was the controlling factor in the successful operation of the Water Bank, although the process of water transfer had to go through the SWRCB.

Conclusions Regarding the Performance of C-DWR

Given the complexity of the decision-making process faced by C-DWR, it is difficult to sort out any management errors. Many of the criticisms described above could be expected and in all likelihood must have been expected by the Department. Yet the drought experience clearly offers some suggestions for improvement:

- **A clearly defined mission during the drought would have been very helpful for C-DWR.** The Department cannot resolve all water conflicts in California. During a drought C-DWR has to make more controversial decisions and must be prepared for criticism. Californians, and especially the state's environmental community, expect the C-DWR to be much more than a body representing the interest of SWP contractors.

- **C-DWR expertise proved invaluable.** Judging from the quality of C-DWR publications and the high professional quality of its staff, there is not a single other organization in the country that would have more expertise in hydrology, planning, water conservation, engineering, and other areas of water resource management than C-DWR. However, the role of the Department in assisting water districts and other governmental bodies in coping with the drought was not appreciated. Some changes are needed to rectify and clarify the situation.

- **More control, more means, and more openness would strengthen C-DWR performance.** More control over the state's water resources, and adequate facilities to meet the state's water needs seem to be prerequisites for improving the C-DWR to do more. However, some controversial decisions can be defused by opening them to a public debate and obtaining a clear mandate to meet the state's water management objectives.

Bureau of Reclamation and CVP

The criticism of superagency behavior was also meant to apply to the Bureau of Reclamation and its operation of the Central Valley Project. The CVP controls more than twice as much storage as SWP and can deliver three times as much water. In addition, the Bureau controls the deliveries of the California's basic apportionment of 4.4 MAF of Colorado River supplies plus any surplus water. In fact, the presence of federal control in California's water management by far surpasses the role of SWP, MWD/SC, and other large agencies. Several issues related to CVP surfaced during the interviews. They are summarized below.

Takeover of CVP by the State

Many respondents thought that the California water management system cannot be optimized to balance all important water needs in the state, because there is not a single agency controlling all developed water. Some even suggested that the Governor should appoint a water czar to coordinate all water operations. There were also proposals that the C-DWR assume operational control of the CVP, thus moving the CVP from federal to state control.

The agricultural users of CVP water did not object to the contemplated takeover. They would support it as long as they would have a say in how the project would be operated and maintained. One respondent feared that CVP could become a state environmental project. The CVP is the most complex project among all the Bureau of Reclamation Projects in the nation, and its transfer would have to be thought out very well. The existing uses, including environmental and recreational benefits, would have to be preserved.

At the time of the interviews, the Bureau of Reclamation and the State Resources Agency were working diligently on the feasibility of the takeover. The CVP takeover was a key point in the Governor's April 6 water plan. During the time of the interviews, participants indicated that negotiations were actively proceeding in designing an MOU by the end of the calendar year. Representatives of the CVP water contractors believed that in the final analysis the C-DWR and the Bureau will spend a lot of time and money only to find out that there is not much to be gained in the long run by the takeover. One respondent remembered that during the past 40 years, this is either the third or fourth attempt by the state to take over the CVP, so chances are it will fail like all previous attempts.

Environmental groups were not sure if a takeover would further their objectives. Although all CVP supplies affect water flows in the Delta, an environmentally sound operation of both projects would be required to benefit the resources in the Delta. Currently the CVP and SWP operations in the Delta are coordinated according to the Coordinated Operation Agreement COA) between the two projects.

Departures from Established Rule Curves

Respondents from the agricultural sector complained that the CVP did not really have a good concept of what would happen during a drought. During its existence, the project experienced only one year of drought, in 1977. The operating rule set during the 1960s defined firm supply as the amount of water that would be delivered (through a period like the 1928-34 drought), with a maximum of 25 percent reduction in four out of seven years. Furthermore, there was to be not more than 100 percent deficiency in water deliveries in any ten-year period. These firm yield provisions of the CVP contracts were not followed during the fourth and fifth years of drought. For example, prior to the Miracle March rains in 1991, the depleted reservoir storage in the fifth year of the drought led to the announcement of cutbacks in CVP entitlements. The reduction in deliveries included:

- 25 percent supply to agricultural contractors
- 75 percent supply for Sacramento River water rights holders and San Joaquin River exchange contractors
- 25 to 50 percent supply to urban contractors, depending on their contracts (C-DWR 1991b)

Thus, the cutbacks in agriculture during the fourth and fifth years of the drought were about 50-75 percent of normal deliveries.

Some respondents maintained that the departure from the old rules was a result of shifting the CVP operations to a greater protection of urban and environmental uses. In 1977, the CVP storage was drawn down to 1 MAF. For 1992, CVP plans to retain 2 MAF in storage. They pointed out that 2 MAF of carry-over storage would support irrigation needs on 600,000 acres, generating in San Joaquin Valley $4 billion worth of economic activity.

Warren Act Controversy

Water districts not served by CVP and districts receiving both CVP and SWP water were very critical of the provision of the federal legislation, known as the Warren Act, which prohibits the use of the Bureau facilities to move nonproject water. One respondent characterized the act as a "shameful hypocrisy." The act was revoked in 1991 under the Reclamation States Drought Relief Act (H.R. 355).

Rescheduling of Annual Deliveries

The CVP was praised by some participants from the agricultural sector for changing its rules for making contract deliveries. Before 1991, the districts and farmers had to take all contract deliveries in one year or lose the unused amounts. The balance did not carry over to the next year. The Bureau changed the rules during the critical period of the drought and allowed "rescheduling" of deliveries by keeping the balance in carry-over storage. This added flexibility greatly assisted farmers in crop planning.

Conclusions Regarding the Performance of CVP and USBR

In comparison with SWP, the Bureau of Reclamation and CVP seemed to have kept a "low profile" during the drought, but they maintained that posture only because of overriding law. They accommodated water needs in the state, if possible, but were not very forthcoming. The criticisms of CVP, which emerged during the interviews, could be summarized as follows:

- **Authorizing federal legislation has to be reviewed to give CVP more flexibility.** All reclamation projects are operated according to authorized project purposes. Those purposes constrain the options for managing the projects to meet critical water needs during a major drought.

- **Environmental pressures may diminish the protection of CVP supplies offered by senior water rights.** New developments in the environmental sector, such as the ESA, equates members of the agricultural and fishing community with regard to water allocation. This added dimension could place constraints on future deliveries of CVP supplies to agriculture.

ENVIRONMENTAL AND REGULATORY ORGANIZATIONS

State Water Resources Control Board

The SWRC played an important role during the drought by acting on requests for water transfers and by monitoring compliance with, and enforcement of, water laws. The survey results testified to the difficult role of SWRCB. Survey participants representing various sectors were critical of the Board's performance.

Critical Comments

The Board was criticized for its "lack of role" and its constant lamenting about what its role was. That role could not be determined to the satisfaction of all interested parties. The Board held hearings in order to put together a plan on how and when water management institutions should change their operations and make allocation decisions. However, the plan that was developed as a result of those hearings was very controversial and was not implemented.

Both urban and agricultural users of water become very nervous when their water rights are under review. The Board was under pressure by the environmental community to look at water rights in order to determine whether the public trust values are being preserved. During the ongoing process of developing interim standards for the Delta, the Board asked the water users to explain how they are putting water to beneficial use. They also wanted to know what can be done to improve declining public trust values. Agricultural water rights holders suspected that the Board was actually trying to improve the reliability of urban water supplies and satisfy environmental needs at the expense of agricultural supplies.

Finally, the Board was also characterized as an "impediment" to water transfers because current staffing could not handle the amount of requests for transfers and the work associated with facilitating them. It should be noted that no transfer proposals failed.

The SWRCB View

The SWRCB is well aware of its difficult role in administering water rights in California. Water transfers are one tool used in dealing with the effects of the drought. However, by no means are they the answer to water management. During the drought, all transfers that came before the SWRCB were approved, and with very minor exceptions, all of the water approved was actually transferred and put to beneficial use. As expected, not everyone was happy with the provisions of all the transfer approvals. The SWRCB must balance the competing needs for limited water supplies and act on transfers in a way that protects holders of water rights as well as in-stream beneficial uses.

Conclusions Concerning the Criticism of SWRCB

It seems fair to say that the drought and especially the large number of water transfers created extreme demands for Board decisions. Ensuring the compliance with the complex system of water laws to allow water transfers is not an easy matter. One conclusion is:

- **The Review Process has to be accelerated without compromising the requirements of the law.** Some improvements have already been accomplished by passing state legislation (AB 10x) in 1991 that declares that no temporary transfer of water under any provision of law for drought relief in 1991 or 1992 will affect any water rights. The drought focused attention on the Board's difficult role of the protector of public trust values, thus increasing the sensitivity of the Board's decision-making process.

Environmental Community

A considerable amount of time during the interviews was given to allow participants to voice concerns and anxieties pertaining to the environmental community and environmental laws and regulations. The intensity of the discussions was the highest among the participants representing agricultural interests. Urban suppliers seemed to have moderated their initial reactions and no criticisms were made by governmental resources agencies (both state and federal).

Complaints against the Environmental Community

Many participants made statements that environmental interests and environmental institutions stopped or slowed down a number of water projects throughout the state. The drought crisis is a direct result of not being able to build enough water storage and conveyance facilities because of that opposition.

One respondent representing agriculture stated that environmental groups can generally be separated into a "reasonable" faction and the "unreasonable" faction. While the reasonable faction seems to understand the needs of agriculture, the unreasonable component aims at shutting down the California agriculture at any cost. The unreasonable faction holds the farmers hostage and gradually puts them out of business, resulting in more water and land for the environment. The respondent noted that the unreasonable faction in the environmental community is making a stand against the farmers although the environmentalists have no relevant constituency and no economic accountability.

Some respondents complained that the environmentalists advocating water transfers were putting constraints on pumping and on the export systems. They stated that the environmentalists express the need for more outflows through the San Francisco Bay facilities for fisheries. This can be achieved by putting constraints on the export pumping from the Delta on both the SWP and the CVP. However, some respondents believed limited water amounts could be transferred from north to south with current restrictions put on the Delta and the export systems by Interim Standards Decision for the Delta by SWRCB.

Complaints against Environmental Legislation

The federal Endangered Species Act and the state Threatened and Endangered Species Act received complaints and criticisms coming primarily from the agricultural sector. Several respondents stated that these laws had been enforced in a piecemeal manner, with the result that water development in California was stopped. Furthermore, they viewed these laws as being flawed because they provided no balance; one species can be preserved at the expense of others. The law should consider all species at the same time.

The Point of View of the Environmental Community

One of the main objectives of the environmental community in California is to reform water laws and water institutions so that there is no discrimination against environmental uses of water. The existing water law requirements were developed, along with the development of the western frontier, for the use of water out of the streams and rivers. In-stream water uses were never a part of this development. This neglect cannot be justified, and a water law reform will be needed to allow in-stream water rights.

There is a need for equity and fairness in water allocation. Environmental respondents agreed that this drought provided a long-awaited opportunity for the environmental sector to become part of the allocation process.

Conclusions Regarding the Criticism of the Environmental Community

During the drought, the environmental community seemed to have gained significantly more attention and a greater degree of consultation on water management issues. Environmental interest groups are now an active player at the negotiating table and have a profound influence on water management in California. The influence of the environmental group has already impacted the agricultural and urban sectors through the Three-Way Process. Therefore the conclusions are:

- **The drought permitted the environmental community to influence water management decisions in the state.** Although the environmental community has demonstrated its ability to block water development projects before the 1987-92 drought, they were able to enter into negotiations and consensus building with the urban and agricultural sectors during the drought.

  For example, Mono Lake Committee has been actively involved in the protection of environmental interests related to water issues during the drought. In addition, this organization is involved with water-marketing proposals and public conservation education. During the fifth year of the drought, Mono Lake Committee was active in helping to execute the replacement of 15,000 acre-feet of water from the Los Angeles groundwater basin with water purchased from MWD at seasonal rates. This water, which would help create a park, was to be injected into the ground as part of the conjunctive management scheme. The group stated that this will be a recreation and flood control project for the city of Pasadena. This example illustrates the spirit of consensus between the environmental and urban communities in the transfer of water.

  Aside from drought-related developments, the environmental community will likely continue to have an active and powerful role in California water management.

- **Governmental agencies responsible for environmental resources played an important role in water management.** The California Department of Fish and Game (DFG) played a pivotal role in leading the state efforts to preserve the state's aquatic resources. DFG played an important advisory role to water agencies (including SWRCB, C-DWR, USBR, Department of Energy [DOE], the Department of Parks and Recreation, and the U.S. Army Corps of Engineers) pertaining to the movement of water and need for releases to protect aquatic life.

VII. INITIATIVES AND REFORMS

This chapter summarizes the views of the survey participants on actions that should be taken to enhance the ability of the state's water management system to cope with future droughts. We asked the interviewees and group interview participants for their opinions on what should be done to improve water management in California. We counted more than 170 suggestions of initiatives and reforms that need to be considered. A listing of various suggestions is included in Appendix D. A majority of them stem directly from the experiences of participants (and others) during the 1987-92 drought.

The suggestions for changes are presented under four broad categories: (1) water policy initiatives at the state level (including federal involvement); (2) agricultural initiatives and needs; (3) urban water management; and (4) environmental protection. Each category addresses the needed changes to those who are expected to implement them.

SUGGESTED STATE POLICIES AND INITIATIVES

For the most part, the suggestions were directed at the Department of Water Resources, the state government, and the U.S. Bureau of Reclamation. The suggested changes and improvements revolve around several key issues which are described below.

Solving the Delta Problem

In almost every interview, the respondents indicated that some of the issues surrounding the Delta must be resolved. Generally, respondents agreed that physical improvements in the Delta are needed to achieve more efficiency in moving water stored in the Sacramento-San Joaquin basin to the south. During low flows, only a portion of water released from the upstream reservoirs can be pumped out for exports because the pumping operations cause migration of salt water from the San Francisco Bay toward the pumps. This reverse flow results in the increase in salinity of the exported water and affects the freshwater supplies for most off-stream users in the Delta and water quality for urban uses and for aquatic life.

Generally, the survey participants agreed that the Delta problem has to be resolved using a balanced approach in which the additional facilities are built and operated. The facilities would not only allow more exports to the south, but also enhance and maintain water quality in the Delta. There is a need for a "socially accepted" water quality control plan for the estuary. The hydrology of the Delta is very complex, and the current operations are not supported by any scientific models. Instead, they are based on experience with reverse flows. Interviews revealed that water professionals (engineers, hydrologists, biologists, and others) know how to solve the problem on the technical level, but political will is needed to approve the necessary construction.

The Governor's proposed Delta decision-making process can lead to a recommendation which can be politically salable.

Completion of SWP

The current users of SWP water and the SWP operators indicated that the ability of SWP to satisfy water needs is dependent on the completion of SWP facilities as planned, including more water development in the Sacramento-San Joaquin basin. The solutions in the Delta will increase firm SWP supplies, but additional storage will be needed to reach the planned firm supply of 4.2 MAF. The present dependable supplies of SWP are 2.3 MAF.

Some participants representing agricultural users of SWP water indicated that the completion of SWP facilities may not be possible. This is because they do not have the funds and would be unwilling to invest in SWP. During the drought, the users found that SWP supplies were not reliable and were unlikely to become more reliable for them in the future. They maintained that SWP water is becoming too expensive to be used by agriculture. Although, in part, this is political rhetoric and resentment caused by the deep cutbacks of deliveries to agriculture, the fiscal difficulties of agricultural water districts are real.

Water Bank and Transfers

Almost all respondents considered the Water Bank an important and very useful development of the drought. The following suggestions pertaining to the Water Bank and water transfers were made by the participants:

- A state Water Bank should be institutionalized and become a permanent part of the water management system, including normal supply year operations.

- All institutional barriers to water transfers should be removed during drought (such as the issue of water rights held by water districts or users, federal subsidies, restrictions on movement of water through federal facilities) except for those that protect against third-party impacts and negative environmental externalities.

- A Water Bank office should be established as a broker for water transfers independent of the C-DWR and SWP.

- A streamlined approval process for all water transfers should be developed.

- Water marketing and transfers should be developed as a viable alternative through new legislation and more institutional cooperation.

Some respondents representing agricultural districts were concerned about losing their water supplies to the environment and urban areas because of the Water Bank. However, others believed that if "enough money is put on the table," agriculture can find significant amounts of water for sale. As long as the effects of water transfers on water rights holders are safeguarded or compensated and the transfers are not made at the expense of environmental degradation, the Water Bank is a viable alternative for many water shortage problems in the state. However, it must be noted that the frequency and duration of bank operations will affect the amount of water it can make available.

Long-Term Drought Planning

Many respondents expressed the opinion that water management in California should move away from crisis management to long-term planning. Various suggestions on the important elements of the planning process were made. Selected suggestions are listed below:

- Californians should establish priorities for alternative uses of water during droughts and be prepared to sacrifice some uses during times of water supply shortages.

- The state should look at pricing of developed water and eliminate the existing large differences in the cost of water in order to create greater conservation incentives for all users. Marginal cost pricing should be incorporated into long-term water plans.

- The cost of water supplies for environmental resources has to be determined, and these supplies have to be acquired at taxpayer expense.

- The state should develop a mechanism that triggers drought response actions automatically without a lengthy and contentious legislative process.

- Long-term planning should focus on alternatives such as water banking and marketing, off-stream storage, conjunctive use of surface water and groundwater, water reclamation and desalination, and long-term water conservation in agriculture and urban uses.

- Equitable long-term ways of protecting environmental resources in the state must be found.

- Long-term water supply plans should have an optimal level of drought protection (supply reliability) built into them.

- The Three-Way Process and other such consensus processes should be relied upon in building a consensus behind the long-term plan.

There were many other suggestions on how to approach the planning. Several respondents also suggested that the long-term planning for drought protection cannot be isolated from policies aimed at controlling population growth in the state, especially the policies aimed at in-migration. As one respondent put it, "there should be some way for the federal government to realize that unlimited immigration into the United States is playing havoc with California because 75 percent of foreign immigrants wind up in California or Florida." By 2010, the state population is projected to increase by approximately 8 million people. This is a critical concern in preparing long-term water supply plans.

Water Management and Allocations

Many suggestions of survey participants pertained to the allocation of the state water resources for various uses and for various activities. Selected suggestions within the management category are listed below:

- A holistic approach to the management of state water resources is needed to increase the availability of water through all possible means. This includes weather modification, reclamation, groundwater recharge and conjunctive use, desalination, and optimization of all operations.

- Water management should combine resource values with economic principles to satisfy water needs in the state by following the example of the electric energy industry. A rigorous analytical process should be employed in water management decisions.

- The state should cut down on the amount of firm hydroelectricity production during drought to make water available for environmental uses. Investments should be made in bulk energy transfer facilities to take advantage of imported power.

- The state should look into groundwater regulation. Large groundwater basins in San Joaquin Valley should be managed possibly by self-regulation of users. More work on groundwater storage and mapping of aquifers is needed.

- Water management in the state should be centrally coordinated. At the minimum, the communication and cooperation between state and federal agencies should be improved. More preferable would be a transfer of CVP operational responsibilities to the state. The Governor should appoint a water czar to manage resources with enough power to cut through unproductive water politics.

- General policy reform and consensual solutions should be emphasized in trying to change water management in the state. The Governor needs to "twist some arms" in the agricultural sector in order to make the Three-Way Process more productive.

- A massive public information and education program is needed to educate Californians about water issues and drought in order to gain public support for the proposed reforms in water management.

- The state should develop a computerized data bank containing comprehensive water-planning and management information. The database should be continually updated and made available to water agencies.

In addition to these management approaches, the respondents made numerous comments pertaining to water allocation in the state. Most of these suggested that more water should be allocated to environmental uses and that allocation should be fair (or equitable) to all sectors. Some respondents advocated prioritizing water uses in the state and using the system of priorities in allocation decisions. Environmental resources agencies want water allocation on "more equitable basis" so that in-stream flows for fisheries, water deliveries to wetlands, and other environmental purposes are brought into the allocation process. They want to be given the same consideration as the urban and agricultural users of developed water.

Institutional Change

The environmental community called for institutional change, including the reform of existing agencies as well as water laws and regulations. Their major points pertaining to the reform of water institutions can be summarized as follows:

- Water law in California should be revised to allow for in-stream water rights. One participant who represented environmental interest believed that above-the-minimum natural flows in many California rivers will exist only as long as the urban or agricultural users do not need them. They will develop more storage and perfect water rights to capture these flows. In-stream water rights would protect some natural flows. The existing system of water law protects off-stream uses.

- Water quality and minimum-flow standards established by EPA and SWRCB are not adequate for restoring and protecting environmental resources. The environmental community proposes that the existing standards be considered as "baseline" only and should be supplemented by mitigation of impacts on aquatic resources with water set aside for that purpose.

- It concerns the environmental community a great deal that the existing water management institutions such as SWP and CVP are loyal simply to their clients (i.e., water districts with contracts) and not to protecting public trust values. Because of this loyalty, these institutions will discriminate against environmental uses of water because the latter impede their ability to serve their clients. State water management institutions should be given a clear mandate to manage all water resources in the state in a well-balanced way without discriminating against

specific uses. A greater role of these institutions in protecting public trust values is needed.

Participants representing the state and federal agencies shared some suggestions for institutional change but were less demanding with respect to "equal treatment" of all uses. However, they also would like to have a clear mandate from California voters to protect public trust values. As one respondent put it, "more good will, professionalism, and supportive legislation could go a long way toward enhancing environmental quality in the state."

On December 9, 1992, the SWRCB released a draft Interim Water Rights Decision, "Decision 1630, Water Quality Objectives and Flow Requirements" (D-1630), for public review, to complement their 1991 Salinity Control plan. In many respects, this proposed action is the epitome of a lesson learned because it addresses the many environmental concerns heretofore not addressed. The Bureau of Reclamation (USBR) and the C-DWR shall maintain water quality conditions and flow rates in the channels of the Delta and Suisun Marsh equal to or better than the standards set forth in D-1630. This task may be accomplished by:

- Reduction of diversion at the pumps in the southern Delta
- Release of natural flow or water in storage
- Operation of the Delta Cross Channel gates
- Other measures or combinations of the above and other measures

The USBR shall maintain the standards set in Decision 1630 for pulse flows in the San Joaquin River at Vernallis.

The draft Interim Decision 1630 laid down guidelines governing water use. These include:

- Diversion and use of water from the watershed of the San Joaquin River by specified water rights holders
- Reservoir releases by water rights holders on the Mokelumne and Calveras rivers and their tributaries
- Repayment for pulse flows on the Sacramento and San Joaquin rivers
- Diversion and use of water for urban uses by specified water rights holders
- Using runoff forecasts with no less than 90-percent and 95-percent probabilities of exceedence by C-DWR and USBR, respectively, for determining initial water delivery commitments

- Establishment of the Bay/Delta Estuary Water Project Mitigation Fund for the purpose of improving fish and wildlife conditions in the Bay/Delta Estuary and in its watershed

- Monitoring in the Bay/Delta Estuary to be conducted by the C-DWR and USBR

- Role of Executive Director in determining additional information requirements from specified water rights holders

- Granting of variances by the Executive Director to the C-DWR and USBR regarding fishery standards laid down in D-1630

- Ensuring the continuous real-time monitoring (from February through June) by C-DWR and USBR to detect the presence of salmon smolts and striped bass eggs and larvae in the Sacramento River upstream of the Delta Cross Channel gates

- Terms and conditions in Decision 1485 that are rescinded or shall remain in effect

Since the release of D-1630, several natural and regulatory events have occurred which diminish the urgency of adopting an interim water rights decision. Additionally, the SWRCB has received feedback and comments on D-1630 which it has carefully considered. Many of the comments recommended changes and also that the SWRCB prepare an Environmental Impact Report (EIR) and conduct further hearings before adopting a decision. "The comments include a letter from Governor Wilson asking the State Water Board to return to the effort of establishing permanent standards for protection of the Delta. Consequently, the State Water Board will not consider adopting D-1630 as an interim measure, nor will it consider any alternative water right decision until it has prepared environmental documentation under Public Resources Code Section 21000 et seq. and has conducted further hearings" (SWRCB 1993).

Generally, many respondents called for more state action in reforming the existing water management system in California. Greater attention to environmental issues, management of groundwater resources, and more state control over the developed water were among the most important needs for change.

AGRICULTURAL INITIATIVES

Many suggestions for improvements in water management were directed specifically toward the agricultural sector. The suggestions that came from governmental institutions and statewide associations representing agricultural interest are listed below. The suggestions furnished by governmental institutions focused on drought impacts on the district financial situations and the hardships suffered by farmers.

- More conservation know-how and technology should be infused into California agriculture. Research and development in improving the efficiency of irrigation water use should be continued. Farmers should be advised and educated on how

to use less water, what kinds of machinery to use, and how to manage labor in order to produce efficiently.

- Agricultural water districts should be more flexible and should adjust their water delivery schedules (frequency and duration) according to the requirements for optimal water application on the irrigated crops. They should also improve their public relations by clearly communicating the purposes for which water is used in their districts and the degree of efficiency they were able to achieve (in water distribution and crop application).

- Other agricultural water districts should learn from Westlands Water District how to manage water supplies efficiently. All water should be metered and the districts should pursue conjunctive use and groundwater recharge programs to eliminate groundwater overdraft.

- The state or other governmental entities should develop a system of adequate economic incentives to encourage more farmers to adopt innovative and efficient irrigation technologies.

The agricultural organizations interviewed praised the farmers and certain agricultural districts for their ingenuity and initiative demonstrated during the drought. Some of the innovative efforts demonstrated by Westlands Water District included the following:

- All canals were lined.

- District utilized underground piped delivery.

- Deliveries are through allotment.

- Water was metered.

- District utilized sophisticated computer systems to maximize water use in the district.

- District had analogous practices to BMPs in urban areas.

- District has co-funded farmers to do studies on irrigation and water efficiency techniques.

URBAN WATER MANAGEMENT

A number of general and specific suggestions were made regarding the management of water in urban areas. We grouped these suggestions under the general categories: (1) reliability of urban water supplies and long-term planning; (2) design, implementation, and enforcement of demand reduction programs; and (3) growth control.

Long-Term Planning and Reliability

Respondents who represented urban water controllers often emphasized the need for long-term planning for drought protection and the need for overall improvement of reliability of urban water supplies. The term *reliability* is used in California to describe the continuity of water supply at adequate levels during periods of drought and other situations such as an earthquake. Urban areas do not want to risk large shortages in their water supplies that would paralyze urban economies. In practice, the reliability means that if SWP contracted with a district for a certain quantity of water to be delivered on a firm basis, then SWP should deliver this amount during drought years. If the deliveries are not reliable, then urban water suppliers do not know where they stand and how much effort and money they should devote to finding and developing local sources and other supply- and demand-side alternatives.

Several other suggestions of the participants for better planning for protection against future droughts include:

- Water agencies should develop very clearly defined carry-over storage goals and adhere to them. They should utilize emergency supplies, for example, if the projected storage falls below the goal.

- Water districts should build interconnections with neighboring districts and tie into the California "plumbing system."

- Preparations should be made for an extreme-drought scenario, and standby supplies such as desalination should be considered as a part of such preparations. Also, a resiliency to drought should be built into long-term plans to prepare for a sustained drought lasting more than seven years.

- Long-term plans should be more sophisticated and should place more emphasis on alternatives with supply flexibility such as water marketing and water transfer agreements.

- Urban water providers should adopt criteria for the allowable levels of shortage during droughts and then plan and conduct their water resources programs to meet the adopted reliability criteria.

- Some degree of political involvement is needed in formulating water supply policies at the county and city levels and local water district boards.

These suggestions can simply be summarized by saying that urban water suppliers should do significantly more planning for dealing with future droughts and enhance their preparedness to respond to water shortages. Environmental community is calling for including "planned shortages" into urban long-term water supply plans. Urban suppliers are reluctant to agree to this concept because an "arbitrary level" of supply deficit may not be optimal in terms of the long-term cost of coping with droughts. The deficit planning also nullifies the "extra cushion" always present in supply plans that may be seen as part of supply reliability.

Significant progress toward better planning has already been made in California, thanks to state legislation that requires many urban water providers to prepare and submit urban water management plans every five years to C-DWR (AB 797). This legislation has been amended by AB 11x to include a detailed drought contingency plan for meeting various deficit levels up to 50 percent.

Demand Reduction Programs

Urban water supply agencies have learned many valuable lessons from their efforts to reduce water demands during the drought. Two examples:

- Water rationing should be done through pricing because it is the best way of achieving reductions in demands without causing revenue shortfalls. Rationing without price increases undermines customer confidence when rates have to be increased to balance revenues.

- Local agencies should join in sponsoring mass media public information programs. The messages and announcements of rationing requirements should be made jointly, using common definitions so that the confusion of water users is minimized. Such cooperation will also save money on purchasing "air time."

The respondents offered a number of suggestions on "how to do it right." Selected suggestions of demand reduction programs are listed below:

- Water district representatives should improve methods to communicate water supply situations in the district to the media. They should communicate clearly what their water needs are, how much supply is available, what the expected shortages are, and what they want to accomplish through their demand reduction program. They should also specifically inform civic leaders, their large customers, and all customers as often as possible.

- The general public should be educated to stop believing that unlimited water is their God-given right, and also that a drought is not a sufficient excuse for water shortages affecting their lifestyles.

Several participants were very critical of the demand reduction programs used by water supply agencies. One respondent believed that urban suppliers should free themselves from the "psychosis of irrational rationing." Urban users could afford, and should be able to buy, all water they needed at prices much below the cost of severe mandatory rationing in urban areas.

The "green industry" was also very critical of the inability of urban water supply agencies to design rationing programs that would not automatically put all landscape contractors out of business. The participants from the "green industry" suggested that rationing plans should be based on an allocation of reasonable water amounts in combination with inverted block rate

structures to force urban users to use water very efficiently. They were strongly opposed to outright bans on landscaping or irrigation through overhead watering "until the drought is over."

ENVIRONMENTAL PROTECTION

The 1987-92 drought pushed already degraded ecosystems and populations to the brink of collapse in California. Actions taken to ameliorate these conditions were transfers by the Department of Fish and Game via the Water Bank and much discussion of environmental problems. A simple message that "water is not free because it has tremendous value in the stream or river" seems to have been accepted by the majority of Californians. The interviews revealed great support for allocation of water supplies for environmental protection. Urban and agricultural interests recognized environmental needs for water supplies. However, the most important development during the drought was that the three sides were willing to talk and compromise using the Three-Way Process. The three major water-user groups in California (agriculture, urban, and environment) formed the Three-Way Process to address the issue of water shortage in the state. All three groups have recognized the need to work together in meeting their own water needs as well as satisfying common interests of all major groups.

The Three-Way Process

Several suggestions were made during the interviews on how the Three-Way Process should be expedited and on what is causing holdups in the negotiations.

- People who sit at the negotiating table and make decisions should devote more energy to convincing their constituencies to accept their decisions.
- The three sides should make an extra effort to reach a consensus and stop blocking the actions of each other (which, as history shows, they can do very effectively).
- Urban and agricultural sides should address environmental problems and improve the conditions of aquatic resources, because it will serve their interests.
- Agricultural negotiators have to convince the farmers to deal with environmental and urban sectors through consensual ways.
- All three sectors should make more efficient use of water resources that they currently have.
- The Three-Way Process is important to all sides for finding solutions to the Delta problem and other issues, because the political process has failed in this task.

- The Three-Way Process should use professional leadership and seek help in employing the techniques of alternative dispute resolution (ADR).

It is difficult to predict whether the Three-Way Process will be successful. At the time when the interviews were conducted, the environmental and urban sides tended to be optimistic about the process, while the agricultural side was somewhat reluctant and often frustrated.

Environmental Needs

Participants affiliated with the environmental community offered suggestions for an improved water management system and environmental quality. These are:

- A flexible system of water management is needed with more fairness toward environmental uses of water so that the environment does not suffer the most during future droughts.

- Environmental impacts need greater public recognition and some equitable ways of protecting the environment must be found.

- Environmental quality standards must be revised in order to better protect aquatic resources during periods of extended drought.

- The quality of water in tributaries in the upstream portions of major rivers needs to be improved.

- Firm supplies of water are needed for the existing wetlands.

- A water fund should be established to purchase water for environmental purposes.

- Water institutions should not discriminate against the environment.

- In the Delta, along with the improved reliability of urban supplies, environment should be brought along, and all water use purposes should be optimized.

In summary, the environmental community would like to achieve a better position for negotiating environmental needs for water. The environmental interests coupled with existing environmental regulations were able to effectively stop almost all water development in the state. Apparently the drought has convinced all sides that future stalemates in solving water problems will hurt all sides.

SUMMARY OF NEEDS AND SOLUTIONS: THE GOVERNOR'S THREE-YEAR PLAN

The most important and immediate need is, according to one respondent, that "the state of California needs to talk, do some thinking ahead, and look at water issues collectively." Once the three sides reach a consensus on future water policy in the state, most problems can be solved quickly. On April 6, 1992, the Governor unveiled a plan for "Ending California Water Wars." The following is a summary of the major points of the Governor's plan.

The Governor envisioned a comprehensive, balanced, long-term water policy supported by interim short-term measures. The drought demonstrated that creative solutions are possible to handle water shortages, and these solutions should be continued and enhanced in the future. Examples of these developments include the following:

- The Governor was confident that mutual cooperation among the urban, agricultural, and environmental groups through the Three-Way Process would help meet the following objectives by 2010: (1) safe and reliable water supplies for municipal and industrial uses in urban areas, (2) sufficient long-term water supplies at a reasonable cost for agricultural areas, with dry-year groundwater reserves where feasible, and (3) protection of threatened and endangered species in the environmental sector as well as the restoration and protection of fish and wildlife resources and aquatic habitat.

- There is an urgent need to fix the Delta. The Governor indicated that a council comprising members from the urban, agricultural, and environmental sectors would be responsible for providing guidance to the planning and decision making in future water management. This committee would be assisted by a separate technical advisory panel to ensure that equity and fairness prevail in meeting the needs of the urban, agricultural, and environmental sectors. The overall intention was the development of a scientific long-term solution to ensure the protection for the Bay-Delta Estuary. Certain immediate short-term actions were necessary in the south Delta for restoration of the environment and improvement of water supply. The Governor called for the California Environmental Protection Agency (CAL-EPA) and the SWRCB to continue working in coordination with the federal EPA in developing interim water quality standards by the end of 1992. These interim actions included (1) construction of flow-control barriers, (2) enlargement of some channels, and (3) utilizing new pumps to shift pumping to winter months. The SWRCB held hearings and studies during the summer and fall and issued a draft Interim Standards decision on November 24, 1992.

- Off-stream storage should be pursued, since it does not conflict with the environmental goals and offers a more viable proposition than conventional dams. Additionally, other forms of storage were being evaluated. These include using rice fields for storage in wetlands in the Sacramento Valley and using islands as storage reservoirs and possible waterfowl habitat in the Sacramento-San Joaquin Delta.

- The CVP should come under state control, and the Governor identified a negotiating team to work out a transfer plan over six months.

- The Water Bank demonstrated the power of market forces. Water marketing should be expanded in future water management. However, water transfers should not adversely affect groundwater resources, fish and wildlife, and rural communities. The Water Bank concept should be extended on a regional role to develop an interstate Water Bank. The Governor pledged his support of legislation regarding water transfers provided it met the following criteria: (1) water transfers must be voluntary; (2) water transfers must not be harmful to fish and wildlife resources and their habitats; (3) water transfers must not cause overdraft or degradation of groundwater basins; (4) entities receiving transferred water should prove that they are using water efficiently such as, carrying out BMPs and water efficiency practices; and (5) water rights holders of contracted water should play a decisive role in determining what is done.

- Water recycling and reclamation should be increasingly utilized in the future, since it provides reliable supplies for agriculture, greenbelts, recreation, and industrial uses.

- Desalination of brackish groundwater is cost-effective in certain parts of the state, including some areas in the San Joaquin Valley and Southern California.

The Governor's plan confirms most of the points of view expressed by the survey participants on actions that should be taken to cope with future droughts. The Governor's plan focuses on a long-term comprehensive water policy supported by interim short-term measures. The Governor also emphasized mutual cooperation through the Three-Way Process and the need to fix the Delta. His plan addressed off-stream storage, the future controlling body of the CVP and expanding water transfers in the future. Finally, his plan emphasized other viable alternatives for increasing future water supply, and including water recycling and reclamation and desalination of brackish water.

VIII. SYNTHESIS OF LESSONS LEARNED

The first part of this report provided background information on the economy and water resources of California and a detailed description of the events of the 1987-92 drought. The views of survey participants on drought management were summarized in the preceding three chapters. This chapter presents the conclusions of this study together with relevant background information. It also includes a description of the management and decision-making environment for drought planning and policy in California prior to the drought. Important lessons for water management and planning stem from relevant experiences of individuals who control or influence water management in the state. These experiences and lessons were identified by analyzing the contents of 34 field interviews with 101 individuals representing 57 organizations. Our synthesis of lessons learned includes information from the previous chapters as well as additional observations of survey participants on the relevant lessons of the drought.

DEFINITION OF LESSONS LEARNED

The study was designed with a broad definition of "lesson learned" in mind. We encouraged study participants to look retrospectively on their experiences during the drought and provide us with answers to such questions as "What worked and what did not work?" and "What needs to be changed, preserved, or done in the future?" We also asked the participants to focus on several aspects of the drought including critical impacts, performance of water institutions, public response, communication and cooperation, role of the media, critical legislation, timing of response actions and innovative drought management approaches. Background information was located and examined in order to place the information gathered by the interviews within the context of documented drought actions and to compare expectations to the reality of drought.

The new knowledge that has been brought forth by the drought represents the important lessons learned. In general, such incremental knowledge would be identified by (1) contrasting "expectations" and "what actually happened," (2) analyzing the basis for decision making during the various stages of the drought, and (3) examining the overall performance of the California water management system. However, the existing system of water management consists of complex physical and institutional arrangements. It cannot easily be addressed by a unified and comprehensive statewide management plan consisting of strategic, tactical, and emergency measures. This means that a formal statewide drought response plan does not exist. There is no sequence of predetermined actions for all eventualities that would constitute an official statewide drought contingency plan. Federal, state, and local water institutions share the responsibility of coping with adverse impacts of drought. For example, during a drought, the state formulates a plan for dealing with another dry or critically dry year. However, the lack of a formal drought contingency plan does not indicate that California is unprepared for droughts. Major water providers have provisions for curtailing water deliveries during dry and critically dry years. Local and regional water supply agencies also have plans for dealing with water shortages. An unwritten plan for water management during drought emerged from the experiences of the 1976-77 drought in California. We characterized this plan in order to provide

the reader with a baseline (i.e., pre-1987) approach to drought management in the state. This plan is described below. In the sections that follow, the performance of this plan and other outcomes of the 1987-92 drought are summarized in terms of lessons learned. We view these lessons as useful pieces of practical wisdom acquired by drought experience. We invite the readers to examine the evidence and opinions presented in this report in order to draw their own conclusions and identify other relevant lessons for water management during drought.

PRE-1987 CALIFORNIA'S DROUGHT MANAGEMENT PLAN

The Institute for Water Resources of the U.S. Army Corps of Engineers has devised a planning framework for studying the performance of water management systems and developing a better way to manage water during drought. According to this framework, responses to water shortages can be categorized as strategic, tactical, or emergency. Strategic (or long-term) measures involve modification of existing infrastructure, laws, and institutional arrangements to achieve an optimal level of protection against droughts in the long term. Tactical (or short-term) measures can be implemented within the framework of existing laws, institutional arrangements, and infrastructure. Such measures constitute a drought contingency plan and must be set into place before drought occurs. Finally, emergency measures are those that are necessary when the long-term protection involving strategic preparations and short-term tactical measures prove to be insufficient because of low-probability events or unexpected outcomes. Sections that follow summarize the strategies and tactical measures that existed prior to the 1987-92 drought. An expanded discussion of these measures together with a description of strategic, tactical and emergency measures in drought management are presented in Chapter III.

Pre-1987 Strategic (Long-Term) Measures

The water management system in California has been established in order to provide "dependable supplies" to the major population centers and agricultural areas in the state. The dependability of supplies relates to drought. Therefore, the major water development projects, such as the Central Valley Project and the State Water Project, were designed and operated to provide adequate protection to water users against periodic droughts. The degree of drought protection is a function of the amount of "carry-over" storage in the major reservoirs. In addition to surface-water storage, the drought management plan that existed in California prior to the six-year drought of 1987-92 included other features. The overall strategic drought protection features found at all levels of water management (i.e., local, state, regional, and federal) included:

- Provision of extra storage in surface-water reservoirs and maintenance of the stored water as carry-over water to be used during dry years

- Conjunctive use of surface water and groundwater to maximize the quantity of groundwater in storage by relying on plentiful surface water during wet years

- Development of a statewide water distribution system to move water from supply surplus areas to areas with inadequate local supplies or drought-affected areas

- Permanent improvements in the balance of supply and demand (statewide and locally) and supply reliability by increases in efficiency of water use and development of additional supplies

The above features of the existing water management system do not "drought proof" California. As the experience of the 1976-77 drought demonstrated, tactical restrictions on water use must be used if there are two critically dry years in order to reduce the risk of experiencing severe environmental and economic impacts. Unlike the severe drought events in other parts of the country, the California drought of 1976-77 did not result in major additions to the supply base (i.e., developed water). Between 1977 and 1986, only four major reservoirs were completed. Subsequently there was less supply-side surplus, since growth in supply did not keep up with growth in demand. Also, the success of water conservation efforts during the 1976-77 drought was publicized worldwide. As a result, the emphasis in drought management was shifted from water development to a greater reliance on temporary reductions of water demand.

Tactical (Short-Term) Measures

In general, the short-term drought response measures used in the state prior to the 1987-1992 drought included the following tactical actions:

- Curtailment of surface-water deliveries by SWP and CVP to urban and agricultural users in order to maintain adequate carry-over storage for possible subsequent dry years

- Curtailment of water flows and deliveries for environmental uses including relaxation of minimum flows and water quality standards

- Temporary increases in the use of groundwater in order to replace the surface-water supply shortages or to replace the water retained in carry-over storage

- Transfers of water within the state from sources with surplus supplies (e.g., Colorado River) to water-short areas (e.g., North Marin County)

- Reduction of water use through voluntary conservation and rationing in urban areas and by agriculture through crop shifting and land fallowing to make up for the reduced deliveries and protect to the remaining supplies

- Activation of standby supply alternatives such as reclamation of brackish or saline water and municipal wastewater, cloud seeding, and other emergency supplies.

The use of these measures depends on actual drought conditions and the local feasibility of each action. For some areas, the use of groundwater or standby supplies is not feasible. Large-scale transfers of water depend on the availability of interconnections to the major state distribution network and the availability of water that can be transferred. Some options also exist for transfers of water within individual regions. The two short-term response options that are always available are protection of the remaining supplies and reduction in water use. This is actually a single option if viewed from the perspective of a local self-contained water supply system. At the local level, reduced deliveries of the CVP or SWP water can be met (i.e., replaced) using local sources, water conservation, or cessation of some uses. The success of the drought response plan is critically dependent on the timing of drought response actions. Normally, significant shortages in precipitation and runoff in the Sacramento River basin will not translate to automatic proportionate reductions in water deliveries. The large amount of water storage affords the operators of the SWP and CVP and some local projects some response lag time. However, generally speaking, two consecutive critically dry years will most likely trigger tactical response actions. Once the drought conditions are in effect, the decisions on water deliveries and the amount of carry-over storage are made for one water year in advance and can be changed from year to year.

Emergency Measures

Federal, state, and local water supply agencies use emergency measures primarily to deal with the interruptions of water deliveries caused by earthquakes. However, a state of emergency can also be declared by the governor in cases where drought-related water shortages require extraordinary actions. Federal and state drought assistance programs are available to an individual or community, provided the entity meets the following criteria:

- The entity is located in a county designated as a disaster or emergency area.
- The entity is designated as an Emergency Drought Impact Area by an appropriate agency (C-DWR 1978).

In the first case, designations are made by the President at the request of the Governor. In the second case, designations are made by the Interagency Drought Emergency Coordinating Committee (IDECC). Water shortage emergencies are governed by Sections 350-58 of the California Water Code, and these appear in Appendix C.

LESSONS OF THE 1987-1992 DROUGHT

The 1987-92 drought put long-term strategies of drought protection and short-term drought management approaches to a severe test. During six years of drought, state water controllers implemented a number of drought measures in order to maintain about 60 percent of the statewide reservoir storage. This level of carry-over storage has been maintained since 1990 for three consecutive water years which have been designated as critical, based on the

Sacramento River Index. For comparison, during the 1976-77 drought, with two consecutive critically dry years, the statewide reservoir storage was depleted to 35 percent. This suggests that the experience of the 1976-77 drought resulted in a more conservative operation of the major water supply projects. However, this security of held-back water reserves was not free. There were some economic, social, and environmental costs of coping with shortages. Nevertheless, one should not overlook the fact that California was in a better posture in 1993 following six years of drought than it was entering 1978 after only two years of drought. Although it is easy to criticize water management for not reacting to the drought fast enough or allowing certain environmental and economic impacts to occur, those impacts could have been much greater and the current situation much worse if the operations mirrored those of the 1976-77 period.

These and other outcomes of the drought point to several lessons both for long-term planning for drought protection and for tactical preparedness to respond to future droughts. In this section, we present those lessons of the drought which stem directly from the experiences of the 1987-92 drought. The factual information on the outcomes of the drought is presented in Chapter IV. The views of survey participants on the issues of drought planning and response are described in Chapters VI and VII. After stating each lesson, we explain its meaning and support it with relevant background information.

1. The nature of social, environmental, and economic impacts of a sustained drought points to a need for careful and more realistic drought planning.

The 1987-92 drought has revealed more about the nature of the adverse impacts of drought than any previous drought. It showed that the impacts of drought can go beyond the "first order" consequences of not having enough water to support the established off-stream and in-stream uses. Some social, environmental, and economic impacts of this multiyear drought have exhibited some unexpected cumulative and propagating effects.

First, some impacts of the drought propagated and intensified because the affected systems are complex and interrelated in the process. For example, because of drought, less hydroelectricity was produced. This had a direct economic impact because a higher cost replacement energy had to be produced to meet the demands. Furthermore, the demand for electricity increased significantly during the drought (because of more cooling and more groundwater pumping), so that the economic impacts were further intensified.

A parallel path of impacts stemming from reduced hydropower production rippled through the environment. Because most releases of water for hydropower are not diverted to off-stream uses they serve to maintain minimum streamflow and water quality. Additional environmental effects occurred as replacement thermopower was produced. Large thermal plants are located in urban areas of Southern California and San Francisco Bay area. These plants increased air pollution in places where air quality is already low. At the same time, more production of thermal power also contributed to deterioration of water quality. Some thermal plants are located in the Sacramento-San Joaquin Delta and use the Delta water for cooling. Because of higher generation, more thermal pollution entered the Delta and caused further deterioration of water quality.

A similar tracing of environmental and economic impacts can be made for reduced water deliveries to agricultural users. Less irrigation water translated into less return flows that support wetlands. Reduced agricultural water deliveries also meant that irrigation districts received less revenue, but they had to pay a fixed cost to SWP (or CVP), regional agricultural agencies and others selling water regardless of whether they received contracted amounts or not. This means that they had to spread more or less the same cost (or debt) over a smaller volume of water sold and fewer farmers. As reduced water deliveries persist from year to year, the price of water continues to go up, so that fewer farmers can afford it, and more land goes out of production and farmers out of business. A continuing drought could lead to an acceleration of this "debt spiral" effect.

Furthermore, some impacts occurred because of the length of the drought. For example, during the drought, minimum-level streamflows persisted year after year for six years. As a result, their impacts on fish populations accumulated, threatening to destroy entire populations because of the short life-cycle time of anadromous species. The cumulative effects became clearly visible during the 1987-92 drought. They were not so apparent during the 1976-77 drought. The winter-run chinook salmon, which is already classified as a threatened species, had dropped to very small numbers. Similar cumulative impacts could be found in other areas as well. However, identifying and quantifying impacts, cumulative or otherwise, is difficult. Other factors besides the long drought could have impacted the number of returning spawners. For example, the salmon catch off the coast of California was higher during the 1987-92 period than during the wetter years of 1983-85. How much of the response of salmon population is owed to drought? How much to the increased catches?

The drought impacts can be moderated by temporarily reducing water demands. However, one of the greatest difficulties in employing the demand-side options arises from the issue of equity. Almost any rationing scheme (either ad hoc or through contractual conditions) will introduce unfair distribution of the burden. Equity effects probably are the most important social impact of drought. The impacts may become exaggerated when we try to fix them by laws and regulations. Water managers trained in civil engineering or hydrology may have little experience and understanding of social behaviors. Poorly designed rationing schemes will quickly polarize society into interest groups and destroy the sense of community in local areas as well as in the entire state. Some water users will be treated, or will feel they are treated, unfairly. For example, farmers may ask "Why should irrigation districts be cut 75 percent when urban areas are cut only 25 percent?" Farmers feel that they need water to grow food, while urban areas "waste" it on lawns. Urban dwellers may wonder why farmers should "grow subsidized crops with subsidized water," while they have to risk losing their jobs because of strict rationing provisions. Furthermore, unfair distribution of burdens will also crop up within the farming community. Some farmers have wells on their land, others do not. Also, those who invested in high-efficiency irrigation systems may receive no water while others who continue to "waste" water receive their full deliveries. Irrigation districts experience fiscal impacts since they are exposed to greater costs and emergency programs and in return they are faced with less revenue and the fiscal "lag" effects of conservation.

The above recognition of the nature of drought impacts demonstrates the complexity of the relationship between water availability and the functioning of human and environmental systems. The long-term planning for drought protection and preparedness must more

realistically reflect this complexity. For example, the cumulative environmental impacts of a sustained drought revealed the need to reexamine our current approaches to the protection of environmental resources. The long-standing practice of developing ambient water quality standards to protect the aquatic resources may not be adequate. The impacts of the ongoing drought brought the "environmental standards" approach into question. The aquatic ecology is very complex, and the drought has demonstrated that just maintaining water quality standards for several years did not prevent devastating effects on some aquatic populations. Monitoring the conditions of aquatic life and taking appropriate preplanned measures to protect their survival during a sustained drought may be necessary. There is a definite need to understand the aquatic ecology better. On December 9, 1992, the State Water Resources Control Board published a draft of Water Rights Decision (D-1630) which would require the SWP and CVP to maintain stricter water quality standards in the channels of the Sacramento-San Joaquin Delta and Suisun Marsh. However, the adoption of this decision has been delayed until the Board prepares an Environmental Impact Report (EIR) and conducts further hearings. Another important development related to the protection of environmental resources is the current ongoing process of establishing a new federal agency, the United States Biological Survey within the Department of Interior.

2. Severe drought can change longstanding relationships and balances of power in the competition for water.

The drought crisis and grim outlooks for the future brought about some changes in California's water politics. These included: (1) realignment of alliances, (2) attempts at negotiation, (3) public relations, and (4) new environmental legislation.

Realignment of alliances. In the past, the divisions in California's water politics ran between those who diverted water (agriculture and urban water providers) and those who wanted to keep water in the streams (environmental community). The urban community was further divided between north and south. The debates were fueled by entrenched beliefs often having very little relationship to reality. The drought focused public opinion on water issues and shifted the division lines among the warring factions. Urban users began to gravitate away from agriculture to reach some agreements with the environmental community even before the drought. The Memorandum of Understanding on urban water conservation Best Management Practices was signed in December 1991, and it brought together the northern and southern urban users with the environmental community. About the same time, the media began "farmer bashing," which added to the strength of the urban-environmental alliance and pushed the agricultural sector into a losing position.

Public relations gap. Farmers and irrigation districts have also learned to recognize the importance of communicating their needs, conditions, and irrigation techniques to the urban public and environmental community. The farmers have been actively involved during the drought in critically examining water use and water efficiency techniques in farms, talking about the timing of deliveries, looking at transfers, and promoting conservation. However, agricultural districts have to identify an appropriate forum to communicate to the public and the policymakers about water utilization and problems experienced on the farm. Participants indicated that it was this lack of communication that has resulted in adverse public opinion regarding agriculture and its efforts to use water efficiently.

Attempts at negotiation. The drought crisis created a need for negotiations involving all three sectors. The Three-Way Process was established to work toward a consensus on water policy among the urban, agricultural, and environmental interests. Although the drought was not a major factor in the origins of the process, the drought crisis helped to bring the sides together in developing short-term emergency measures. The state government, while not being a party during the earlier stages of the negotiations, embraced the Three-Way Process. The Governor used some of the initial agreements of the Three-Way Process to formulate a new water plan for California. However, the situation is still volatile, and more work on reaching the consensus is needed.

The negotiations of the Three-Way Process showed that consensual approaches to solving the most urgent environmental problems offer some hope for the future, but reaching a compromise is very difficult. The difficulties encountered lend support to one of the axioms of negotiations theory which states that a party will not engage in negotiations if it perceives that it will lose regardless of the outcome (i.e., it is better for a dominant party not to begin negotiation). The Three-Way Process became bogged down at the end of the drought and had little effect on the new legislation which imparted some fundamental changes into California's water management.

New environmental legislation. The Central Valley Project Improvement Act of 1992 has been called one of the most important pieces of environmental legislation ever passed. It reallocates an estimated 800,000 acre-feet of California's developed water from off-stream to in-stream uses. Had the long drought not engaged the media and the public in debate on the equity of California water allocations, it is unlikely that the bill would have passed, since it was vigorously opposed by the agricultural community. The law changes the longstanding balance of power in California water politics, and raises an important thought for water experts elsewhere in the U.S. The passage of the CVP act after six years of drought headlines suggests that dominant parties should reconsider the premise that no negotiation means no loss.

3. Irrigation can provide complementary environmental benefits.

The impacts of the reduced agricultural deliveries of developed water to agriculture revealed that in many areas environmental resources are critically dependent on water deliveries to the state's irrigated agriculture. Many wetlands in the Central Valley are maintained by return flows from irrigation. These wetlands received very little water during the drought as farmers reduced water application rates and irrigated acreage. The drought also brought to the attention of resource managers the fact that the flooded rice paddies in the Sacramento Valley provided a critical support to waterfowl. The Central Valley provides winter habitat for 20 percent of all ducks counted in the United States and 50 percent of all mid-winter waterfowl in the Pacific Flyway (California Rice Industry Association, 1992). Because almost 90 percent of the Valley's original wetlands have been lost, only 60,000 acres of protected wetlands support waterfowl. Additional habitat is provided by some 600,000 acres of ricelands, which in 1991 were reduced to 300,000 acres due to low water supplies. Therefore, the reduced rice production during the drought had an adverse effect on wildlife habitat.

The new knowledge about the interdependence between rice production and waterfowl habitat led the Nature Conservancy of California (established by the California Rice Industry Association) to the development of a ricelands/wetlands multipurpose use project. The project would: (1) create upward of 100,000 acres of winter wetland habitat by flooding rice paddies in winter, (2) provide nearly 300,000 acre-feet of off-stream storage capacity, (3) provide for aquatic biodegradation of the rice stubble (rather than burning stubble that creates air pollution problems), and (4) sustain the communities and economies that have become dependent on rice production. This project demonstrates that the irrigated agriculture in California can avoid the loss of its water supplies to satisfy environmental needs by expanding its water management into multipurpose uses. California's 30 million acres of farmland (of which almost one-third is irrigated) not only produce agricultural products but also serve as an important wildlife habitat in agricultural regions. Farmers and irrigation districts have opportunities for enhancing the environmental benefits of their lands and become a leader in the stewardship of environmental resources. Agriculturalists are in a position to recognize the environmental needs for water and adjust their operations to satisfy such needs. Flood protection and groundwater recharge are examples of other purposes that can be satisfied in conjunction with irrigation.

4. Land use regulation must be the mechanism for urban growth management policies which accept limited water supply.

The drought provided some new evidence for a longstanding debate on whether or not constrained water supplies fail to prevent or slow down growth in urban areas. The city of Santa Barbara has been viewed by many survey respondents as an example of an urban entity which put constraints on the expansion of water supply sources in order to slow down urban growth. However, the urban area continued to grow, although a major portion of new growth occurred outside Santa Barbara in the Goleta area. The city of Santa Barbara sought to expand its storage in the Gibraltar and Cachuma reservoirs prior to the drought, but its efforts failed. Because increases in water supplies did not keep pace with the growing water demand, the area suffered severe shortages during drought. Severe rationing of water had to be imposed, reaching a cutback of 45 percent during the most critical year. The rationing imposed significant hardships on the residents for an extended period of time. As part of the rationing plan, the city implemented a total ban of overhead watering of urban landscapes of any kind, thus causing brownouts and some loss of landscaping. The damaged landscapes and related loss of income from tourism were considered by survey respondents as significant economic impacts on the Santa Barbara area.

The drought-related water shortages and the hardships suffered by the residents seem to have turned the policy of constrained supplies around. The area had to scramble for water and acquire very expensive supplies. The voters approved two expensive alternatives: the connection to the Coastal Branch of the State Water Project and a desalting plant. The cost of water from these sources was 2 to 3 times higher than the cost of most expensive water elsewhere in the state. The Santa Barbara City Council also approved a "critical period planning approach," according to which the city will have enough water to survive the worst drought on record (i.e., 1946-51 period) and in addition will have a 10 percent extra supply as a safety margin.

The experiences in the Santa Barbara area during the earlier years of the drought and in other urban areas of the state are interpreted by the water professionals in California as proof that water supply (or more specifically, restricting the planning for water supply) cannot be used to control urban growth. Limited capacity of local water supply sources can be used as a legitimate reason to constrain urban growth, but land use decisions must be the vehicle and mechanism for growth control. Water supply planning must keep pace with projected increases in consumptive use which may occur under any growth scenario. This is so that it will not cause the development of a supply/demand imbalance. Such imbalances have occurred locally due to "slow" demand growth with no corresponding augmentation of water supplies or long-term management of demand. The practical effect is to cut into prudent supply reserves, thus assuring recurrent drought emergencies.

5. The success of drought response plans should be measured in terms of the minimization and equitable redistribution of actual impacts (as opposed to water shortages), but there is much to be learned about the best ways of accomplishing it.

Information on environmental and economic impacts of the drought is of critical importance to the formulation and implementation of adequate drought response measures. By comparing the various impacts, water controllers should be able to adjust the allocation of dwindling water supplies so that the most severe impacts are minimized. However, the short-term mitigation of environmental and economic impacts during the 1987-92 drought often relied on judgment and anecdotal evidence. Measurement and valuation of drought impacts for selecting water management options must be enhanced.

The survey participants were well aware of the implications of quantified impacts on water management decisions. Those whose water supplies were curtailed gave a detailed description of all impacts and attached a dollar value of losses wherever possible. They were fully cognizant of the difficulties in measuring drought impacts, as well as the dangers involved in comparing the economic losses suffered by various economic sectors. They recognized the tendency of impact evaluation studies to be focused on impacts that can easily be quantified in dollar terms, while undercounting those impacts that cannot be easily assigned dollar values. Although the economic impacts are of immediate concern to people because they often translate into lost jobs, there was almost a unanimous opinion that the most severe effects of the drought fell on the ecological resources of the state. Objections to this view were raised by representatives of the agricultural sector. Some agriculturists felt that the environmental damages were exaggerated by the resources management agencies and the environmental community in order to take away water from agriculture.

Attributing changes in economic performance and environmental resources to drought is not a simple task. Attaching dollar values to these changes is even more difficult and almost impossible in the case of impacts on the environment. Because of these difficulties, there is a tendency to focus only on impacts that can be measured and valued in monetary terms (e.g., loss of production of hydroelectricity). Many other impacts with potentially higher economic losses (e.g., degradation of fisheries or urban lifestyles) are usually described in qualitative terms only. Anecdotal evidence and speculations about drought impacts have to be used in making drought response decisions. During drought there is insufficient time to study the impacts carefully and make accurate predictions of potential consequences. As a result, qualitative statements about

the impacts influence drought response decisions of water agencies. The mass media play a large role in disseminating anecdotal evidence about various impacts, often focusing on some impacts and overlooking others. The lesson here is that the assessment of potential impacts of water shortages must be conducted prior to drought. This allows selection of the best strategic and tactical measures for coping with drought through a systematic drought planning process.

6. Severe droughts can expose some inadequacies in the performance and role of state and federal water institutions.

The state government regulates the use of natural water resources in California. In addition, SWP and CVP, the state and federal water agencies, respectively, also control a major portion of developed water. Therefore, the success of coping with the shortages of precipitation and runoff depends on how well the SWP and CVP systems are operated. The drought revealed some inadequacies in the state and federal water institutions which pertain to their roles and responsibilities in drought management.

Many survey respondents said the drought showed that California water needs one water boss to manage all water resources in order to meet the state's water needs and to protect public trust values. Although there were many positive opinions about the performance of California Department of Water Resources (its expertise compares well to any agency in the country, and it proved invaluable during the drought), respondents had three types of suggestions about the current state organization.

First, they complained that there is insufficient differentiation between C-DWR and the State Water Project (SWP). Although its mission is much broader, during the first four years of the drought, the role of the C-DWR was mainly limited to the operation of the SWP. During those years, SWP tried to satisfy the demands of its customers for water within the limits of its rules, as one would expect of a water supplier. C-DWR did have to provide for greater protection of environmental resources, a water use in competition with SWP deliveries, but only when the evidence of cumulative impacts on fisheries came to public attention around the fourth year of the drought. Some respondents called for an organizational division that would reflect the fact that the interests of SWP customers are narrower than the interests of California generally.

Second, respondents believed that the State Water Resources Control Board (the Board) was asked to do too much. The Board was created to allocate surface water rights and to regulate water quality. During the drought, the Board had to assure that the available water supply was allocated according to established water rights; the rush of water transfers created an unprecedented load. In 1991, emergency legislation (referred to as AB 16x) was passed to remove statutory time limits for Board actions on water rights applications and petitions during droughts. The law also authorized the Board to adopt drought emergency regulations (effective for 270 days), without review or approval by the Office of Administrative Law. The state legislature also charged the Board with administering state financial assistance for water reclamation projects (AB 15x).

Finally, some respondents said the C-DWR should do more to share the benefits of their expertise. Several respondents indicated that timely information on water supply conditions should be given high priority because it is invaluable to all water providers and resource agencies (timely publication of the California Cooperative Snow Surveys Bulletin 120-91 was regarded as one of the best investments among all drought-coping mechanisms).

The CVP of the U.S. Bureau of Reclamation's ability to respond to California's needs was severely hampered until Federal law was changed in 1991. While the SWP was scrambling for water and needed federal conveyance facilities to move water around, it could not do so in several instances. This was due to the Warren Act, which prohibited the use of CVP facilities for moving nonproject water while allowing to use them for bringing nonproject water for its own uses. This law was repealed during the fifth year of drought by Reclamation States Drought Relief Act of 1991 (H.R. 355). Because the CVP "sits on the biggest chunk" of developed water in the state, the Bureau is a likely target for often unfair accusations stating that the federal projects "sit back and let the state suffer while they take care of their own." Because differences in deliveries put some neighboring farmers under very different water supply conditions on their farms, the curtailments in water deliveries imposed by SWP and CVP should be agreed upon and made more uniform. The Coordinated Operation Agreement of 1986 made great progress in the direction of increased cooperation in maintaining water quality in the Delta, but it did not cover all the contentious issues. The Bureau has also learned the value of being more flexible in their operations with their own customers. During the last three years of the drought, CVP allowed farmers to leave water in storage for the next year water deliveries, thus changing the previous "use it or lose it" policy. This allowed the farmers to plan ahead better and maximize the benefits from available deliveries. This makes the operations of CVP more difficult, but pays off in terms improved relations and water conservation. These experiences indicate that resolution of the federal-state institutional issues would enhance the effective management of water supplies during drought.

In general the state and federal bureaucracies can be expected to give high priority to cooperation during drought. For many water institutions, the drought is a real test of their performance. Officials and administration make an extra effort to perform well and are willing to cut "red tape" in order to speed up the administrative process wherever possible. This behavior of water institutions and other entities should not be overlooked in resolving some long-standing contentious issues and setting forth a framework for better cooperation during future droughts.

Recently, the State of California and the U.S. Department of the Interior have signed a Memorandum of Understanding which outlines the conditions for a possible takeover of CVP by the State. However, the memorandum is neither specific or binding.

7. The overall success of water rationing plans depends on their design and reliance on increases in water rates.

By the second year of drought, most residents of California had no doubt that the state was experiencing a major drought. The media were constantly reporting on the drought problem, which focused public attention on water. When there is no drought, most people become interested in water management only when there is a rate increase. As the drought

continued the public focused on other issues related to water supply. Some areas were ready to support solutions and investments in long-term water conservation and improvements of water supply reliability. The publicity of the impacts of drought on fish populations convinced urban users that their conservation efforts were important for saving the environment. Survey participants unanimously agreed that the public response to drought (i.e., cutting back on their water use) was very good. There were some differences of opinion among respondents on the reasons for such a good response and the apparent unfairness of raising water rates of users who had reduced water use.

The 1987-1992 drought confirmed the lesson of previous droughts that urban households and businesses will cut back on water use. It also enhanced understanding that certain conditions that must exist in order to achieve cooperation. Urban users can conserve water on a short-term basis; however, the more important lesson is that people will conserve if they are convinced that: (1) there is a real crisis; (2) water conservation plan is fair; (3) hardships are manageable; and (4) their conservation efforts really matter. In communities where all these conditions were present, the customers proved extremely cooperative and exceeded rationing goals. In those communities where some conditions were not met, the response of water users was not so good, and the number of complaints was often unmanageable.

During the 1987-92 drought, several water agencies were reminded that water-rationing plans can be very controversial. Some rationing plans can be worse than others. Sometimes, while achieving the same intended water savings, the plans may hurt more people, cause greater burdens on some groups of users than others, and cause greater economic losses in the urban economy. All plans are unfair to some users, but those that rely solely on fixed allotments, percent cutbacks, or total bans on certain uses may be perceived as unfair to a significant portion of urban water users.

An important new lesson of the 1987-92 drought is that increases in water rates should precede or accompany rationing plans. When rationing plans are not accompanied by an increase in water rates on account of drought, it causes problems for the water agency, in addition to imposing burdens on water customers. These problems occur, because they lead to revenue shortfalls when the drought continues for several years. To balance the revenue, usually water rates are increased after the crisis is over, which may be viewed by customers as a sign of inefficient management of the district. Pure price rationing was not used during the drought; however, those water districts that raised rates and instituted rationing plans fared very well, both in terms of achieving conservation targets and balancing their revenues during the rationing period. However, not all water districts and local governments are convinced that pure price rationing is the best and least costly form of rationing. Pure price rationing involves raising the price of water to the level where the customer response to the price increase will achieve the desired conservation target. Prices would be decreased if conditions improve or increased if the drought intensified. The pure price rationing could also be used at the most critical stages of the drought crisis, where the level of prices would be linked to the amount of the remaining supply. Water suppliers who experienced revenue shortfalls became strong supporters of the price rationing. The Los Angeles Department of Water and Power was trying to convince the City Council to allow the Department to impose a drought surcharge before the rationing program was called for. However, many agencies consider pure price rationing as impractical because of problems in identifying the water price/demand relationships.

8. Mass media can play a positive role in drought response, especially if some guidelines are followed.

The California drought of 1987-92 was a major news story. The newsworthiness of the drought created an opportunity to focus public attention on California's water issues. The media saw their role during the drought as informing the public on how supply allocations are made and what the consequences of the allocations and related decisions are. Although the primary objective was to cover the breaking news on drought, some media, especially the major newspapers, tried to look at water supply issues from a broader statewide perspective. Reporters, in their inquiries, usually wanted answers to the questions of the general public. During drought, what people wanted to know is "How much water is it prudent to use?" or "How much water is it prudent to save?" The public also wanted to make sure that water agencies were not asking them for unnecessary sacrifices.

The media are governed by the rules of objective reporting, newsworthiness, and their perceptions of what the public wants to know. They cannot be managed by water agencies. If they were, they would not be able to sell news fairly. The questions "Are we in a drought?" or "Is the drought over?" are not silly questions from the media's point of view. Reporters understand the thinking modes and perceptions of the general public much better than water professionals. For them, once the water supply situation is called a drought, it automatically implies that behavior has to be changed from normal behavior to crisis behavior. Such a change is newsworthy. In general, the media can be very useful in promoting water conservation, especially if water agencies follow some guidelines.

Many participants in this study agreed that press releases must be very precise and complete in order to avoid confusing the media. Water managers must be prepared to give straightforward answers to questions asked by the press. Media reporters cannot improve on the clarity of the message. More likely the statements will become even more confusing after they are repeated in the press. Media cannot explain complex water management issues. What is very interesting to water professionals is usually "too dry" for newspapers, radio, and television. Long feature articles on water issues do not sell newspapers and, if included, are read by very few. However, those who read them may become well informed.

It is difficult for water agencies to publicly admit that they are in trouble. The drought showed that if they did not fear a negative response from their customers and were candid in their public remarks, they could always count on public cooperation without losing their jobs. Some conditions, however, have to be met. First, the managers must make sure that their response actions are easily defendable so that the public knows what they are trying to achieve and why. They must have some rules, or tactical response measures, established. Second, the water shortage situation, the response decisions, and objectives have to be clearly communicated to the media, civic leaders, and the public. Media cannot be expected to develop explanations of difficult decisions for the public. They have to get a clear message from the source of those decisions.

9. Market forces are an effective way of reallocating restricted water supplies.

The drought forced water agencies and water professionals to seek creative solutions to water shortage problems. However, very few radical solutions were implemented. Rather, there was a greater diffusion of known technologies. Development of technological innovations takes time and more innovations are likely to be developed in the wake of the California drought.

The six-year California drought did provide an opportunity for water controllers to test one idea they had toyed with for a long time. The drought helped them to cut the red tape and they actually did it. It even worked much better than expected. This successful experiment was the 1991 Drought Emergency Water Bank. The Water Bank offered California a way of obtaining "more water," even after four years of drought, at a price that was readily paid by urban users, some farmers, as well as environmental resources agencies. The bank worked exceptionally well to the satisfaction of most interests although some counties expressed serious concern over possible depletion of local groundwater. The difficulties encountered offered additional lessons on how to organize the bank to work even better in the future.

The 1991 Emergency Water Bank demonstrated a number of important lessons: (1) water markets, even when severely controlled and constrained, will work; (2) water has high value for many buyers, and there are willing sellers; (3) very significant amounts of water can be found if money is put on the table; and (4) third-party interests in market transactions can be protected. The respondents voiced concerns regarding restrictions in the Water Bank rules, especially those pertaining to the conditions imposed on water buyers.

The Water Bank and other water transfer mechanisms were at the forefront of new developments during the drought. New knowledge about physical systems and environmental response was gained because of the transfers. The experiences with the Water Bank and other transfer mechanisms are likely to have profound implications on California's future water policy. Although water transfers may not obviate the need for more water development, the new development likely will proceed with water transfers in mind. In other words, more water storage and transmission facilities may have to be built to facilitate water transfers throughout the state. Some additional water development may also be needed to increase the ability of water supply agencies to capture high flows for recharging groundwater.

CONFIRMED LESSONS OF PREVIOUS DROUGHTS

In addition to the new knowledge in the form of "useful pieces of practical wisdom," described in the previous section, the 1987-92 California drought also has confirmed several important lessons of previous droughts. These confirmed lessons are presented below.

1. Water in the aquifers continues to be the most effective strategic weapon against drought.

While short-term water conservation, temporary water transfers, and Miracle March rains in 1991 helped California water users get through the six years of drought, the state's urban and agricultural economies were really saved from a disaster by the availability of groundwater reserves. This can easily be verified using some crude numbers. Total water withdrawals in the state during a normal year are approximately 40 MAF of which 24 MAF come from surface water and the balance of 16 MAF comes from groundwater. In the 1991 water year, water rationing in urban areas saved about 1 MAF. The 1991 Water Bank shifted 0.8 MAF from agriculture to urban and environmental uses (many of the temporary transfers in 1991 depended upon groundwater and at least one-third of the 0.8 MAF was substituted through increased groundwater withdrawals). The March rains added 10 percent to the statewide reservoir storage, or about 4 MAF. Estimates of increased groundwater pumping indicate that some additional 8 MAF were pumped from groundwater aquifers. Because the statewide carry-over storage did not change between 1990 and 1991, the conservation and groundwater pumpage made up the shortfall caused by the estimated 57 percent deficit in statewide water year runoff. Total SWP deliveries (entitlement and other deliveries) were 47 percent of 1987 deliveries. Additionally, CVP deliveries in 1991 were 38 percent of 1987 deliveries.

Therefore, if we were to "give credit" for saving California's economy from a disaster, we need to acknowledge that, statewide, increased groundwater pumping was eight times as important as urban water conservation or water transfers. It was even twice as important as the Miracle March rains. This is not to say that water managers had very little to do with keeping the state out of a total disaster. Groundwater supplies would have been depleted had it not been for the large amounts of developed surface water that, during wet years, substitute surface water for groundwater use by farmers. Without CVP and SWP, a majority of the state's groundwater basins would likely be mined and the groundwater storage would be greatly diminished due to subsidence. At the same time, much of the remaining water in storage would be too deep or too saline to be recovered usefully or economically.

The realization of the role of groundwater reserves in drought protection is an old but nevertheless very important lesson. Almost 60 years ago, White (1935) had documented the value of groundwater supplies during the drought of 1928-1934. Overdrafting the aquifers during droughts is effective in the short-term, as long as they are recharged when surface-water supply becomes available. According to this lesson, the state should put more emphasis on groundwater management in its long-term (strategic) water plan. During this drought, groundwater storage in the San Joaquin Valley was depleted by some 11 MAF. This depletion has to be replaced as soon as surface supplies become available; until the aquifers are refilled, the state remains much more vulnerable. The same must be done with all other aquifers for California to survive similar droughts in the future. Increased reliance of off-stream uses on groundwater should also enhance the protection of environmental uses against droughts by preserving in-stream flows.

California is blessed with many groundwater aquifers holding some 250 MAF of usable water. These aquifers are a great asset for drought protection, but only if their long-term overdrafting can be controlled. There is a need for more coordinated management of

groundwater on the regional level. Southern California has long recognized the value of groundwater supplies, and several major groundwater basins in that region have been adjudicated. The state can help in passing laws to expedite the adoption of groundwater management plans or other forms of self-regulation by local and regional entities. The local regulation of groundwater might reduce overdrafting in the future, since people are getting concerned about exporting groundwater. Even more important, the state agencies can help with hydrogeologic research to identify groundwater basins in terms of total and usable storage, safe yields, recharge areas, water quality problems, and other necessary data for groundwater management. Finally, more groundwater recharge and conjunctive use of surface water and groundwater are among the best ways of keeping the groundwater reserves viable. Natural recharge proceeds almost at capacity during wet years, and it will not significantly increase because of lowering of groundwater tables. Artificial recharge and conjunctive use of surface water and groundwater will help maintain adequate banks of groundwater. California has plenty of overdrafted aquifers to provide very large storage for future droughts.

2. The surest way to mitigate the adverse social, environmental, and economic impacts of a sustained drought is to obtain more water.

What we learned about the cumulative and propagating nature of impacts from the 1987-92 drought suggests that the surest way of mitigating them is to provide more water from groundwater basins or surface storage reservoirs and use it to replace the deficiencies of precipitation and runoff. Both environmental and economic impacts of a sustained drought could be greatly moderated if more water could be found and delivered.

Obtaining more water includes long-term programs aimed at reducing demand by improving efficiency of water use. Demand management can produce "more water" and thus make a significant difference in urban and agricultural sectors. Obviously, the environment does not have such an option. There is little delay in impacts on environmental resources. They began with the first year of drought and accumulated as the drought continued. Agriculture is in a somewhat better position to modify water demand than environment, but quick gains in efficiency can only be made at a cost. The costs stem from managing irrigation more intensively, moving away from marginal soils, and postponing the leaching of salt accumulations in the soil. Finally, urban water-rationing programs also carry a price tag, but urban households and businesses use water for diverse purposes and, if given justification, can cut back on some less essential uses. However, their ability to reduce water use may be somewhat preempted by long-term efficiency improvement programs.

The "more water" option eliminates the need to distribute the burden of shortages among off-stream water users. It may also benefit the environment if the additional water can be obtained without high environmental costs (e.g., those often associated with the construction of large-scale in-stream water storage reservoirs). The drought has shown that environmental quality standards are necessary but not sufficient to protect fish and wildlife from cumulative impacts of a sustained drought. Again, more water is the only remedy for protecting some species from extinction. However, if there is no water held behind dams or in the ground, more water for one sector must come from another sector. Water controllers who operate major storage reservoirs must face the difficult task of taking water from one sector and giving it to another and be accused of "playing God." Water institutions are well aware of these problems

and see the development of adequate supplies to keep pace with growth of consumptive use as their most important option. However, they believe this option has been taken away from them during the last two or three decades because of two factors: (1) a belief that limiting water supply could control growth and (2) environmental laws and regulations that made it possible for environmental interests to stop water development projects.

The drought has shown, however, that water management in California does not have to be a "zero sum game," where gains of one sector are achieved at the expense of other sectors. There are other options for obtaining more water. More water can come not only from new storage but also from reallocation of existing supplies and voluntary transfers among off-stream users as well as from long-term improvements in the efficiency of water use. The results of our survey indicate that the urban, agricultural, and environmental interests are not strongly polarized with respect to all these "more water" options. All three sectors support further improvements in water use efficiency. Irrigators are not opposed to voluntary transfers on a temporary basis if their long-term interests are protected. Finally, the environmental community would support the development of new water storage, especially off-stream storage, if the agencies who operate the storage facilities do not discriminate against environmental uses of water. Their main objective is not to stop all water development but to reform the existing water institutions (both bureaucracies and water law) so that environmental uses of water are given equal standing with urban and agricultural sectors in water management decisions.

3. Early drought response actions and proper timing of tactical measures are essential in short-term management of droughts.

The 1987-92 drought has confirmed an earlier belief that droughts in California are truly unpredictable. In hindsight, taking earlier actions would have been warranted during both California droughts. The lesson of the 1976-77 drought was not lost on urban water providers. They made no bets on the drought to be over soon and maintained aggressive demand reduction programs through the most critical year of 1991. The 1987-1992 drought confirmed the earlier lesson on the importance of early drought response.

The timing of cutbacks in water deliveries from the major projects must be examined carefully because it affects user sectors differently. No timing of cutbacks would satisfy all users of the CVP and SWP water at the same time. Early cutbacks to agriculture translate to economic impacts that become certain. Late cutbacks increase the risks to urban areas and also preempt future options for protecting against environmental damages. Generally speaking, urban areas would like to leave more water in storage to prevent deep cutbacks in deliveries at later, more critical stages of drought. The drought experiences indicate that farmers want maximum delivery during a given drought year and are willing to receive no supplies next year. However, in testimony at the SWRCB's Interim Water Rights Hearing, an agricultural economist testified that some studies show farmers can achieve greater profits with slightly reduced quantities of supply but increased certainty of supply.

4. Local and regional interconnections among water supply systems proved to be a good insurance policy against severe water shortages.

Historically, urban and rural communities throughout the U.S. made strong efforts to develop their own water supplies and have control over their own fate. The desire for such local autonomy is also present in California. The 1987-92 drought demonstrated in several California communities that the self-reliance and self-sufficiency in terms of their "owned and operated" sources of water supply may not be an effective strategy for protection against multiyear droughts in the future. Actually, this strategy of local "self-sufficiency" in water supply can have disastrous consequences during drought. Examples of difficulties caused by guarded self-sufficiency were found in the San Francisco Bay area and in Santa Barbara. Santa Barbara is a good example of a closed system. The city did not have any connections to other neighboring systems, and it was very difficult to bring water to them. The only short-term alternative available to them was a tanker bringing water through the sea. Later, a complex system of transfers and exchange arrangements by a number of districts was devised and implemented to bring some supplies to Santa Barbara.

The confirmed lesson here is that water districts should be encouraged to share their supplies with their neighbors and may also have to learn to rely more on external sources of supply over which they will have very limited control. This lesson does not apply to all water suppliers in the state. Some communities have abundant sources of supply and do not have to turn to water imports for many years. However, the number of districts that have to hook up to the statewide "plumbing system" is increasing. Unfortunately, this lesson may be lost on both the districts relying on the SWP water as well as some districts using the CVP water. Their experience is that the project supplies are not reliable, because they have been cut back. They feel they cannot count on SWP (or CVP) to keep their supplies uninterrupted and must develop more local or independent supplies, even if costs of such development are very high. Although a lesson on the importance of interconnections has been recognized during previous drought experiences, it has not been acted upon by many local providers of water.

SUGGESTED WATER MANAGEMENT INITIATIVES AND REFORMS

The experiences and lessons of the 1987-92 drought were translated by survey participants into specific actions that should be taken in order to enhance the capability of California's water management system to cope with future droughts. Below we present some of the participants' suggestions under the categories of strategic (long-term) and tactical (short-term) measures. The sequence of these suggestions does not follow any particular order and the specific suggestions were not selected to form a coherent set of recommendations. Rather they represent our reporting of those suggestions which were voiced by survey respondents most frequently. Complete listings of these suggestions are included in Appendix D.

Strategic Measures Suggested by Survey Participants

The strategic (long-term) measures listed below represent the views, perceptions, and opinions which were offered by survey participants.

1. The Sacramento-San Joaquin Delta problem has to be resolved. Physical improvements in the Delta are needed to improve the efficiency of moving water stored in the upriver reservoirs to the south and to enhance and maintain water quality in the Delta.

2. SWP facilities have to be completed. The present dependable supplies of SWP are 2.3 MAF per year. The improvements in the Delta will increase firm SWP supplies, but additional storage will be needed to reach the originally planned firm supply of 4.2 MAF per year.

3. A permanent Water Bank should be established. A Water Bank Office should be established as a broker of water transfers at any time. The office should be independent of C-DWR and SWP. The institutional barriers to water transfers should be removed except for those that protect against third-party impacts and negative environmental externalities.

4. The state should move away from "crisis management" and focus more on "long-term planning." Long-term planning for drought protection should focus on alternatives such as water banking and marketing, conjunctive use of surface water and groundwater, water reclamation and desalination, as well as water conservation in agriculture and urban uses.

5. Marginal cost pricing should be incorporated into long-term water plans. Pricing of developed water should be revised in order to eliminate the existing large differences in the prices paid per acre-foot of water, thus creating greater incentives to use water efficiently.

6. Groundwater management should be improved. The state should look into groundwater regulation. More work on groundwater storage and mapping of aquifers is needed. Large groundwater basins in the Central Valley should be managed, possibly, by self-regulation of users.

7. Water management should be centrally coordinated. The operations of CVP should be transferred to the state, and the Governor should appoint a water czar to manage all State Water Projects.

8. The state should develop a computerized data bank. The bank should contain regularly updated comprehensive water-planning and management information and should be made readily accessible to all water agencies.

9. California water law should be revised to allow for in-stream water rights. The existing system of water law protects off-stream uses. In-stream water rights would afford some protection of natural flows.

10. Enforced mitigation of impacts on aquatic resources should be undertaken in order to enhance water quality and minimum-flow standards. The standards established by EPA and SWRCB are not adequate for restoring and protecting environmental resources.

11. More conservation technology and know-how should be infused into California's agriculture. Farmers should be educated on how to use less water, what kind of machinery to use, and how to manage labor in order to increase water use efficiency. A system of economic incentives should be developed to encourage more farmers to adopt innovative and efficient irrigation technologies.

12. Improved reliability of urban water supplies is needed. Water districts should develop more sophisticated long-term water plans with adequate protection against a sustained drought lasting 10 to 15 years. The districts that are isolated and face supply limitations should also build interconnections with neighboring districts and tie into the California system of aqueducts where feasible.

13. Long-term water management plan should take environmental needs into account. Environment should be brought along, and all water use purposes should be optimized by combining resource values with economic principles.

14. Environmental needs for water should be met. A water fund should be established to purchase water for environmental purposes. Firm supplies of water for existing wetlands should be obtained.

15. A better management of fish and wildlife under normal conditions is needed. The impacts of drought on fish and wildlife depend on the overall health of these environmental resources prior to drought. Better normal and wet year protection for fish and wildlife is needed in order to provide some additional elasticity during drought.

Tactical Measures Suggested by Survey Participants

The tactical (short-term) measures provided below represent the views suggested by survey participants.

1. State should develop and adopt clear triggering mechanisms for drought response. State drought response actions should be triggered automatically without a lengthy and contentious process of passing drought emergency legislation.

2. Californians should establish water use priorities. During periods of shortage, priorities in water use should be invoked and low-priority uses should be sacrificed if necessary.

3. A streamlined approval process for all water transfers should be developed. Drought Water Bank should be expanded, and exchanges and transfers outside the state bank should be facilitated.

4. A massive public information and education program is needed. Californians need to be better educated about water issues and droughts in order to gain public support for reforming the existing water management system.

5. The state should cut down on the amount of firm hydroelectricity production during drought. Stored water should be made available for environmental uses. Investments should be made in bulk energy transfer facilities to enhance the capability for importing power during droughts.

6. Agricultural water districts should be more flexible. They should adjust their water delivery schedules (frequency and duration) according to the requirements for optimal water application on the irrigated crops.

7. A better accountability in agricultural water use must be achieved. All irrigation water should be metered, and the districts should communicate to the public the degree of efficiency they were able to achieve.

8. Urban water suppliers should develop very clearly defined carry-over storage goals and adhere to them during drought. Tactical short-term measures should be implemented whenever the carry-over storage goals are not expected to be maintained by the end of the water year.

9. Urban water agencies should plan for water deficits. They should lessen the pressure on water development by planning for a 25 percent shortage during droughts and then only develop or obtain firm supplies to meet 75 percent of normal water demand.

10. Water rationing should be done through pricing. Increasing the price of water during drought is the best way of achieving reductions in demand without causing revenue shortfalls.

11. Water agency representatives should improve the communication of their water supply situation. They should clearly communicate to the media, civic leaders, and customers what their water needs are, how much supply is available, what the expected shortages are, and what they want to accomplish through their demand reduction program.

12. Environmental impacts must be given greater attention. Some equitable ways of protecting the environment must be found. Water institutions should not discriminate against environmental uses of water.

CONCLUSION

The six-year California drought of 1987-92 focused the attention of the public as well as water controllers and influencers on the shortcomings of the existing water management system in the state as defined by its water infrastructure, institutional arrangements, and the system of water rights. This management system is becoming increasingly inadequate in protecting the established in-stream and off-stream water uses against multiyear droughts.

Some of the lessons contained in this report point to specific changes that Californians should consider. More generally, however, the drought experiences merely demonstrated the shortcomings of the system, and water managers and citizens must now begin the work of designing new systems that will perform better in future droughts.

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APPENDIX A

WATER POLICY LEGISLATION, LITIGATION, AGREEMENTS AND DROUGHT LEGISLATION SINCE 1991

WATER POLICY LEGISLATION, 1980-1987

Water Transfer

AB 178 (N. Waters), Chap. 1655 of 1984: Extends the law protecting areas of water origin to all future exporters from a number of Northern California watersheds.

AB 2010 (Isenberg), Chap. 1384 of 1986: Authorizes Director, C-DWR, to negotiate with the Bureau of Reclamation for State to own or operate part or all of federal CVP.

AB 2746 (Katz), Chap. 918 of 1986: Requires a State or local agency owning a water conveyance facility to let another local agency transfer water to a purchaser by unused capacity; transferor must pay fair compensation.

AB 3427 (Kelley), Chap. 364 of 1986: Permits a water transfer agreement to exist more that 7 years, if mutually agreed to by agency and transferee.

AB 3722 (Costa), Chap. 970 of 1986: Requires C-DWR to set up a program to facilitate the voluntary exchange or transfer of water.

SB 1700 (Torres), Chap. 1241 of 1986: Requires C-DWR to negotiate with the Bureau of Reclamation for purchase and transfer of water.

Water Conservation

Executive Order B-62-80 of 1980: This executive order directed all state agencies, department, boards, and commissions to continue to seek ways to implement water conservation practices in connection with their programs and activities.

Executive Order B-68-80 of 1980: This executive order directed (1) C-DWR to prepare a plan of water conservation, reclamation, and management for the State Water Project to recommend actions that could be taken by the State and its water contractors to reduce demand for water and, (2) C-DWR to implement a program of recycling agricultural drainage and brackish water with the objective of desalting 400,000 acre-feet by the year 2000. The Executive Order also urged the SWRCB to require water conservation plans in exercising its authority on water rights.

Water Code Sections 375-377: These sections allow public retail water suppliers to, by ordinance or resolution, adopt a water conservation program, and require the installation of water saving devices, except for agricultural users.

Water Code Sections 10610-10656: These sections require every urban water supplier providing water for municipal purposes to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually to prepare and adopt, in accordance with prescribed requirements, an urban water management plan containing prescribed elements.

Water Code Section 1009 and 71610.5: These sections authorize municipal private water companies to prepare water conservation plans to reduce water use which can require water conservation retrofit devices.

Public Utilities Code Section 761 and 770: These sections give the California Public Utilities Commission board authority over water utilities it regulates (private) which would allow it to require water utilities to adopt programs for water conservation.

AB 797 (Klehs), Chap. 1009 of 1983: Establishes the Urban Water Management Planning Act to require water conservation and management plans by urban water suppliers.

AB 1732 (Costa), Chap. 377 of 1984: Authorizes sale of general obligation bonds to cover the State's share of waste water projects; for waste water reclamation projects and water conservation loans.

AB 2542 (Peace), Chap. 429 of 1984: Provides that use of Colorado River water reduced by water

conservation measures will not cause the loss of water rights.

AB 1029 (Kelley), Chap. 938 of 1985: Authorizes any water supplier or water user to finance water conservation or reclamation and sell the conserved or reclaimed water to another water supplier or water user.

AB 1658 (Isenberg), Chap. 954 of 1986: Requires agricultural water suppliers to determine whether they have significant opportunities to save water. Existence of such opportunity requires that supplier prepare and adopt an Agricultural Water Management Plan.

AB 1982 (Costa), Chap. 6 of 1986: Provides $150 million in low-interest loans to local agencies for water conservation, groundwater recharge, and agricultural drainage projects. (Approved by voters in June 1986.)

AB 325, Chap. 1145 of 1990: Requires California cities and counties to adopt a water-efficient landscape ordinance by January 1, 1993 (unless they can prove that such ordinance is unnecessary). AB 325 also directed C-DWR to draft a Model Water-Efficient Landscape Ordinance, recently completed. Cities and counties must adopt this Model Ordinance by January 1, if they have not adopted their own by then.

Off-stream Storage

AB 3792 (Isenberg), Chap. 1656 of 1984: Authorizes the Los Banos Grandes Reservoir, south of the Delta, as part of the SWP.

Ground Water and Water Quality

AB 1362 (Sher), Chap. 1046 of 1983: Establishes regulatory provisions to prevent groundwater contamination from hazardous substances stored in underground tanks.

AB 1803 (Connolly), Chap. 881 of 1983 and AB 1803 (Connolly), Chap. 818 of 1985: Requires the Department of Health Services and local health departments to evaluate public water systems for potential contamination.

AB 2013 (Cortese), Chap. 1045 of 1983: Requires persons storing hazardous substances in underground containers to file a hazardous substance statement with SWRCB.

AB 2183 (O'Connell), Chap. 378 of 1984: Authorized an additional $75 million for the Safe Drinking Water Program.

AB 3566 (Katz), Chap. 1543 of 1984: Requires regulation of toxic pits in order to prevent contamination of groundwater.

AB 3781 (Sher), Chap. 1584 of 1984: Requires testing of underground tanks before and after installation to protect groundwater from leaks.

AB 1156 (Areias), Chap. 1034 of 1985: Enacts the Groundwater Recharge Facilities Financing Act, authorizing C-DWR to make grants to local agencies for groundwater recharge facilities.

SB 187 (Ayala), Chap. 268 of 1985: Confirms authority of C-DWR to build groundwater storage facilities south of the Delta as part of SWP; requires C-DWR to contract with local agencies in such programs.

AB 2668 (O'Connell), Chap. 410 of 1986: Authorized an additional $100 million for the Safe Drinking Water Program.

AB 3127 (Areias), Chap. 1152 of 1986: Requires counties and cities to adopt water well abandonment ordinances that meet or exceed standards in C-DWR Bulletin 74-81.

Fish and Wildlife (State)

SB 512 (Hart), Chap. 6 of 1984: Enacts the Fish and Wildlife Habitat Enhancement Act of 1984, authorizing issuance of $85 million in bonds for fish

and wildlife habitat enhancement. (Approved by voters in June 1984.)

AB 723 (Campbell), Chap. 1259 of 1985: Authorizes SWRCB to consider streamflow requirements in applications to appropriate water.

SB 400 (Keene), Chap. 1236 of 1985: Enacts the Fisheries Restoration Act of 1985 for restoration of fishery resources and habitat damaged by water diversions and projects.

SB 1086 (Nielsen), Chap. 885 of 1986: Requires the Wildlife Conservation Board, by January 1, 1988, to inventory land along the upper Sacramento River and determine priority of land valuable to fish and wildlife. Creates an Upper Sacramento River Fisheries and Riparian Habitat Council to develop, for submission to the Legislature, the Upper Sacramento River Fisheries and Riparian Habitat Management Plan to provide for the protection, restoration, and enhancement of fish and riparian and associated wildlife for the area between the Feather River and Keswick Dam.

Fish and Wildlife (Federal)

HR 1438 (Chappie, Bosco, Shumway), PL 98-541: Establishes the Trinity River Basin Fish and Wildlife Management Program to restore and maintain fish and wildlife populations in the basin.

HR 3113 (Miller, Coelho, Lehman), PL 99-546: Authorizes the Secretary of the Interior to enter into agreements for coordinated operation of the federal CVP and SWP and to preserve Suisun Marsh.

HR 4712 (Bosco), PL 99-552: Establishes the Klamath River Basin Conservation Area Restoration Program to restore anadromous fishery in the river.

Delta Levees

AB 955 (Peace), Chap. 1271 of 1985: Requires C-DWR to plan for continued water exports, should Delta levees fail.

AB 3473 (Johnston), Chap. 824 of 1986: Requires C-DWR to inspect local agencies' nonproject levees to ascertain degree of compliance with maintenance standards.

SB 2224 (Garamendi), Chap. 1357 of 1986: Authorizes C-DWR and The Reclamation Board to determine the need for State financial aid to Delta reclamation and levee districts to maintain levees that protect State highways.

SIGNIFICANT WATER POLICY LITIGATION

U.S. Supreme Court Cases

California v. United States (1978)

The U.S. Bureau of Reclamation, in operating New Melones Reservoir, must comply with State water rights law, unless it is inconsistent with congressional directives to do so. This is the leading Supreme Court decision requiring the United States, in most instances, to comply with the substance and procedures of State water rights law. The Ninth Circuit Court of Appeal later held that the conditions imposed by the State Water Resources Control Board (SWRCB) on New Melones were consistent with congressional directives (*United States v. State of California, State Water Resources Control Board*, 694 F.2d 1171 (1982))).

(438 U.S. 645, 98 S.CT. 2985)

United States v. New Mexico (1978)

This case limited the amount of water the U.S. Forest Service could claim under the "reserved rights doctrine" to water necessary for the primary purposes for which the National Forests were reserved; that is, preservation of timber and securing favorable flows for private and public uses under state law. Water

for secondary purposes -- for example, stock watering and environmental, recreational, or scenic purposes -- could be acquired only in the same manner as any other public or private appropriator under state law. The *California v. United States* and the *New Mexico* cases both emphasize Congress' historic deference to state water law.

(438 U.S. 696, 98 S.Ct. 3012)

California Cases

National Audubon Society v. Superior Court (1983)

The public trust doctrine applies to the City of Los Angeles' rights to divert water from streams tributary to Mono Lake. The State retains supervisory control over its navigable waters under the public trust to protect such uses as navigation, fisheries, commerce, recreation, and scenic and environmental values. This prevents any person from obtaining a vested right to appropriate water in a manner harmful to the public trust. As a matter of necessity, SWRCB may grant rights to take water needed in distant parts of the State, even if public trust uses are harmed, but it must take public trust into account and protect public trust values wherever feasible. SWRCB retains continuing supervision and may reconsider allocation decisions, even if the decisions were made after consideration of public trust values. SWRCB and California courts have concurrent jurisdiction to consider and protect public trust values.

(33 Cal.3d 419, 189 Cal.Rptr. 346)

Imperial Irrigation District v. State Water Resources Control Board (1986)

After an adjudicatory hearing, SWRCB found that failure to undertake additional water conservation measures was unreasonable under Article X, Section 2, of the California Constitution. The Court affirmed SWRCB's authority under the Constitution and Water Code Section 275 to conduct such a hearing and to enforce its order.

(186 Cal.App.3d 1160, 231 Cal.Rptr. 283)

United States v. State Water Resources Control Board (1986)
[The Consolidated Delta Cases]

This decision (Racanelli) covers eight cases challenging SWRCB's Decision No. 1485, issued in 1978, and its Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh. The decision recognizes SWRCB's broad authority and discretion over water rights and water quality issues, including jurisdiction over the federal CVP.

(182 Cal.App.3d 82, 227 Cal.Rptr. 161)

Fullerton v. State Water Resources Control Board (1979)

(90 Cal.App.3d 590, 153 Cal.Rptr. 518)

California Trout, Inc. v. State Water Resources Control Board (1979)

(90 Cal.App.3d 816, 153 Cal.Rptr. 672)

These two cases hold that an appropriation of water cannot be made for in-stream flows because some physical control over the water is a necessary element of the doctrine of appropriation.

1991 DROUGHT LEGISLATION

State Legislation

The following bills were introduced in Extraordinary Session.

AB9x (Cortese) Water transfers: This bill gives the governing body of a water supplier explicit authority to enter into contracts, either with the Department of Water Resources' water bank or with other water suppliers, for transfer of water outside the service area of the water supplier. An urgency measure.

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter 1-91).

AB 10x (Costa) Water transfers: This bill explicitly declares that no temporary transfer of water under any provision of law for drought relief in 1991 or 1992 will affect any water rights. An urgency measures.

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter 2-91).

AB 11x (Filante) Urban Water Management Plans: This bill requires every urban water supplier to prepare an urban water shortage contingency plan. It requires the plan to include data on water usage, an estimate of water supply at yearly intervals (assuming worst-case shortages), stages of action to respond to possible water supply shortages of up to 50 percent, mandatory prohibitions on wasteful practices, consumption limits that would apply in the more restrictive stages of shortages, penalties for excessive use, an analysis of the financial effect of the plan on the supplier, a draft resolution or ordinance to implement the plan, and a mechanism to determine actual reduction in water use pursuant to the plan. This bill requires suppliers to include these contingency plans in their urban water management plans, and it requires suppliers to forward their plans to C-DWR by January 31, 1992. The bill requires water suppliers providing water indirectly to retail customers to prepare plans, and it requires suppliers to coordinate with other suppliers in their area in preparation of shortage contingency plans. The bill exempts implementation of water shortage contingency plans from the California Environmental Quality Act (CEQA), provided the project would not significantly affect water supplies for fish and wildlife. After January 31, 1992, the bill disqualifies noncomplying urban water suppliers from State drought assistance until the suppliers submit water shortage contingency plans.

STATUS: This bill became law without the Governor's signature (Extraordinary Session Chapter 13-91).

AB 12x (Costa) Department of Fish and Game: drought management activities: This bill appropriates $15.277 million from the General Fund to the Department of Fish and Game to minimize the effects of the drought on fish and wildlife trust resources and protect populations of fish and wildlife. An urgency measure.

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter 11-91).

AB 14x (Jones) Department of Forestry and Fire Protection: funding: This bill would appropriate $20.4 million from the General Fund to the Department of Forestry and Fire Protection for Fiscal year 1991-92 for increased fire protection activities and for capital outlay involving installation or rehabilitation of wells and installation of pipelines as needed to restore adequate water supplies to fire stations and conservation camps. An urgency measure.

STATUS: This bill was passed by the Assembly. It failed passage in the Senate Committee on Budget and Fiscal Review.

AB 15x (Kelley) Reclamation projects: emergency assistance: This bill would appropriate $10 million from the General Fund to the State Water Resources Control Board for State financial assistance (loans and grants) to local water suppliers for water reclamation projects that can be completed and provide reclaimed water by June 30, 1992. An urgency measure.

STATUS: This bill is before the full Assembly.

AB 16x (Mays) Water resources: This bill removes statutory maximum time limits for action by the State Water Resources Control Board on water rights applications and petitions during drought emergencies or critically dry years. It authorizes the State Water Resources Control Board to adopt drought-response emergency regulations, effective for 270 days, without review and approval by the Office of Administrative Law. An urgency measure

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter 12-91).

AB 18x (Areias) Property taxation: deferral: This bill would authorize counties to permit owners of agricultural land to defer payment of fiscal year 1991-92 property taxes, but it would restrict their deferral to owners whose land has been damaged as a result of drought. An urgency measure.

STATUS: This bill has been passed by the Assembly and the Senate; it has been returned to the Assembly for concurrence in Senate amendments.

SB 9x (Bergeson) Water appropriation: water suppliers: This bill explicitly authorizes water suppliers to contract with customers for water when customers voluntarily reduce or eliminates use of water. An urgency measure.

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter

SB 12x (Ayala) Drought relief and assistance: This bill secures legislative approval for projects potentially eligible for funding under the 1988 Water Conservation Bond Law and the 1986 Water Conservation and Water Quality Bond Law. An urgency measure.

STATUS: This bill has been signed by the Governor (Extraordinary Session Chapter 10-91).

The following legislation was introduced during the Regular Session.

AB 455 (Cortese) Development projects: water supply: In response to drought conditions, this bill would require each urban water supplier to submit a copy of its urban water management plan and a copy of its capital improvement plan to each city and county within its service area and would require lead agencies under CEQA to consult with water suppliers on the availability of a "long-term, reliable supply of water" for proposed development projects. The bill would require water suppliers to make written determinations on the availability of this water supply and would require lead agencies, relying on the water suppliers' written determinations, to make written findings on the availability of water supply for the proposed development project. The bill would define "long-term, reliable supply of water" to mean water availability consistent with water purveyor plans, programs, and policies, and it would declare that the existence of a long-term, reliable supply of water does not create entitlement to or a permanent right to water and does not include a guarantee concerning the ability of a water retailer to serve its customers. The bill would authorize public agencies to charge fees to cover costs of services required by the bill. The bill would limit its requirements to projects of sufficient statewide, regional, or areawide environmental significance.

STATUS: This bill is before the full Assembly.

AB 1357 (Cortese) water shortage emergencies: This bill would enact the Drought Response Act of 1991 and would authorize the Governor to declare a drought emergency if, by February 15 the current year is dry or critically dry and if the two previous years have been dry or critically dry. The bill would require the director of the Department of Water Resources, prior to the Governor's declaration, to prepare and submit to the Legislature a report on the geographic extent of the water shortage and on drought mitigation measures that could be implemented on an emergency basis. The bill would authorize the director, prior to issuing the report, to begin planning and developing facilities and technology to assist in the mitigation of the effects of the drought, and it would authorize the director to undertake specified actions to provide water supplies to water-short areas. The bill would create a Drought Response Account in the Reserve for Economic Uncertainties and would express legislative intent that this account have a balance of $1 million at the beginning of each fiscal year. An urgency measure.

STATUS: This bill has been referred to the Assembly Committee on Water, Parks and Wildlife.

AB 1387 (O'Connell) Safe drinking water and drought relief bonds: This bill would place a $200 million General Obligation bond act (the California Safe Drinking Water and Drought Relief Bond Law of 1992) on the June 1992 primary election ballot and

would use bond revenues to finance a safe drinking water program ($150 million) and drought relief program ($50 million). This bill would revise the method of calculating the rate of interest on loans under the California Safe Drinking Water Bond Law of 1976. An urgency measure. (The substance of this bill has been amended into AB 2112, Polanco).

STATUS: This bill is being held in Assembly Committee on Banking, Finance and Bonded Indebtedness.

AB 1580 (Cortese) Water resources: urban water management: This bill would require each urban water supplier to amend its urban water management plan to include an estimate of agricultural water use, to identify and evaluate wastewater recycling activities currently adopted, and to describe water-saving fixtures and appliances for industrial, residential. commercial, agricultural, and governmental uses and the strategies proposed to meet short-term and long-term supply deficiencies in time of drought and emergency.

STATUS: This bill has been passed by the Assembly and by the Senate; it has been returned to the Assembly for concurrence in Senate amendments, then placed in the Assembly Inactive file.

AB 1972 (Wyman) Agriculture: low-interest loans: This bill would require the Director of the Department of Food and Agriculture to establish a program of low-interest loans to agricultural producers who suffer drought damage to orchards, vineyards, or other perennial agricultural plants.

STATUS: This bill has been referred to the Assembly Committee on Agriculture.

AB 2247 (Areias) Loans: linked deposits: agricultural operators and small businesses: This bill would make legislative findings that the State's recent economic downturn, drought, and freeze have created great economic hardship on small farms and businesses. The bill would create the California Treasurer's low Cost Loan Program for Small Business and Agriculture, a linked deposit program (an agreement between the State Treasurer and lending institutions where the Treasurer deposits state funds in the lending institution at reduced interest rates for deposits and the lending institutions agrees to lend the equivalent amount of money to eligible borrowers at reduced interest rates for loans). The bill would authorize the Treasurer to allocate up to 3 percent of the Pooled Money Investment Account to this program. An urgency measure,

STATUS: This bill has been referred to the Assembly Committee on Ways and Means.

SB 436 (Davis) Drought emergencies: liability for precipitation: This bill would create an exemption for public entities from civil liability for ordinary negligence based on occurrence or quantity of precipitation. The bill would include in the exemption any liability based on precipitation allegedly caused by cloud seeding, but it would limit this exemption to those places and time periods covered by a Governor's proclamation of emergency under Government Code Section 8625 due to drought. The bill would exclude from this exemption any liability resulting from failure to properly design, install, operate, or maintain flood control facilities.

STATUS: This bill has been referred to the Senate Committee on Judiciary.

SB 1168 (Marks) Water: drought relief: vessels and water meters: This bill would increase vessel registration fees and would appropriate revenues from these increased fees to the Department of Boating and Waterways for drought relief, with a priority of maintaining or increasing water levels in lakes used for recreational boating. The bill would require, effective January 1, 1992, that all new service be metered and, effective January 1, 1994, that all water service be metered,

STATUS: This bill failed passage in the Senate Committee on Transportation.

Federal Legislation

H.R. 355 (Lehman) Reclamation States Drought Relief Act of 1991: This bill would authorize the Secretary of the Interior to construct temporary facilities and drill new wells to mitigate drought losses; to assist willing buyers in the purchase of

water from willing sellers; to purchase water for delivery under temporary federal contracts; to participate in State-established water banks; to make projects and non-project water available, within and outside an authorized project service area, using federal storage and conveyance facilities, for agricultural, municipal, and industrial, and fish and wildlife purposes; to make loans to water users for drought response activities; to study measures for water conservation, augmentation and efficient use; to prepare cooperative drought contingency plans; and to study the need for a Reclamation Drought Response Fund.

STATUS: This bill has passed the House and the Senate. It has been returned to the House for concurrence in Senate amendments.

H.R. 1281 (Whitten) Dire emergency supplemental appropriations: Among other appropriations, this bill appropriates $25 million to the Department of the Interior for the construction program of the Bureau of Reclamation to meet the emergency needs of areas affected by the continuing drought in the western United States.

STATUS: This bill has been signed by the President (Public Law 102-27, April 10, 1991).

S. 586 (Bradley) Reclamation Drought Act of 1991: This bill would permanently authorize the Bureau of Reclamation, after consulting with governors of affected states, to undertake management and conservation activities to alleviate temporary drought conditions, to provide information and technical assistance to willing buyers and sellers of water, to prepare drought contingency plans for federal reclamation projects, and to contract for storage and conveyance of project and non-project water for use within and outside of authorized project service areas.

STATUS: This bill has been referred to the Senate Committee on Energy and Natural Resources.

S. 711 (Seymour) Drought response: This bill would provide the Secretary of the Interior with authorizations similar to those proposed in H.R. 355. Additionally, this bill would authorize loans for the purchase of interim supplies of water and for structural and non-structural activities to mitigate drought effects, and it would authorize the Secretary on the Interior to establish a $10 million "Reclamation Drought Response Fund" to finance drought-relief activities authorized by the act.

STATUS: This bill has been referred to the Senate Committee on Energy and Natural Resources.

Public Law 102-575, Title 34 Central Valley Project Improvement Act of 1992: The key legislated purposes of this title are:

(a) to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California;

(b) to address impacts of the CVP on fish, wildlife, and associated habitats;

(c) to improve the operational flexibility of the CVP;

(d) to increase water-related benefits provided by the CVP to the State of California through expanded use of voluntary water transfers and improved water conservation;

(e) to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and

(f) to achieve a reasonable balance among competing demands for use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial power contractors.

Title 34 mandated ten major areas of change in the management of the CVP:

- 800,000 acre-feet of water dedicated to fish and wildlife annually;
- tiered water pricing applicable to new and renewed contracts;
- water transfers provisions, including sale of water to users outside the CVP service area;
- special efforts to restore anadromous fish population by 2002;

- Restoration Fund financed by water and power users for habitat restoration and improvement and water and land acquisitions;
- no new water contracts until fish and wildlife goals achieved; no contract renewals until completion of an Environmental Impact Statement (EIS); terms reduced from 40 to 25 years with renewal at the discretion of the Secretary of the Interior;
- installation of the temperature control device at Shasta Dam;
- implementation of fish passage measures at Red Bluff Diversion Dam;
- firm water supplies for Central Valley refuges; and
- development of a plan to increase CVP yield.

APPENDIX B

STATE WATER PROJECT WATER DELIVERY RISK ANALYSIS AND CRITERIA FOR 1989

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Division of Operations and Maintenance

STATE WATER PROJECT
WATER DELIVERY RISK ANALYSIS
AND CRITERIA FOR 1989

December 1988

GORDON K. VAN VLECK Secretary for Resources	GEORGE DEUKMEJIAN Governor	DAVID N. KENNEDY Director
THE RESOURCES AGENCY	STATE OF CALIFORNIA	DEPARTMENT OF WATER RESOURCES

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INTRODUCTION

This report discusses the Water Delivery Risk Analysis[1] for 1989 and its associated criteria and implementation procedures. Risk Analysis is used to estimate the level of State Water Project (SWP) water deliveries that can be met during a year while maintaining prudent storage reserves for supporting deliveries in subsequent years. The estimated delivery capability is intended to be conservatively low to assure the water contractors of a base supply to plan their annual operations. Implementation procedures define the method for periodically updating that estimate as the winter and spring water supply develops.

The Risk Analysis Curve is a graphical presentation of the relationship between the forecasted Sacramento River Index[2] (SRI) for the water year[3] and SWP water delivery capability for the calendar year. The SRI is used as an indicator of the available water supply. It is also the parameter used in State Water Resources Control Board Decision 1485 (D-1485) for classifying types of water years and establishing the corresponding level of protection for the Sacramento-San Joaquin Delta. Those classifications are shown in Table A which has been extracted from D-1485. It should be pointed out that D-1485 uses median forecasts for establishing the year classification but the Risk Analysis application uses the more conservative forecasts defined in this report for determining water delivery capability.

Tables which show historical SRI data by water years, both chronologically and in ascending order, are included as Tables D and E. These tables show the high variability of the historical water supply.

SWP WATER DELIVERY RISK ANALYSIS FOR 1989

The 1989 Risk Analysis used the same operating and decision-making criteria to develop the curve as were used in the 1988 Rule Curve procedure. The values of these criteria for 1989 are:

- Storage threshold for scheduled surplus water deliveries is 3.0 million acre-feet (MAF).
- Average Annual Critical Period Supply (AACPS) is 2.26 MAF.

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[1]In 1988 and prior years the Water Delivery Risk Analysis was identified as the Rule Curve procedure.

[2]In 1988 and prior years the Sacramento River Index was identified as the Four Basin Index. It consists of the forecasted or computed unimpaired flows of the Sacramento River near Red Bluff, the Feather River at Oroville Reservoir, the Yuba River at Smartville, and the American River at Folsom Reservoir.

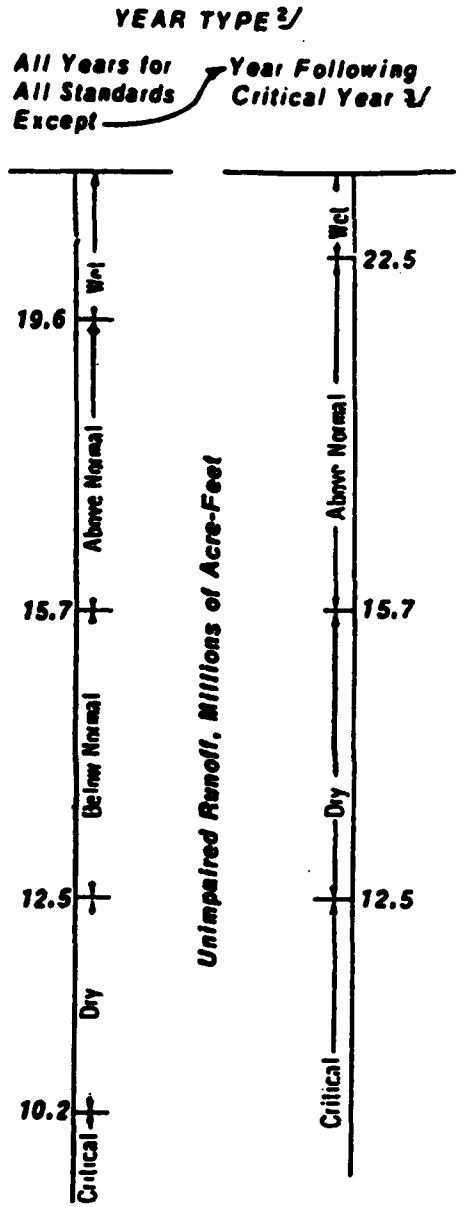
[3]A water year begins on October 1 and ends the following September 30.

TABLE A. 4/

WATER YEAR CLASSIFICATION

Year classification shall be determined by the forecast of Sacramento Valley unimpaired runoff for the current water year *(October 1 of the preceding calendar year through September 30 of the current calendar year)* as published in California Department of Water Resources Bulletin 120 for the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

YEAR TYPE	*RUNOFF, MILLIONS OF ACRE-FEET*
Wet 1/	equal to or greater than 19.6 (except equal to or greater than 22.5 in a year following a critical year). 3/
Above Normal 1/	greater than 15.7 and less than 19.6 (except greater than 15.7 and less than 22.5 in a year following a critical year). 3/
Below Normal 1/	equal to or less than 15.7 and greater than 12.5 (except in a year following a critical year). 3/
Dry	equal to or less than 12.5 and greater than 10.2 (except equal to or less than 15.7 and greater than 12.5 in a year following a critical year). 3/
Critical	equal to or less than 10.2 (except equal to or less than 12.5 in a year following a critical year). 3/



1/ *Any otherwise wet, above normal, or below normal year may be designated a subnormal snowmelt year whenever the forecast of April through July unimpaired runoff reported in the May issue of Bulletin 120 is less than 5.9 million acre-feet.*

2/ *The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.*

3/ *"Year following critical year" classification does not apply to Agricultural, Municipal and Industrial standards.*

4/ From footnote 2 of Table II, page 41 of D-1485.

- Carryover storage[4] for 1989 (on October 1, 1988) included 1.93 MAF storage in Lake Oroville and San Luis Reservoir (State share) and 0.06 MAF water owed to the SWP from the Central Valley Project in accordance with Article 6(e) of the Coordinated Operating Agreement, for a total of 1.99 MAF.

- Target storage[5] is based on the equation developed in 1988, which is applied to carryover storage. The equation[6] for determination of target storage is:

  $$TS = 1.0 + 1/2\ (BS-1.0)$$

  Where

  TS = Target storage for the end of the water year in MAF
  BS = Carryover storage for the beginning of the water year in MAF

  Target storage for October 1, 1989 is therefore:

  $$TS = 1.0 + 1/2\ (1.99-1.0)$$

  $$= 1.5 \text{ MAF}$$

The procedure for determining delivery approvals has been changed somewhat for 1989 in two respects:

- The initial delivery approval is based on a probability of exceedence of approximately 91 percent as determined from the 1906-1985 historical values of the SRI. Last year's initial approval was based on the December 7, 1987 estimate of the SRI at 99 percent exceedence probability, provided by the DWR Division of Flood Management. Monthly approval updates will be based on 99 percent probability of exceedence as in 1988.

- The change in exceedence probability for the initial approval increases the likelihood that a lower value of water delivery capability will occur in subsequent months. For that reason, it may be necessary to partially rescind approved deliveries beginning in March.

This Risk Analysis procedure is again being implemented on a one-year trial basis.

---

[4]The amount of combined storage in Lake Oroville and San Luis Reservoir (State share), together with other water available for Project export, at the beginning of a water year.

[5]The amount of combined storage in Lake Oroville and San Luis Reservoir (State share) to be reserved at the end of a water year for supporting Project water deliveries during subsequent years.

[6]The equation expresses the strategy of allowing storage to decrease halfway from carryover storage to minimum conservation storage of 1.0 MAF, which is dead storage of State share of San Luis Reservoir plus minimum power pool in Lake Oroville plus a small allowance for excess of October deliveries over expected inflow.

Development of Risk Analysis Curve

The 1989 Water Delivery Risk Analysis Curve (Figure 1) was developed by performing three series of 57 one-year operation studies using historic water year hydrology from 1922 through 1978. In all three series of studies, the beginning storage in SWP reservoirs was the actual carryover storage (1.99 MAF).

The end-of-water year storage (Oroville plus State share of San Luis) in the first series of 57 one-year studies was set to 1.0 MAF. That storage is slightly above minimum power pool which allows for a small amount of continued drawdown during the following October. The results of these studies indicate the maximum delivery capability using the water supply and all available water in storage. These results are plotted as the curve segment from 0 to the AACPS (2.26 MAF). The horizontal offset at 2.26 MAF water delivery capability represents the additional water supply needed before further entitlement deliveries can be approved.

In the second series of these studies, the ending storage was allowed to be no less than the target storage, 1.5 MAF. Regressing the delivery points from this series of 57 one-year studies provides a curvilinear relationship of potential deliveries versus SRI forecasts. This is shown in Figure 1 as the solid line between the AACPS and the requested entitlement deliveries.

The third series of 57 one-year studies required an end-of-year storage of 3.0 MAF, which is the surplus water delivery threshold used in the Risk Analysis. The delivery points for this series of studies were regressed to develop the curve for determination of the SRI necessary for various levels of surplus water delivery. This is shown as the solid line above the requested entitlement deliveries.

The horizontal offset of these two lines at the requested entitlements level represents a gross estimate of the additional SRI water supply which must be available to recharge end-of-year storage in Lake Oroville and San Luis Reservoir (State share) from the target storage for entitlement water deliveries (1.5 MAF(to the threshold storage for surplus water deliveries (3.0 MAF).

Also shown on Figure 1 are the AACPS and the levels of requested entitlement and surplus water delivery for 1989.

Reinstatement of applied reductions begins when the projected SRI runoff exceeds the amount indicated by the Risk Analysis to meet further increases if verified by operation studies.

Figure 2, "Frequency of Sacramento River Index," is included to provide a method of estimating the probability of receiving any specific SRI runoff volume. For example, the probability of receiving a SRI runoff of at least 9.2 MAF (the amount which occurred in water year 1988) is 90.6 percent.

Figure 1.

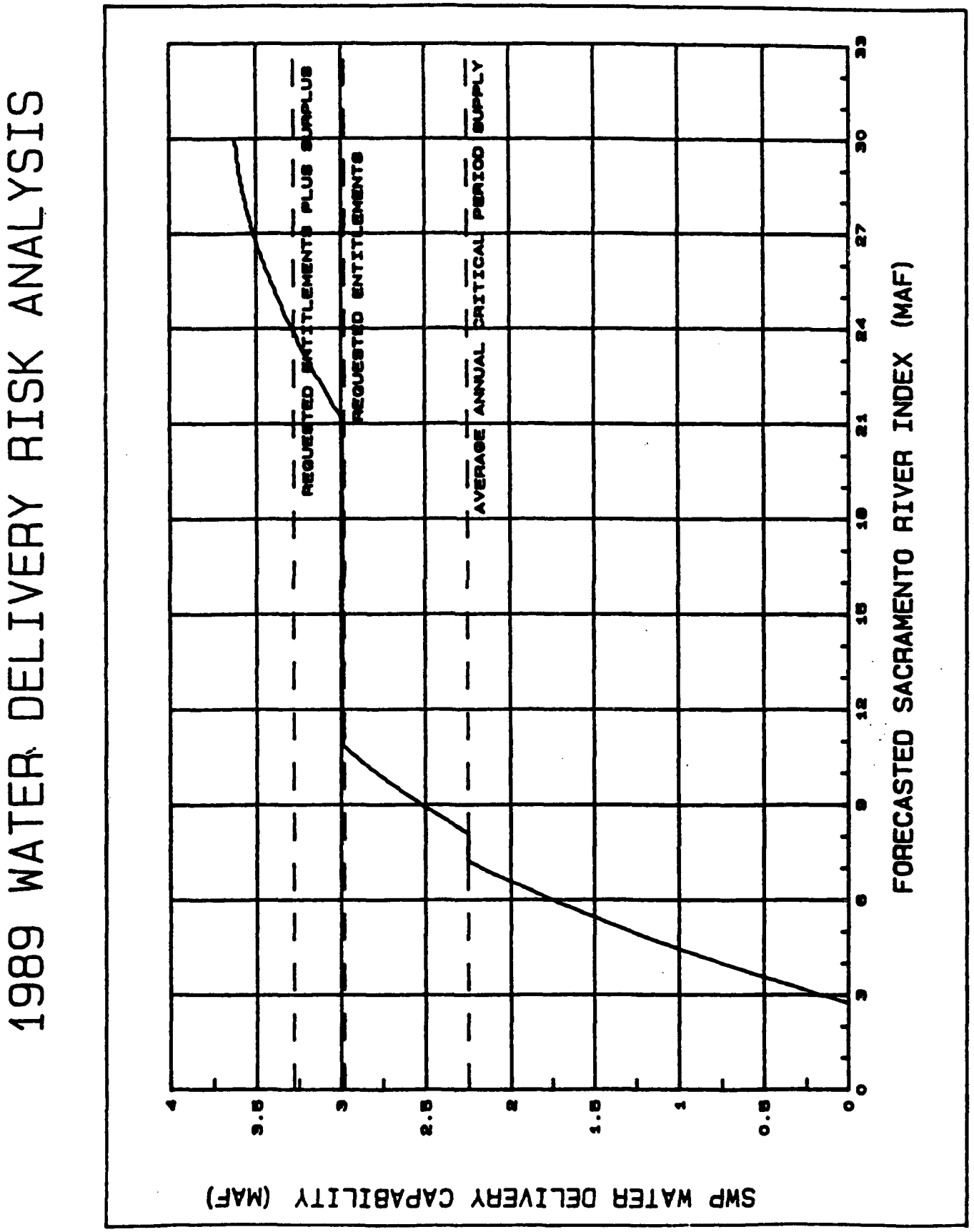
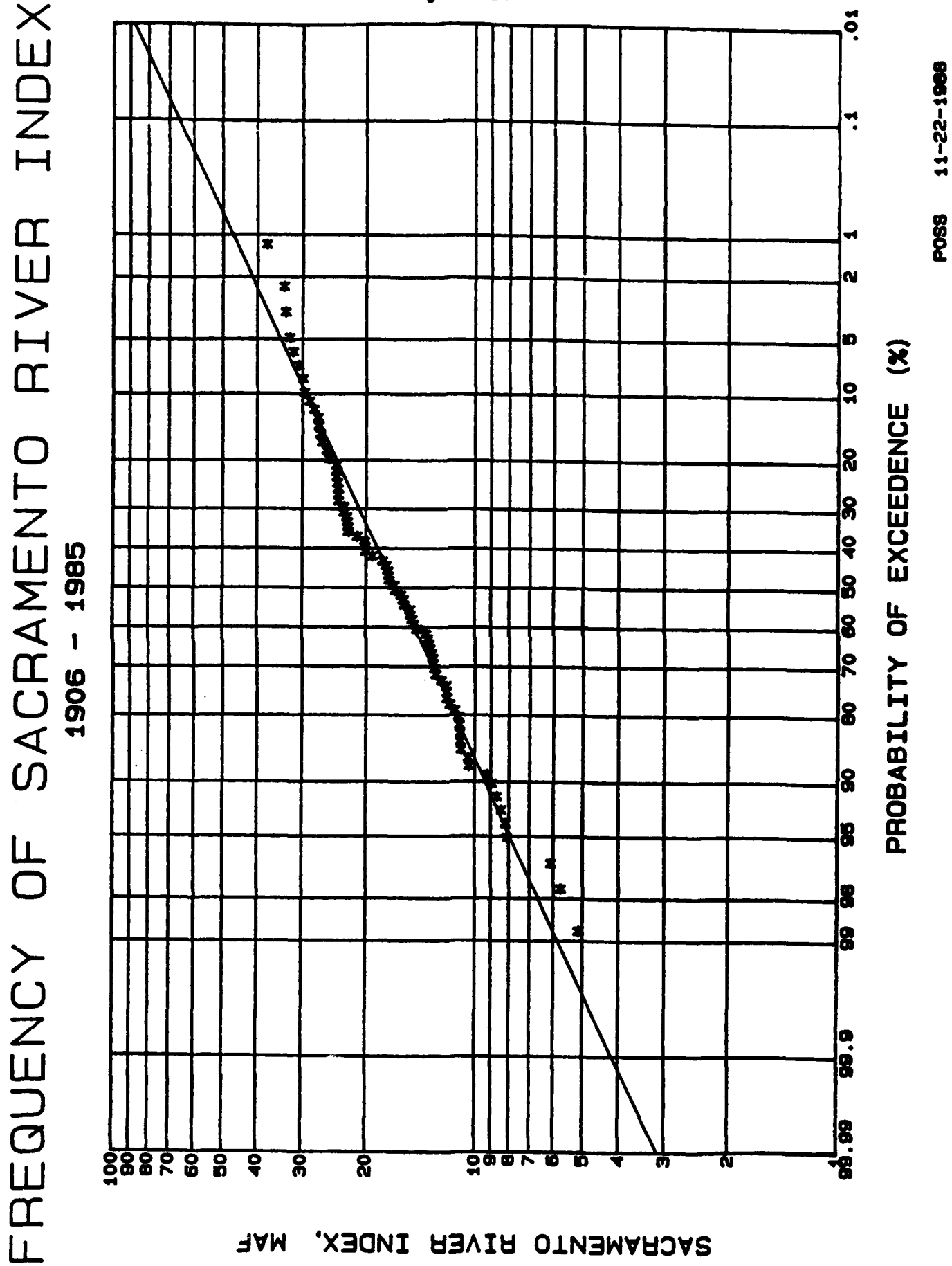

1989 WATER DELIVERY RISK ANALYSIS
REQUESTED ENTITLEMENTS PLUS SURPLUS
REQUESTED ENTITLEMENTS
AVERAGE ANNUAL CRITICAL PERIOD SUPPLY
SWP WATER DELIVERY CAPABILITY (MAF)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
3
6
9
12
15
18
21
24
27
30
33
FORECASTED SACRAMENTO RIVER INDEX (MAF)

Figure 2.


FREQUENCY OF SACRAMENTO RIVER INDEX
1906 - 1985
SACRAMENTO RIVER INDEX, MAF
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
99.99
99.9
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
.1
.01
PROBABILITY OF EXCEEDENCE (%)
POSS 11-22-1988

Monthly Approval Updates

Shortly after the first of each month, January through May, DWR's forecast of the unimpaired runoff of the four stations which make up the SRI, at the 99 percent probability of exceedence level, will be used in conjunction with the 1989 Risk Analysis to provide a gross solution of the annual amount of water available for delivery. This solution must be considered "gross" since the annual index by itself is not indicative of the effect of monthly runoff distributions on annual supply—a wet fall season is not overly beneficial if much of the water must be released to maintain flood control reservation.

The gross solution of the amount of water available for delivery is then allocated to individual contractors for input to an operations study, which is then made in order to verify that the deliveries can be met while maintaining the target storages. That operations study utilizes actual Oroville and San Luis storage at the beginning of the then current month, the forecasted water supplies for the remainder of the water year at the 99 percent exceedence level and approved facility outage schedules. The study also accounts for any special outstanding obligations upon Lake Oroville storage (such as for share of Delta outflow owed to the USBR under coordinated operations or 1988 Yuba County Water Agency purchase, or special entitlement carryover agreements).

1989 WATER DELIVERIES

Delivery requests submitted by the water contractors for 1989 total about 3.02 MAF for entitlement and entitlement-related uses. In addition to that water, requests have also been submitted for about 0.26 MAF of surplus water. A detailed breakdown of the 1989 requests is given in Table B. These requested deliveries have not been approved.

Approved deliveries for 1989 are shown in Table C. These approved deliveries total 2.51 MAF. Approvals have been based on an estimate of 9.0 for the SRI, which is at a probability of exceedence of approximately 91 percent. The 1989 Risk Analysis and operations study support this level of delivery, which requires a 40 percent reduction in agricultural requests.

Subsequent approvals will be determined from the SRI forecasts at the 99 percent level of exceedence and the 1989 Water Delivery Risk Analysis Curve (Figure 1), and verified by operation studies. Entitlement requests in excess of the initial 2.51 MAF will be approved to the extent allowed with increased SRI while maintaining the September 30, 1989 carryover target storage of 1.5 MAF. If the Risk Analysis and operations study for January or February indicate reduced water delivery capability, no reduction in approved deliveries will be made. If the March approval update indicates less water delivery capability than previously approved, approvals will be reduced accordingly. If the April or May approval update indicates less water delivery capability, no reductions will be made, unless projected conservation storage falls below 1.0 MAF.

Surplus water deliveries will not be approved unless SWP operation studies show that the carryover storage (Lake Oroville plus State share of San Luis Reservoir) on September 30, 1989 will be at least 3.0 MAF and then only to the extent that such deliveries are in excess of that needed to maintain the 3.0 MAF surplus water threshold.

TABLE B
1989 REQUESTED WATER DELIVERIES
(Acre-Feet)

State of California
The Resources Agency
File ID: F1989RD

Department of Water Resources
State Water Project Analysis Office
Date: 12/05/88
Page: 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
County of Butte	50	50	120	70	70	90	170	200	170	90	60	60	1200	
Plumas Co FCWCD	25	30	41	75	99	144	159	159	159	40	35	34	1000	
Yuba City	0	0	0	0	0	0	500	600	300	100	0	0	1500	
Feather River 5	**75**	**80**	**161**	**145**	**169**	**234**	**829**	**959**	**629**	**230**	**95**	**94**	**3700**	
Napa Co FCWCD	508	501	549	574	517	410	442	444	556	633	519	513	6166	
Solano Co FCWCD	1399	1226	1413	1545	1671	1580	1735	1725	1620	1592	1520	1394	18420	
North Bay Servi	**1907**	**1727**	**1962**	**2119**	**2188**	**1990**	**2177**	**2169**	**2176**	**2225**	**2039**	**1907**	**24586**	
Alameda Co WD	2977	2757	2977	3180	3287	3180	3287	3287	3180	2977	2290	2321	35700	
Santa Clara VWD	5200	3900	6000	6500	7500	8500	9000	9500	9400	8700	8000	7800	90000	
Zone-7 Alameda	1607	1537	1826	2384	3402	3841	4216	3986	2782	2288	1560	1571	31000	Entitlement
South Bay Servi	**9784**	**8194**	**10803**	**12064**	**14189**	**15521**	**16503**	**16773**	**15362**	**13965**	**11850**	**11692**	**156700**	
County of Kings	400	400	400	400	0	400	400	400	400	400	0	400	4000	Water Types Included
Devil's Den WD	254	381	762	1016	1270	2032	2286	2286	1143	508	381	381	12700	
Dudley Ridge WD	0	0	3675	2937	6499	10613	12990	11415	2560	2548	1020	1343	55600	101MCI ENT WT10
Empire WS ID	60	90	180	240	300	480	540	540	270	120	90	90	3000	111M GW ENT WT08
Kern County WA	15428	21493	66470	85344	143026	203269	200792	196348	89039	34376	25545	31170	1112300	131BYPS ENT WT59
Oak Flat WD	0	168	336	616	672	896	1008	1008	504	224	168	0	5600	151AGR ENT WT01
Tulare Lk BWSD	625	2271	1500	1800	5954	19442	19777	19782	12167	1300	5500	19782	109900	161A GW ENT WT22
San Joaquin Val	**16767**	**24803**	**73323**	**92353**	**157721**	**237132**	**237793**	**231779**	**106083**	**39476**	**32704**	**53166**	**1303100**	181BEN ENT WT46
														191VAL ENT WT47
Avek WA	1672	1993	3895	5530	6250	6735	7495	7720	5425	4070	2483	1732	55000	
Castaic Lake WA	1415	1415	1650	1986	2458	2458	2930	2930	2222	1986	1515	1515	24480	
Coachella Valley	1822	1822	1822	1822	1822	1822	1822	1822	1822	1822	1822	1831	21873	
Crestline-La WA	227	133	133	137	184	207	265	362	265	192	192	168	2465	
Desert WA	3041	3041	3041	3041	3041	3041	3041	3041	3041	3041	3041	3049	36500	
Littlerock CR	0	0	230	230	230	230	230	230	230	230	230	0	2070	
Metropolitan WD	65137	120137	101137	115137	115137	115137	125137	125137	125137	119137	116257	70000	1312627	
Mojave WA	0	0	0	0	0	0	60	60	60	60	60	60	360	
Palmdale WD	0	0	910	910	910	910	910	910	910	910	910	0	8190	
San Bernardino	2000	2000	2000	2000	3800	3800	3800	3800	3800	4800	3000	0	34800	
San Gabriel	0	0	0	1000	2000	2000	2000	2000	2000	2000	0	0	13000	
Ventura Co FCD	0	0	0	0	0	0	0	0	0	0	0	0	0	
Southern Calif	**75314**	**130541**	**114818**	**131793**	**135832**	**136340**	**147690**	**148012**	**144912**	**138248**	**129510**	**78355**	**1511365**	
Total State	**103847**	**165345**	**201067**	**238474**	**310099**	**391217**	**404992**	**399692**	**269162**	**194144**	**176198**	**145214**	**2999451**	
Dudley Ridge WD	4089	5478	0	0	0	0	0	0	0	0	0	0	9567	1988 Carryover
Kern County WA	30880	58510	0	0	0	0	0	0	0	0	0	0	89390	
Oak Flat WD	250	250	0	0	0	0	0	0	0	0	0	0	500	Water Types
Tulare Lk BWSD	10800	10800	0	0	0	0	0	0	0	0	0	0	21600	Included
San Joaquin Val	**46019**	**75038**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**121057**	
Total State	**46019**	**75038**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**121057**	291CYDV ENT WT69
														Wet Weather
Tulare Lk BWSD	26	2681	3000	595	0	0	537	328	0	0	1433	0	8600	Water Types
San Joaquin Val	**26**	**2681**	**3000**	**595**	**0**	**0**	**537**	**328**	**0**	**0**	**1433**	**0**	**8600**	Included
Total State	**26**	**2681**	**3000**	**595**	**0**	**0**	**537**	**328**	**0**	**0**	**1433**	**0**	**8600**	251WET WTHR WT07
Rec/Fish&WildLf	34	30	34	33	34	33	34	34	33	34	33	34	400	
South Bay Servi	**34**	**30**	**34**	**33**	**34**	**33**	**34**	**34**	**33**	**34**	**33**	**34**	**400**	
Fish & Game	20	20	30	80	90	190	240	230	210	50	20	20	1200	Entitlement Related
Parks & Recreat	3	3	5	6	11	26	26	26	26	20	8	3	163	
Rec/Fish&Wildlf	5	4	5	4	4	4	4	4	4	4	4	4	50	Water Types
San Joaquin Val	**28**	**27**	**40**	**90**	**105**	**220**	**270**	**260**	**240**	**74**	**32**	**27**	**1413**	Included
Rec/Fish&Wildlf	349	349	349	690	690	690	927	888	690	690	349	349	7010	601Rec/F&WL WT02
Southern Calif	**349**	**349**	**349**	**690**	**690**	**690**	**927**	**888**	**690**	**690**	**349**	**349**	**7010**	
Total State	**411**	**406**	**423**	**813**	**829**	**943**	**1231**	**1182**	**963**	**798**	**414**	**410**	**8823**	
Devil's Den WD	1496	1349	1438	364	0	0	774	674	0	0	0	1205	7300	Surplus
Empire WS ID	390	160	320	60	0	320	460	460	330	80	260	160	3000	
Kern County WA	0	0	0	0	0	0	0	0	0	0	0	0	0	Water Types
Oak Flat WD	0	57	211	400	600	300	332	0	0	0	0	0	1900	Included
Tulare Lk BWSD	35300	31000	18800	9300	5700	27300	26300	26600	11200	10400	4800	26800	233500	
San Joaquin Val	**37186**	**32566**	**20769**	**10124**	**6300**	**27920**	**27866**	**27734**	**11530**	**10480**	**5060**	**28165**	**245700**	331AGR SUR WT04
Total State	**37186**	**32566**	**20769**	**10124**	**6300**	**27920**	**27866**	**27734**	**11530**	**10480**	**5060**	**28165**	**245700**	
JG Boswell	0	1000	0	1000	1750	1750	2500	0	0	0	0	0	8000	Surplus Related
Shell Cal Prod	0	0	0	0	0	0	0	370	982	982	982	982	4298	Water Types
San Joaquin Val	**0**	**1000**	**0**	**1000**	**1750**	**1750**	**2500**	**370**	**982**	**982**	**982**	**982**	**12298**	Included
Total State	**0**	**1000**	**0**	**1000**	**1750**	**1750**	**2500**	**370**	**982**	**982**	**982**	**982**	**12298**	401Repaymt WT09
Solano Co FCWCD	275	275	275	785	1125	1270	1525	1525	1160	820	405	375	9815	Local
North Bay Servi	**275**	**275**	**275**	**785**	**1125**	**1270**	**1525**	**1525**	**1160**	**820**	**405**	**375**	**9815**	Water Types
Total State	**275**	**275**	**275**	**785**	**1125**	**1270**	**1525**	**1525**	**1160**	**820**	**405**	**375**	**9815**	Included
														681VAL PMT WT71

TABLE C
1989 INITIAL APPROVED WATER DELIVERIES
(Acre-Feet)

State of California
The Resources Agency
File ID: F1989AD

Department of Water Resources
State Water Project Analysis Office
Date: 12/05/88
Page: 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
County of Butte	50	50	120	70	70	90	170	200	170	90	60	60	1200	
Plumas Co FCWCD	25	30	41	75	99	144	159	159	159	40	35	34	1000	
Yuba City	0	0	0	0	0	0	500	600	300	100	0	0	1500	
Feather River 5	**75**	**80**	**161**	**145**	**169**	**234**	**829**	**959**	**629**	**230**	**95**	**94**	**3700**	
Napa Co FCWCD	508	501	549	574	517	410	442	444	556	633	519	513	6166	
Solano Co FCWCD	1399	1226	1413	1545	1671	1580	1735	1725	1620	1592	1520	1394	18420	
North Bay Servi	**1907**	**1727**	**1962**	**2119**	**2188**	**1990**	**2177**	**2169**	**2176**	**2225**	**2039**	**1907**	**24586**	
Alameda Co WD	2977	2757	2977	3100	3207	3100	3207	3207	3100	2897	2230	2321	35080	
Santa Clara VWD	5200	3900	6000	6500	7500	8500	9000	9500	9400	8700	8000	7800	90000	
Zone-7 Alameda	1607	1537	1793	2291	3220	3658	4018	3817	2775	2241	1560	1571	30088	Entitlement
South Bay Servi	**9784**	**8194**	**10770**	**11891**	**13927**	**15258**	**16225**	**16524**	**15275**	**13838**	**11790**	**11692**	**155168**	
County of Kings	400	400	400	400	0	400	400	400	400	400	0	400	4000	Water Types Included
Devil's Den WD	152	229	457	610	762	1219	1371	1371	686	305	229	229	7620	
Dudley Ridge WD	0	0	2205	1762	3899	6368	7794	6849	1536	1529	612	806	33360	101MCI ENT WT10
Empire WS ID	36	54	108	144	180	288	324	324	162	72	54	54	1800	111M GW ENT WT08
Kern County WA	10280	14279	42472	54165	90280	131008	128884	125191	57178	22249	16615	20059	712660	131BYPS ENT WT59
Oak Flat WD	0	101	202	370	403	538	605	604	302	134	101	0	3360	151AGR ENT WT01
Tulare Lk BWSD	375	1363	900	1080	3572	11666	11866	11869	7300	780	3300	11869	65940	161A GW ENT WT22
San Joaquin Val	**11243**	**16426**	**46744**	**58531**	**99096**	**151487**	**151244**	**146608**	**67564**	**25469**	**20911**	**33417**	**828740**	181BEN ENT WT46
														191VAL ENT WT47
Avek WA	1661	1862	3099	4316	4950	5389	6021	6246	4501	3454	2340	1717	45556	
Castaic Lake WA	1415	1415	1650	1986	2458	2458	2930	2930	2222	1986	1515	1515	24480	
Coachella Valley	1822	1822	1822	1822	1822	1822	1822	1822	1822	1822	1822	1831	21873	
Crestline-La WA	227	133	133	137	184	207	265	362	265	192	192	168	2465	
Desert WA	3041	3041	3041	3041	3041	3041	3041	3041	3041	3041	3041	3049	36500	
Littlerock CR	0	0	230	230	230	230	230	230	230	230	230	0	2070	
Metropolitan WD	65137	120137	101137	115137	115137	115137	125137	125137	125137	119137	116257	70000	1312627	
Mojave WA	0	0	0	0	0	0	60	60	60	60	60	60	360	
Palmdale WD	0	0	910	910	910	910	910	910	910	910	910	0	8190	
San Bernardino	2000	2000	2000	2000	3800	3800	3800	3800	3800	4800	3000	0	34800	
San Gabriel	0	0	0	1000	2000	2000	2000	2000	2000	2000	0	0	13000	
Ventura Co FCD	0	0	0	0	0	0	0	0	0	0	0	0	0	
Southern Calif	**75303**	**130410**	**114022**	**130579**	**134532**	**134994**	**146216**	**146538**	**143988**	**137632**	**129367**	**78340**	**1501921**	
Total State	**98312**	**156837**	**173659**	**203265**	**249912**	**303963**	**316691**	**312798**	**229632**	**179394**	**164202**	**125450**	**2514115**	
Dudley Ridge WD	4089	5478	0	0	0	0	0	0	0	0	0	0	9567	1988 Carryover
Kern County WA	30880	58510	0	0	0	0	0	0	0	0	0	0	89390	
Oak Flat WD	250	250	0	0	0	0	0	0	0	0	0	0	500	Water Types
Tulare Lk BWSD	10800	10800	0	0	0	0	0	0	0	0	0	0	21600	Included
San Joaquin Val	**46019**	**75038**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**121057**	
Total State	**46019**	**75038**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**121057**	291CYDV ENT WT69
Rec/Fish&WildLf	34	30	34	33	34	33	34	34	33	34	33	34	400	
South Bay Servi	**34**	**30**	**34**	**33**	**34**	**33**	**34**	**34**	**33**	**34**	**33**	**34**	**400**	
Fish & Game	20	20	30	80	90	190	240	230	210	50	20	20	1200	Entitlement Related
Parks & Recreat	3	3	5	6	11	26	26	26	26	20	8	3	163	
Rec/Fish&Wildlf	5	4	5	4	4	4	4	4	4	4	4	4	50	Water Types
San Joaquin Val	**28**	**27**	**40**	**90**	**105**	**220**	**270**	**260**	**240**	**74**	**32**	**27**	**1413**	Included
Rec/Fish&Wildlf	349	349	349	690	690	690	927	888	690	690	349	349	7010	601Rec/F&WL WT02
Southern Calif	**349**	**349**	**349**	**690**	**690**	**690**	**927**	**888**	**690**	**690**	**349**	**349**	**7010**	
Total State	**411**	**406**	**423**	**813**	**829**	**943**	**1231**	**1182**	**963**	**798**	**414**	**410**	**8823**	
Solano Co FCWCD	275	275	275	785	1125	1270	1525	1525	1160	820	405	375	9815	Local
North Bay Servi	**275**	**275**	**275**	**785**	**1125**	**1270**	**1525**	**1525**	**1160**	**820**	**405**	**375**	**9815**	Water Types
Total State	**275**	**275**	**275**	**785**	**1125**	**1270**	**1525**	**1525**	**1160**	**820**	**405**	**375**	**9815**	Included
														681VAL PMT WT71

Unscheduled water deliveries will be allowed when available by direct diversion from the Delta:

- If such water is in excess of approved delivery amounts,
- If electrical energy and excess pumping capacity are available,
- If delivery of unscheduled water will not adversely affect other deliveries or carryover storage, and
- If SWP reservoirs south of the Delta are projected to be fully recharged by the end of April. (This requirement does not apply to unscheduled water deliveries from the North Bay Aqueduct.)

Requests for Additional Entitlement Deliveries

Approvals of additional entitlement deliveries will not affect previously approved entitlement deliveries. Requests and approval of additional entitlement water may, however, cause one or more of the following:

- Reduced September 30, 1989 carryover storages in SWP reservoirs, which may require a higher SRI runoff in 1990 to provide a comparable level of deliver
- Delayed reinstatement of entitlement reductions
- Reduction of previously approved surplus water deliveries pursuant to provisions of the annual surplus water contracts
- Delayed approval of requests for additional surplus water deliveries
- Reduction of unscheduled water that otherwise would be available

Carryover Water

Requests have been made to defer until early 1989 the delivery of approximately 0.12 MAF of entitlement water which would have been delivered in October-December 1988. Because the Risk Analysis curve development procedure uses the October 1 through September 30 water year, the determination of water delivery capability for the corresponding calendar year is not significantly affected by this carryover of water. The carryover can be delivered in addition to the 2.51 MAF delivery approval. Carryover quantities are not shown on the 1989 Water Delivery Risk Analysis Curve (Figure 1).

TABLE D
SACRAMENTO RIVER INDEX FOR ENTIRE WATER YEAR
(Millions of Acre-Feet)

Year	Sacramento	Feather	Yuba	American	SRI
1993*	9.7	5.8	3.0	3.4	21.9
1992	5.2	1.9	0.9	0.9	8.9
1991	4.0	2.1	1.2	1.2	8.4
1990	4.8	2.1	1.2	1.1	9.2
1989	6.6	3.7	2.2	2.3	14.8
1988	5.4	2.0	0.9	0.9	9.2
1987	5.3	2.1	0.9	0.9	9.1
1986	10.9	6.7	3.5	4.6	25.7
1985	5.5	2.6	1.3	1.6	11.0
1984	9.5	5.8	3.2	3.9	22.4
1983	17.2	9.4	4.7	6.4	37.7
1982	13.3	9.0	4.9	6.1	33.3
1981	6.4	2.5	1.1	1.1	11.1
1980	9.7	5.5	3.2	3.9	22.3
1979	5.6	3.0	1.7	2.0	12.4
1978	12.0	5.7	3.0	3.2	23.9
1977	3.4	1.0	0.4	0.3	5.1
1976	4.8	1.8	0.7	0.8	8.1
1975	9.4	4.9	2.4	2.6	19.2
1974	15.9	8.4	4.0	4.3	32.5
1973	9.6	4.7	2.7	3.0	20.0
1972	6.6	3.2	1.7	1.9	13.4
1971	10.8	6.0	2.9	3.0	22.6
1970	11.7	6.3	2.9	3.2	24.1
1969	11.8	7.1	3.7	4.4	27.0
1968	6.9	3.5	1.6	1.7	13.6
1967	10.5	6.3	3.3	4.0	24.1
1966	7.3	2.9	1.4	1.4	12.9
1965	10.4	6.9	3.9	4.5	25.7
1964	5.2	2.6	1.5	1.6	10.9
1963	9.9	6.3	3.3	3.6	23.0
1962	7.5	3.7	1.9	2.1	15.1
1961	7.2	2.6	1.1	1.0	12.0
1960	6.5	3.2	1.7	1.7	13.1
1959	6.7	2.9	1.2	1.2	12.0
1958	15.1	7.0	3.5	4.1	29.7
1957	7.2	3.6	2.0	2.1	14.9
1956	13.3	8.0	4.0	4.6	29.9
1955	5.7	2.5	1.3	1.6	11.0
1954	9.3	4.2	1.9	2.0	17.4
1953	9.7	5.2	2.6	2.7	20.1
1952	11.5	8.0	4.1	5.0	28.6
1951	9.1	5.7	3.5	4.6	22.9
1950	5.7	3.8	2.2	2.7	14.4
1949	6.0	2.6	1.5	1.9	12.0
1948	7.7	3.9	2.0	2.2	15.8
1947	5.1	2.5	1.4	1.4	10.4

TABLE D (Continued)
SACRAMENTO RIVER INDEX FOR ENTIRE WATER YEAR
(Millions of Acre-Feet)

Year	Sacramento	Feather	Yuba	American	SRI
1946	8.2	4.2	2.4	2.9	17.6
1945	6.7	3.7	2.1	2.5	15.1
1944	4.7	2.9	1.4	1.5	10.4
1943	8.5	5.6	3.1	3.9	21.1
1942	11.3	6.7	3.4	3.9	25.2
1941	14.3	6.5	3.1	3.1	27.1
1940	10.5	5.7	2.9	3.4	22.4
1939	4.4	1.9	0.9	1.0	8.2
1938	14.7	8.6	4.0	4.5	31.8
1937	6.0	3.2	1.9	2.3	13.3
1936	7.1	4.3	2.6	3.4	17.4
1935	7.5	4.3	2.2	2.6	16.6
1934	4.5	2.0	1.0	1.1	8.6
1933	4.6	2.0	1.1	1.3	8.9
1932	5.1	3.3	2.1	2.6	13.1
1931	3.3	1.4	0.6	0.7	6.1
1930	6.1	4.0	1.8	1.7	13.5
1929	4.4	1.8	1.0	1.1	8.4
1928	7.6	4.2	2.4	2.5	16.8
1927	11.0	5.7	3.5	3.7	23.8
1926	5.7	3.1	1.6	1.4	11.8
1925	8.1	3.1	2.1	2.7	16.0
1924	3.3	1.3	0.6	0.5	5.7
1923	5.3	3.1	2.1	2.8	13.2
1922	6.7	5.1	3.0	3.3	18.0
1921	11.5	6.0	3.2	3.2	23.8
1920	4.2	2.2	1.3	1.5	9.2
1919	7.8	3.6	2.0	2.2	15.7
1918	5.4	2.7	1.3	1.5	11.0
1917	7.1	4.7	2.5	2.9	17.3
1916	10.7	6.2	3.3	3.9	24.1
1915	12.6	5.4	2.7	3.2	23.9
1914	13.7	7.0	3.1	4.0	27.8
1913	7.0	2.8	1.5	1.5	12.8
1912	6.6	2.3	1.2	1.3	11.4
1911	10.1	7.1	3.6	5.6	26.4
1910	9.1	4.6	2.8	3.6	20.1
1909	14.6	7.5	4.0	4.6	30.7
1908	7.9	3.6	1.7	1.5	14.8
1907	13.9	9.5	4.5	5.8	33.7
1906	11.3	6.9	3.7	4.8	26.7

Notes: * Refers to 1993 forecast for SRI, C-DWR May 1, 1993.
1. California cooperative snow surveys full natural flows.
2. Data 1986 and later are preliminary.
3. Stations are as follows: Sacramento River above Bend Bridge, near Red Bluff; Inflow to Oroville Reservoir; Yuba River at Smartville; Inflow to Folsom Reservoir.

TABLE E
SACRAMENTO RIVER INDEX FOR ENTIRE WATER YEAR
Listed in Ascending Order
(Millions of Acre-Feet)

Year	Sacramento	Feather	Yuba	American	SRI
1977	3.4	1.0	0.4	0.3	5.1
1924	3.3	1.3	0.6	0.5	5.7
1931	3.3	1.4	0.6	0.7	6.1
1976	4.8	1.8	0.7	0.8	8.1
1939	4.4	1.9	0.9	1.0	8.2
1991	4.0	2.1	1.2	1.2	8.4
1929	4.4	1.8	1.0	1.1	8.4
1934	4.5	2.0	1.0	1.1	8.6
1992	5.2	1.9	0.9	0.9	8.9
1933	4.6	2.0	1.1	1.3	8.9
1987	5.3	2.1	0.9	0.9	9.1
1990	4.8	2.1	1.2	1.1	9.2
1988	5.4	2.0	0.9	0.9	9.2
1920	4.2	2.2	1.3	1.5	9.2
1947	5.1	2.5	1.4	1.4	10.4
1944	4.7	2.9	1.4	1.5	10.4
1964	5.2	2.6	1.5	1.6	10.9
1955	5.7	2.5	1.3	1.6	11.0
1918	5.4	2.7	1.3	1.5	11.0
1985	5.5	2.6	1.3	1.6	11.0
1981	6.4	2.5	1.1	1.1	11.1
1912	6.6	2.3	1.2	1.3	11.4
1926	5.7	3.1	1.6	1.4	11.8
1949	6.0	2.6	1.5	1.9	12.0
1961	7.2	2.6	1.1	1.0	12.0
1959	6.7	2.9	1.2	1.2	12.0
1979	5.6	3.0	1.7	2.0	12.4
1913	7.0	2.8	1.5	1.5	12.8
1966	7.3	2.9	1.4	1.4	12.9
1960	6.5	3.2	1.7	1.7	13.1
1932	5.1	3.3	2.1	2.6	13.1
1923	5.3	3.1	2.1	2.8	13.2
1937	6.0	3.2	1.9	2.3	13.3
1972	6.6	3.2	1.7	1.9	13.4
1930	6.1	4.0	1.8	1.7	13.5
1968	6.9	3.5	1.6	1.7	13.6
1950	5.7	3.8	2.2	2.7	14.4
1989	6.6	3.7	2.2	2.3	14.8
1908	7.9	3.6	1.7	1.5	14.8
1957	7.2	3.6	2.0	2.1	14.9
1945	6.7	3.7	2.1	2.5	15.1
1962	7.5	3.7	1.9	2.1	15.1
1919	7.8	3.6	2.0	2.2	15.7
1948	7.7	3.9	2.0	2.2	15.8
1925	8.1	3.1	2.1	2.7	16.0
1935	7.5	4.3	2.2	2.6	16.6
1928	7.6	4.2	2.4	2.5	16.8

TABLE E (Continued)
SACRAMENTO RIVER INDEX FOR ENTIRE WATER YEAR
Listed in Ascending Order
(Millions of Acre-Feet)

Year	Sacramento	Feather	Yuba	American	SRI
1917	7.1	4.7	2.5	2.9	17.3
1936	7.1	4.3	2.6	3.4	17.4
1954	9.3	4.2	1.9	2.0	17.4
1946	8.2	4.2	2.4	2.9	17.6
1922	6.7	5.1	3.0	3.3	18.0
1975	9.4	4.9	2.4	2.6	19.2
1973	9.6	4.7	2.7	3.0	20.0
1953	9.7	5.2	2.6	2.7	20.1
1910	9.1	4.6	2.8	3.6	20.1
1943	8.5	5.6	3.1	3.9	21.1
1993*	9.7	5.8	3.0	3.4	21.9
1980	9.7	5.5	3.2	3.9	22.3
1984	9.5	5.8	3.2	3.9	22.4
1940	10.5	5.7	2.9	3.4	22.4
1971	10.8	6.0	2.9	3.0	22.6
1951	9.1	5.7	3.5	4.6	22.9
1963	9.9	6.3	3.3	3.6	23.0
1921	11.5	6.0	3.2	3.2	23.8
1927	11.0	5.7	3.5	3.7	23.8
1915	12.6	5.4	2.7	3.2	23.9
1978	12.0	5.7	3.0	3.2	23.9
1970	11.7	6.3	2.9	3.2	24.1
1967	10.5	6.3	3.3	4.0	24.1
1916	10.7	6.2	3.3	3.9	24.1
1942	11.3	6.7	3.4	3.9	25.2
1965	10.4	6.9	3.9	4.5	25.7
1986	10.9	6.7	3.5	4.6	25.7
1911	10.1	7.1	3.6	5.6	26.4
1906	11.3	6.9	3.7	4.8	26.7
1969	11.8	7.1	3.7	4.4	27.0
1941	14.3	6.5	3.1	3.1	27.1
1914	13.7	7.0	3.1	4.0	27.8
1952	11.5	8.0	4.1	5.0	28.6
1958	15.1	7.0	3.5	4.1	29.7
1956	13.3	8.0	4.0	4.6	29.9
1909	14.6	7.5	4.0	4.6	30.7
1938	14.7	8.6	4.0	4.5	31.8
1974	15.9	8.4	4.0	4.3	32.5
1982	13.3	9.0	4.9	6.1	33.3
1907	13.9	9.5	4.5	5.8	33.7
1983	17.2	9.4	4.7	6.4	37.7

Notes: * Refers to 1993 forecast for SRI, C-DWR May 1, 1993.
1. California cooperative snow surveys full natural flows.
2. Data 1986 and later are preliminary.
3. Stations are as follows: Sacramento River above Bend Bridge, near Red Bluff; Inflow to Oroville Reservoir; Yuba River at Smartville; Inflow to Folsom Reservoir.

APPENDIX C

CALIFORNIA WATER CODE:
WATER SHORTAGE EMERGENCIES

SECTIONS 350-358 OF THE WATER CODE, "WATER SHORTAGE EMERGENCIES"

Section 350: The governing body of a distributor of a public water supply, whether publicly or privately owned and including a mutual water company, may declare a water shortage emergency condition to prevail within the area served by such distributor whenever it finds and determines that the ordinary demands and requirements of water consumers cannot be satisfied without depleting the water supply of the distributor to the extent that there would be insufficient water for human consumption, sanitation, and fire protection.

Section 351: Excepting in event of a breakage or failure of a dam, pump, pipe line or conduit causing an immediate emergency, the declaration shall be made only after a public hearing at which consumers of such water supply shall have an opportunity to be heard to protest against the declaration and to present their respective needs to said governing board.

Section 352: Notice of the time and place of hearing shall be published pursuant to Section 6061 of the Government Code at least seven days prior to the date of hearing in a newspaper printed, published, and circulated within the area in which the water supply is distributed, or if there is no such newspaper, in any newspaper printed, published, and circulated in the county in which the area is located.

Section 353: When the governing body has so determined and declared the existence of an emergency condition of water shortage within its service area, it shall thereupon adopt such regulations and restrictions on the delivery of water and the consumption within said area of water supplied for public use as will in the sound discretion of such governing body conserve the water supply for the greatest public benefit with particular regard to domestic use, sanitation, and fire protection.

Section 354: After allocating and setting aside the amount of water which in the opinion of the governing body will be necessary to supply water needed for domestic use, sanitation, and fire protection, the regulations may establish priorities in the use of water for other purposes and provide for the allocation, distribution, and delivery of water for such other purposes, without discrimination between consumers using water for the same purpose or purposes.

Section 355: The regulations and restrictions shall thereafter be and remain in full force and effect during the period of the emergency and until the supply of water available for distribution within such area has been replenished or augmented.

Section 356: The regulations and restrictions may include the right to deny applications for new or additional service connections, and provision for their enforcement by discontinuing service to consumers willfully violating the regulations and restrictions.

Section 357: If the regulations and restrictions on delivery and consumption of water adopted pursuant to this chapter conflict with any law establishing the rights of individual consumers to receive either specific or proportionate amounts of the water supply available for distribution within such service area, the regulations and restrictions adopted pursuant to this chapter shall prevail over the provisions of such laws relating to water rights for the duration of the period of emergency; provided, however that any distributor of water which is subject to regulation by the State Public Utilities Commission shall before making such regulations and restrictions effective secure the approval thereof by the Public Utilities Commission.

Section 358: Nothing in this chapter shall be construed to prohibit or prevent review by any court of competent jurisdiction of any finding or determination by a governing body of the existence of an emergency or of regulations or restrictions adopted by such board, pursuant to this chapter, on the ground that any such action is fraudulent, arbitrary, or capricious.

Source: C-DWR, 1977

APPENDIX D

NEEDED CHANGES IN WATER MANAGEMENT

Part 1. State and Federal Government Perspective
Part 2. Urban Perspective
Part 3. Agricultural Perspective
Part 4. Environmental Perspective
Part 5. Point of View of Other Parties

PART 1. STATE AND FEDERAL GOVERNMENT PERSPECTIVE

1. Society should establish priorities for evaluating alternative uses of water during droughts. In times of shortages, certain uses of water may be sacrificed.
2. The state has to look at water pricing and eliminate the existing large differences in the cost of water to different users. Because of price differences, some areas/users waste water, while others conserve.
3. We need to refill about 8 million acre-feet of empty aquifers in California (subsidence, reserve for future droughts).
4. The reservoir operations need to be improved; multireservoir systems should be optimized to include incidental uses (recreation, fisheries).
5. An effort is needed to manage groundwater at all levels. Conjunctive use of groundwater can relieve the adverse effects of the groundwater overdraft (conjunctive use needs to be expanded in California).
6. Remove federal restrictive policies to wheel nonproject water.
7. The cost of saving the environment has to be evaluated, and water for the environment has to be made available at taxpayer cost.
8. COE should handle a small loan program to assist small local communities during drought.
9. Federal government should set quotas for U.S. immigration because 75 percent of new immigrants wind up in California.
10. Greater centralization is needed to manage water in California.
11. Groundwater recharge projects have to be developed to enhance natural recharge rates, and also more surface water should go into recharge during the times of high flow.
12. Fish and Wildlife needs more equitable basis in water allocation so it can share water similar to that received by project users.
13. The state needs to develop a mechanism that triggers drought response actions (such as the Water Bank) automatically without a lengthy and contentious legislative process.
14. There is a need for political recognition to deal with protection of natural resources so that impacts to fish and wildlife are lessened in the future.
15. Changes in water laws have to be made to recognize in-stream water rights.
16. More goodwill, professionalism, and supportive legislation are needed to restore and maintain environmental resources.
17. Media needs to reveal what is happening in agriculture (full spectrum of impacts and what it means to California to shut down farming in the state).
18. The Warren Act restricting water movement should be revoked.
19. Make the federal and state bureaucracies work together better to smooth out operations during drought.
20. The rights have to be better defined to groundwater.
21. The media should put more emphasis on the environmental and regulatory concerns rather than concentrating on state agencies only.
22. The media should inform the public about the trade-offs being made during a drought.
23. Make risk assessments associated with the effects of spills and flood releases on fisheries.
24. Society needs to decided on what it wants.

25. In-stream flow standards and estuarine water quality standards need to be reassessed.
26. All beneficial uses of water should be treated equally.
27. Water management should combine resource values with economic principles to satisfy amount of water the customer wants.
28. California should cut down on the amount of firm hydroelectric production (i.e., during drought) to make water available for environmental and other purposes.
29. Water industry should use a more rigorous analytical process in its water management decision-making process.
30. The state should look into groundwater regulation (after 1977 the aquifers recovered in level but not in volume).
31. Large groundwater basins in San Joaquin Valley should be adjudicated possibly through self-regulation.
32. Agricultural districts should adjust their water delivery schedules to fit the water-conserving farming practices.
33. Agricultural conservation should be enhanced through continued research and development, advising and educating farmers on how to use less water, what kinds of machinery to use, how to manage labor, and overall increase in agricultural technical support services.
34. Build coding towers on thermal power plants to minimize thermal pollution during drought.
35. Better coordination is needed between energy conservation programs and water conservation programs, (e.g., showerheads—water, energy; toilets ULF—water, energy, sanitation).
36. Water industry needs to remove subsidies and market water.
37. There should be fewer players in California water management (now there are too many).
38. The decisions on the operation of SWP should be made by the Director of C-DWR, not the Governor.
39. SWP needs to build new facilities much faster than they are currently being built.
40. A better method to allocate the supply is needed. The existing rule curve is not workable.
41. New legislation and more institutional cooperation will be needed to make water marketing and transfers a viable alternative to more water development.
42. SWP should become a quasi-governmental agency (or corporation) instead of being a part of C-DWR.
43. Changes in water allocation in California need to be made.
44. Environmental standards must be revised.
45. More effort should be put into balancing in-stream and off-stream uses of water by SWRCB.
46. A way of moving water through the Delta should be found to satisfy the purveyors and environmental groups and to protect the resources in the Delta.
47. More emphasis should be placed on conjunctive use of surface water and groundwater.
48. The various impacts of drought (both short-term and long-term) should be quantified.

PART 1. STATE AND FEDERAL GOVERNMENT PERSPECTIVE (Continued)

49. California needs additional water supply to deal with the expanding population.
50. Water supply planning should not be used as a means of suppressing population growth, because it does not work.
51. The most immediate need in water management is to resolve the Delta issues, even if agriculture and urban sectors will have to lose some water to the environment.
52. Population growth in California has to be stabilized.
53. An unbiased state water policy is needed for responding to drought emergencies.
54. Appropriate measures of water supply reliability need to be institutionalized.
55. More emphasis should be placed on water conservation and recycling.
56. Water districts should pursue conjunctive use programs and groundwater recharge programs in order to eliminate groundwater overdraft.
57. Special interest groups representing agricultural, urban, and environmental sectors should reach a consensus and stop blocking the actions of each other.
58. Water marketing should be expanded, with provisions for not creating externalities that affect the environment.
59. It is important to fix the Delta, because it is a major water transfer hub.
60. Off-stream storage south of the Delta is needed as a part of the solution to the Delta's problems.
61. The Three-Way Process should seek help in employing alternative dispute resolution techniques (ADR) to reach a consensus.
62. More conservation technology and know-how should be infused into the California agriculture.
63. A system of adequate economic incentive should be developed to encourage more farmers to adopt innovative and efficient irrigation technologies and practices.
64. Irrigation districts should revise their schedules for delivering water to individual farmers to allow for optimum application of water.

PART 2. URBAN PERSPECTIVE

1. There should be clear long-term carry-over storage goals (e.g., two-year supply on July 1).
2. Water districts should build interconnections to aqueducts.
3. A pipeline should be built to take reclaimed water from the Bay area to Central Valley, where it could be used for irrigation and groundwater recharge.
4. Marginal cost pricing of water should be incorporated into water policy.
5. Need to abandon irrational policies. Instead of rationing, water should be bought through the Water Bank.
6. A sophisticated economic way of drought management should be developed.
7. Massive education programs have to be implemented to educate the public on water issues and droughts.
8. The water industry should be deregulated, and the market forces should determine the price of water.
9. Water suppliers should prepare for the worst-case scenario during a drought and be ready for desalination.
10. The state of California needs to talk and do some thinking ahead, look at issues collectively.
11. Urban customers need to be advised on the meaning of "cutting down by 20 percent"; people need to read their meters; too much savings is bad for revenue.
12. Better communication with the public is needed, especially when the agency is in a crisis mode.
13. California should think of appointing a water czar with the power to cut across sociopolitical barriers and other types of problems.
14. Media should increase public service announcements to encourage conservation.
15. Improve the reliability of urban water supplies.
16. Planning for drought protection should seek long-term optimality.
17. Develop institutions for administering water marketing and water transfers and for protecting third parties.
18. Communication and cooperation between state and federal agencies should be improved.
19. Local water agencies should join in public information programs because of the "news shed effect" to save money and minimize confusion (act jointly and use common definitions).
20. Water professionals should improve their ability to clearly communicate their situation and decisions to the media.
21. State and federal government should determine the priorities of different uses of water during drought.
22. State and federal government should get rid of constraints that prevent water transfers during drought.
23. Long-term water supply plans should have an optimal level of drought protection built into them.
24. More emphasis should be placed on practices with supply flexibility such as marketing and water transfer agreements.

PART 2. URBAN PERSPECTIVE (Continued)

25. Contracts for CVP and SWP water have to be rewritten so that appropriate response actions can be taken earlier during a drought cycle.
26. The general public should be educated to stop believing that a drought is not an excuse for water shortages.
27. SWP and CVP should not be governed by the mandate to serve water for municipal, industrial, and agricultural uses; they also need to protect the environmental uses.
28. Urban water suppliers should address environmental problems and improve environmental conditions of aquatic resources, because it is in their self-interest.
29. Reclamation and reuse of water should be looked at, and the existing barriers and institutional impediments should be removed.
30. Some degree of political involvement is needed in making water supply policies at the county, city, and local water district boards. The policymaking should not be made by shortsighted technicians.
31. Agricultural interests should educate the farmers on how to deal with environmental and urban sectors through consensual ways.
32. There has to be some degree of regulation in water transfers to minimize third-party impacts.
33. Water Bank should be set up for normal supply year operations.
34. The state should set clear standards for the use of greywater and the design of dual water systems to guide the local health departments.
35. Groundwater aquifers have to be better mapped throughout the state.
36. Regulatory agencies should not only look after environmental needs but also consider the needs of water users.
37. Urban, environmental, and agricultural interests should make more efficient use of the water resources that they have.
38. Drought surcharge should be used in the future as a water-rationing mechanism instead of the percent reduction or other rationing plans unaccompanied by price incentives.
39. North and south as well as agriculture, urban areas, and environmental interests should work together to build a water policy consensus.
40. Urban and other utility customers should be charged by separate bills for water, sewer, electricity, and trash.
41. Rationing plans in the future should give urban customers certain amounts of water and let them decide which uses have to be curtailed.
42. Rationing and pricing should always be used together to avoid revenue problems.
43. Urban areas need more flexibility in supplying water (e.g., more supply sources).
44. Overdraft of groundwater sources during normal weather should be avoided in order to have that option for drought.

PART 3. AGRICULTURAL PERSPECTIVE

1. Water districts need to communicate better and more accurately water needs, available supplies, shortages (to media, civic leaders, processors of crops).
2. People need to be educated about water needs, available supplies, and shortages to correct perceptions about water uses.
3. Need groundwater banking, off-stream storage facilities in the Delta (10 years from now another drought; demands will go up and things will be worse).
4. A Water Bank Office should be created independently of C-DWR as a broker and a streamlined approval process for water transfers should be developed.
5. The Endangered Species Act has to be modified. It requires impossible things (barriers, mitigation), and it is not well thought out.
6. Water managers should be allowed to do their job without bringing the public into the decision-making process (it's unproductive).
7. The environmental constraints on Delta exports have to be reviewed, since more developed water, more flows, and more exports are needed.
8. There is a great need for consensus building, the Three-Way Process and the state water plan (Governor) have achieved a lot.
9. Something has to be done to improve the efficiency of transferring water through the Delta through a joint effort.
10. A computer data bank containing water-planning and management information should be developed, continually updated, and made available to water agencies.
11. Interconnections are a must, and all water districts should get these put in place.
12. More water should be stored either in the ground or in reservoirs.
13. Irrigation districts have to communicate better to the public the purposes for which they use water and the efficiencies in use that they achieve.
14. More water storage facilities should be built and water supply infrastructure should be expanded.
15. Bureau of Reclamation should build some safety valves into their operations and give the Secretary of the Department of the Interior discretionary emergency powers to deal with unexpected situations.
16. The general public in California needs to be educated to understand why it takes so much water to grow food, that farmers do not waste water, and that the farmers do not destroy the environment and cause pollution but are concerned about the status of wildlife and fisheries and want to see these resources restored.
17. The Three-Way Process should be used as an instrument to find a solution to the Delta problem, since the political process has failed to achieve its goal.
18. CVP should be transferred to the state so that California could determine its fate through an integrated management of developed water.
19. Agricultural water districts should learn from Westlands Water District about water management and water efficiency techniques.
20. There is a need for national and state policy on food production.
21. Agricultural water districts should be prepared to change their role during drought from one of helping farmers to grow crops to one that is more of a regulator that restricts water usage and acts more like a police force.

PART 4. ENVIRONMENTAL PERSPECTIVE

1. Long-term solutions should be sought instead of implementing ad hoc decisions during a drought.
2. Long-term planning should focus on alternatives such as conjunctive use, in-stream flow, water banking, and off-stream storage.
3. The institutional barriers to water transfers should be removed. These barriers include issues such as, who owns the water, the district or farmers, the question of federal subsidies, and inflexible legislation such as the Warren Act.
4. Efficiency of agricultural water districts with very cheap subsidized water has to be improved. A fundamental skepticism exists about water users doing the right thing when inefficiencies are allowed to continue indefinitely.
5. SWP and CVP should make early cuts in water deliveries and maintain more water in storage in order to make drought progressively worse, but at the same time not allow severe impacts to take place.
6. Better planning in anticipating prolonged drought is needed. The last-minute creation of the Water Bank is a peculiar way to manage water.
7. A more flexible system of water management is needed. There needs to be more equity and fairness so that environment does not suffer the most.
8. Standards generally set are not adequate to protect the environment. Locally it will be best to set baseline standards and supplement them by mitigation of environmental impacts.
9. There needs to be more optimization in operating major projects.
10. We need to be able to reallocate water rights into a fairer system to make allocation of short supplies more equitable.
11. Environmental impacts need greater public recognition, and we must find more equitable ways of protecting the environment. Long-term strategies are needed.
12. Urban areas should build in resiliency through conservation and water reclamation to prepare for a 10-15 year-long drought in the future.
13. In the agricultural-urban-environmental process, people who sit at the negotiating table should convince their constituencies of the reasons for the decisions taken.
14. Water reclamation should be a part of long-term water supply strategies.
15. A holistic approach to water management is needed. (Urban runoff should be captured and infiltrated.)
16. More conjunctive use of surface-water and groundwater should be made.
17. General policy reform and consensual solutions should be emphasized in trying to change water management in California.
18. Water resources should be managed better for the environment as well as for other purposes of use.
19. Central coordination of water management is needed.
20. The quality of the tributaries in the upstream portions of the major rivers needs to be improved.
21. Firm supplies of water are needed for the existing wetlands as well as more wetlands.
22. Media should try to understand the long-term changes that are needed to avoid future drought emergencies in the state.

PART 4. ENVIRONMENTAL PERSPECTIVE (Continued)

1. Developing and passing new legislation during water emergencies should be avoided because it is usually "too hasty" and does not produce solid laws and regulations.
2. A water fund should be established to purchase water for environmental purposes.
3. Changes in the existing water law should be made because these changes are critical to realizing the full benefits of the structural and nonstructural solutions to California water problems.
4. C-DWR should be divided into two parts—State Water Project and State Water Resources.
5. More sophisticated water planning is needed at the local and regional levels of government and water institutions.
6. More studies on water supply reliability conservation, reclamation, and other alternatives should be undertaken.
7. Continuing work on water transfers is needed.
8. More work on groundwater storage is needed.
9. The Delta should be fixed to work better not only for the environment but also for its overall enhancement.
10. Water institutions should be reformed and created that would not discriminate against the environment.
11. The Governor needs to "twist [the] arms" of the agricultural sector in order to make the Three-Way Process happen.
12. The risk of mismanaging the existing and new water supply facilities to benefit only particular interests (mostly urban) must be removed by reforming water laws and water institutions.
13. In the Delta, along with the improved reliability of urban supplies, environment should be brought along, and all water use purposes should be optimized to achieve better water quality in the Delta.

PART 5. POINT OF VIEW OF OTHER PARTIES

1. There should be more cooperation between urban water providers and the "green industry."
2. The benefits of turf and urban landscaping on urban environment (air quality) should be assessed and articulated to the public.
3. Landscape contractors should be educated on efficient use of water, and a licensing process should be established and enforced.
4. More data about dry-year hydrology should be acquired.
5. Anglers should be restricted; they are reaching spots in rivers and reservoirs that normally cannot be reached. Salmon are depleted by fishing pressures.
6. The state should assist the "green industry" in achieving more efficient use of water for urban landscapes by (1) establishing licensing and enforcing it, (2) passing laws to encourage more efficient landscapes, and (3) educating landscapers and the public about conservation in outdoor water use.
7. Water discharged from cooling towers in commercial buildings should be captured and used for landscape irrigation on-site.
8. All water use must be measured, and people should learn how to read their water meters.
9. Rationing plans should be based on a reasonable allocation of water amounts and combined with inverted block rate structures to force urban users to use water efficiently during droughts.

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This report is part of the National Study of Water Management During Drought conducted by the Institute for Water Resources, U.S. Army Corps of Engineers. This report describes the lessons learned of the six-year California drought (1987-1992). The lessons are aimed at improving the management of water resources during future droughts in California and other states throughout the nation. These lessons capture the views of some 100 interviewed participants representing 57 organizations in California that manage or influence the management of water. The participating organizations represented Federal, state, regional, and local water supply agencies as well as environmental, private, and governmental entities that influence water management in the state.

The California drought experience provided the water community with many important lessons. Some of these have been learned and acted upon during the later stages of the drought. Other lessons are yet to be confirmed and are presented in this report as recommendations of the survey participants for water management initiatives and reforms.

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