Recent California Water Transfers: Emerging Options in Water Management

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Abbreviation	Meaning
AEWSD	Arvin-Edison Water Storage District
BuRec	U.S. Bureau of Reclamation
CCWD	Contra Costa Water District
CVP	Bureau of Reclamation Central Valley Project
DFG	California State Department of Fish and Game
DWR	California State Department of Water Resources
EBMUD	East Bay Municipal Utility District
IID	Imperial Irrigation District
KCWA	Kern County Water Agency
MAF	million acre-feet
MGD	million gallons per day
MWD	Metropolitan Water District of Southern California
SCVWA	Santa Clara Valley Water Agency
SCWA	Solano County Water Agency
SFWD	San Francisco Water Department
SID	Solano Irrigation District
SRI	Sacramento River Flow Index
SRWCA	Sacramento River Water Contractors Association
SWP	California State Water Project (DWR)
SWRCB	State of California Water Resources Control Board
TCCA	Tehama-Colusa Canal Authority
WA	Water Agency
WD	Water District
WWD	Westlands Water District
YCFCWCD	Yolo County Flood Control and Water Conservation District
YCWA	Yuba County Water Agency

Preface

Engineers learn from disasters. In this regard, droughts are easy to learn much from, particularly in the arid West where droughts endure long enough that water managers have opportunities and motivation to test innovative water management strategies.

With literally thousands of water suppliers in the state and six years of current drought experience, California water managers have learned much about drought and drought management. We expect that each California water provider has learned at least one new lesson about water management from this drought. This report cannot approach a complete collection and digest of these lessons learned from the current drought. Indeed, this might even be premature, since the individual agencies have not yet completed this drought experience nor had time to integrate these experiences into their future plans. The current California drought has been full of surprises, and we may be surprised yet again, both in the hydrology of the drought and in innovations in drought management. At the time of this writing, the drought is not over and each agency's lesson book is still in draft form.

This report is focussed on a narrow aspect of recent lessons learned from California drought management, that of water transfers. Just as droughts in the 19th and early 20th centuries spawned water storage reservoirs and droughts in the middle to late part of this century motivated consideration of urban water conservation, it seems likely that this current California drought will show the utility and versatility of water transfers. And just as reservoirs and water conservation have become integrated in many complex ways into the operations and plans of many existing water systems, we would like to demonstrate that water transfers offer similar potential for diverse application and integration with other now-traditional water management techniques. The use of transfers in water supply planning and management is no longer mere theory, but has become practice in many parts of California.

As this report goes to press, the President has signed legislation which is likely to lead to sweeping changes in the operation of the Central Valley Project in California. Among the many important changes, some major provisions of this legislation are designed to facilitate the voluntary and compensated transfer of water to those currently outside the Central Valley Project as well as within the project itself. This last-minute item illustrates the changing nature of water transfers, their increasing importance, and the role of government in their adoption and use.

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Summary

This study examines the recent use of water transfers in California. The study's particular emphasis is on the use of water transfers during the current drought and how planners and operators of federal, state, and local water systems can integrate water transfers into the planning and operations of their systems. Through the California experience, the study identifies many motivations for incorporating water transfers into water supply systems, reviews a variety of water transfer types, and discusses the integration of water transfers with traditional supply augmentation and water conservation measures. Some limitations, constraints, and difficulties for employing water transfers within existing systems are also discussed. The study focuses primarily on the technical, planning, and operational aspects of water transfers, rather than the legal, economic, and social implications which have received extensive attention elsewhere.

Transfers and New Choices in Water Management

Historically, advances in water system management have been motivated by socio-economic and environmental considerations. Since the 1970s, the increasing expense and environmental impact of new traditional water supplies (e.g., reservoirs) has motivated innovative use of existing facilities (e.g., conjunctive use and pumped storage schemes) and increased demand management efforts. In recent years, continued growth in water demands and increasing environmental concerns have caused even these innovations to yield "diminishing marginal returns." These economic and environmental conditions, combined with recent droughts, have motivated further efforts to improve traditional supply augmentation and demand management measures and have motivated the recent use and consideration of water transfers. The use of water transfers in California can be seen as a natural development of the water resources profession which is seeking to explore and implement a new approach in water management.

Water transfers have long been a part of water management in many metropolitan areas and irrigation districts. However, these transfers have typically involved parties within the same water use sector, i.e., urban-to-urban or irrigator-to-irrigator transfers and were typically executed between nearby parties, often under the jurisdiction of one water agency using a single water conveyance system.

More recent interest in water transfers has been for achieving economic and relatively equitable allocation of water between users, particularly during water-short conditions. This concept requires extending water transfers to include transfers between different water use sectors. This implies the involvement of many parties with diverse views, facilities, and water demands which are more geographically separated, requiring the use of conveyance and storage systems controlled by other parties. The controversies and complexities of effecting water transfers under these conditions may have initially deterred water managers from pursuing this management option. However, in light of the changing economic and policy environment of water management, the recent experience in California shows water transfers to be a valuable component in water management which offers planners and managers a new choice for enhancing the performance and flexibility of their systems.

Legal and economic theories of water transfers have been discussed extensively for over thirty years. This literature identifies some economic and environmental advantages of water transfers over more traditional forms of management. However, pure theory alone cannot change the use and movement of water.

There has been little systematic examination of the engineering and operational aspects of water transfers. Instead, the mechanics of economically effecting actual water transfers has fallen on the ingenuity of actual system planners and operators. Their tasks are non-trivial, including the operation of complex storage and conveyance systems to meet multiple urban, agricultural, and environmental demands over a range of uncertain hydrologic conditions. These

engineering tasks require rethinking in light of the special opportunities and problems posed by water transfers. The ultimate success of water transfers is to achieve economically the actual delivery of water. This requires the engineering integration of water transfers with more traditional water management.

The experiences with the many forms of water transfer recently employed in California offer an opportunity for developing these neglected technical aspects of water transfers.

Water Transfers in California

California's unique hydrologic conditions form the basis of an elaborate water resource system. California's water supplies are poorly distributed in both time and space. The principal water sources are in the northern and eastern mountains, but the greatest demands occur in the southern and western regions. With a Mediterranean climate, California's precipitation also falls predominantly in the winter, with dry summers during the period of major agricultural and urban demands. As a semi-arid region, California is also prone to multi-year droughts. The water-related infrastructure, institutions, and legislation which have evolved, as well as the conflicts and antagonisms which have arisen over the years, can be traced to these severe imbalances of supply and demand. The physical and human infrastructure developed by State, Federal, and local governments and the private sector has created a highly integrated and intricate water resources system which can store and distribute large quantities of water. This vast system is governed by a large number of diverse water management agencies which, in turn, are governed by a complex set of laws, regulations, judicial rulings, contracts, and coordinating agreements.

Each drought episode has brought new challenges to motivate creative and long-lasting innovations in Californian water management. Response to the 1920s-30s drought focused on construction of storage and conveyance facilities, an approach which continued well into the 1970s. Water conservation became popular in response to its successes in the 1976-77 drought and is now part of almost all California urban water plans and operations.

The current drought also has had significant effects on how water professionals, political leaders, and the public think about water supply. The result has been a refinement of pre-existing water management techniques and experimental implementation of more novel approaches to water management, such as water transfers.

The 1991 and 1992 California Drought Emergency Water Banks were the first major State-brokered water transfer programs in the nation. The Water Banks were established in response to severe water shortages to provide water for critical municipal, industrial, and agricultural needs, preservation of fish and wildlife, and carryover storage for potential additional dry years. The 1991 Water Bank was considered successful because it transferred large quantities of water in a short period of time in a state where water transfers have been especially slow to develop, relative to other Western states. Within a few months of its establishment, the 1991 Drought Water Bank had negotiated for over 820,000 ac-ft of water purchases and almost 390,000 ac-ft of sales, with the remaining water going to instream flows in the Sacramento-San Joaquin Delta and overyear storage for the 1992 water year. In the course of arranging these transfers, 348 individuals, firms, and agencies had sold water, 12 agencies had purchased water, and most other major water users and suppliers in the state had become acquainted with the idea and the opportunities of water transfers. The extension of the Drought Water Bank into a second year demonstrates its overall perceived success, and the changes from 1991 to 1992 show some of the lessons learned from the first year's experience.

The California Drought Water Banks of 1991 and 1992 illustrate the contributions of government involvement in water transfers. State involvement firmly demonstrated State support for water transfers as part of overall water management, increased the probability of success for individual transfers, lowered transaction costs of transfers, and facilitated coordination of transfers with other water movements in the state. The experience of the 1991 and 1992 Drought

Water Banks will likely encourage the independent pursuit of transfers by individual agencies in the future and serve to establish water transfers as a water management technique.

Beyond State-sponsored water transfers, there have been a great number of transfers and exchanges taking place independently of the State. This transfer activity illustrates the diversity of forms and purposes that water transfers can take for both regional and local systems. These types and benefits of water transfers are summarized in the accompanying table.

MAJOR TYPES AND BENEFITS OF WATER TRANSFERS

(a) MAJOR TYPES OF WATER TRANSFERS

Permanent Transfers

Contingent Transfers/Dry-year Options
Long-term
Intermediate-term
Short-term

Spot Market Transfers

Water Banks

Transfer of Reclaimed, Conserved, and Surplus Water

Water Wheeling or Water Exchanges
Operational Wheeling
Wheeling to Store Water
Trading Waters of Different Qualities
Seasonal Wheeling
Wheeling to Meet Environmental Constraints

(b) MAJOR BENEFITS AND USES OF TRANSFERRED WATER

Directly Meet Demand
Use transferred water to meet demand, either permanently or just during drought.

Lower Costs
Use purchased water to avoid higher cost new sources.
Use purchased water to avoid increasingly costly demand management measures.
Seasonal storage of transferred water to reduce peaking capacity.
Use drought-contingent transfers to reduce need for overyear storage facilities.
Wheeling low-quality water for high-quality water to reduce treatment costs.

Improve Reliability
Direct use of transferred water to avoid depletion of storage.
Overyear storage of transferred water to maintain storage reserves.
Drought-contingent contracts to make water available during dry years.
Wheeling water to make water available during dry years.

Improve Water Quality
Trading low-quality water for higher quality water to reduce water quality concerns.
Purchase water to reduce agricultural runoff.

Satisfy Environmental Constraints
Purchasing water to meet environmental constraints.
Wheeling water to meet environmental constraints.
Using transferred water to avoid environmental impacts of new supply capacity.

Integration of Water Transfers in Water Management

To be successful, water transfers must be integrated with traditional water supply augmentation and demand management measures. During California's current drought, both traditional supply infrastructure and demand management strategies have continued to have an important role in water management. However, this role has changed somewhat due to the presence of water transfers. The completion of water transfers in California has required a great deal of engineering. Reservoir, canal, pumping plant, and even river operations have had to be modified to accommodate water transfers in the last few years. The planning of long-term water transfer arrangements has also required a great deal of design and analysis of water management facilities together with detailed studies of water demand and the design of water conservation programs.

The transfer of water between different water uses requires integrated planning, operation, and cooperation of diverse user groups. Since most water for water transfers must economically come from agricultural users and much of this water will go to urban and perhaps environmental uses, any planning for water transfers implicitly integrates urban, agricultural, and environmental water supplies. This necessary coordination of planning and operations between functionally diverse water agencies will imply potentially protracted and probably controversial negotiations, at least for long-term transfer arrangements, such as water exchanges for overyear storage or dry-year water purchase options.

The use of many long-term forms of water transfers, such as dry-year options, implies a tighter integration of water supply planning with drought management planning. To provide for a dry-year transfer, individual farmers, for example, will have to avoid extensive growing of tree, vine, and other perennial crops. Urban areas receiving dry-year options will have to organize these agreements during wet years, and will probably wish to modify their long-term water supply augmentation and conservation programs to incorporate these new dry-year supplies.

Integrated application of water transfers also should increase the ability to overcome conveyance and storage constraints, to adequately address water quality and third-party impacts, and determine selling and purchase prices. Resolution of these operational, environmental, and economic problems is needed to fully integrate water transfers into a region's water resource system.

The integration of water transfers with capacity expansion and demand management techniques is likely to mirror the integration of urban water conservation with capacity expansion measures seen in California after the 1977 drought.

Lessons Learned from California

California's recent experiences with water transfers suggests several potential lessons for federal, state, and local water managers:

1. Water transfers can enhance the performance and flexibility of existing water resource systems.

These benefits can include: increasing the beneficial use of existing supplies, favorable net economic and employment impacts, additional flexibility in drought management, avoidance or reduction of capacity costs, and a better match of waters of different qualities with different water demands.

2. Water transfers must be integrated with traditional supply and demand management approaches.

Water transfers alone will rarely resolve a region's water supply problems in an economical manner. Typically, a more integrated management approach, employing traditional supply and demand management measures, integrated with water transfers, will provide better results in terms of cost, technical performance, and institutional feasibility.

3. Modification and expansion of infrastructure is often required to take best advantage of water transfers.

The operation of existing conveyance, storage, and treatment facilities is likely to require significant changes to facilitate water transfers. In many California cases, the transferred water can only be employed if it is stored for use in dry periods, necessitating new surface water reservoirs or additional use of groundwater storage. Conveyance restrictions, both from physical aqueduct capacities and environmental limitations, are also common.

4. Water transfers can take many forms, each serving a different operational purpose in a water resources system.

The California case illustrates the many forms that water transfers can take and the diverse uses for different types of transfer arrangements. Each form of transfer, when utilized for an individual system, can fulfill a different operational purpose and accommodate different legal or third-party considerations.

5. Appropriate use of water transfers will likely vary between systems, reflecting local conditions.

Each system is somewhat unique, in terms of its supplies, water demands, costs, and alternatives. Different water supply systems will find somewhat different uses for water transfers. Some water supply systems will not need or be able economically to employ water transfers. This variation in individual water system needs helps explain the diverse ways and degrees that water transfers have been employed in California.

6. Water transfers require a broader scope and scale of thinking about water resources management.
The use of water transfers in water management implies a regional and inter-regional integration of different water users and supplies. The differences between the demands of urban water systems and irrigation systems are the reason why transfers can be successful to both parties. The implementation of this broader perspective on water planning will require significant changes in water agencies at the local, state, and federal levels.

7. Environmental, legal, and third-party considerations are important political, planning, and operational considerations in developing and implementing water transfers.
Although not the focus of this study, the environmental, legal, and third-party aspects of water transfers were consistently brought up during our interviews and research. Cases of water transfers, both in California and elsewhere, demonstrate the very high degree of importance of environmental, legal, and third-party impact issues in the development and implementation of water transfers. While these issues are formidable, they are not insurmountable. There are numerous approaches for accommodating, compensating, or mitigating the real and potential third party impacts of water transfers.

8. Government sponsorship is often required for significant water transfers to begin.
State and perhaps Federal governments have an important, and perhaps vital, role in the adoption and acceptance of water transfers as part of water management activities. Government has an essential role in accelerating the use of water transfers, reducing the risk and uncertainty involved in water transfers, reducing the costs of completing water transfer transactions, and demonstrating leadership in the legal, technical, and conceptual transitions required for local agencies to implement water transfers.

9. Drought motivates change.
Historically, major changes in water management philosophy have been motivated and incorporated as a result of experiences during droughts. Recent water transfers in California are an example of how drought has motivated the exploration of new alternatives in water management.

10. Transfers cannot be avoided only delayed.
As increasing demands for water make shortages and droughts more frequent and severe, calls for water transfers are likely to become louder and more forceful. After the 1977 drought, California was able to delay significant water transfers for 14 years, until the next major drought. With the current drought, water transfers are now a significant and permanent feature of water resources planning and management in California.

Chapter 1

Introduction

"As Elche [in Spain] ... the water belongs to parties who do not own the land. The land has no rights. When the farmer needs water, he buys it as he buys any other article. There is a daily water exchange, where one may buy the use of water in an irrigating channel for twenty-four hours, beginning at six in the evening. The prices that are stated to have been paid in times of scarcity, tax our credulity very much."

Report of the Board of Commissioners on
The Irrigation of the San Joaquin, Tulare, and Sacramento Valleys
of the State of California, U.S. Army Corps of Engineers, 1874,
p. 132.

California's recent drought experience offers many lessons to the nation's water resource engineers and planners. This report does not offer a complete discussion of these lessons, but focuses on the lessons for water management arising from the transfer of water between water users, as has become a common occurrence in California over the last two years of drought. California has been at the forefront of water management innovations in many ways for almost a century, since it has a large semi-arid region with rapidly growing urban water demands, extensive irrigated agriculture, and increasing environmental restrictions on water use. California has been a leader in the development of large reservoir and conveyance systems, conjunctive operation of multi-reservoir systems, conjunctive use of surface and ground waters, and urban water conservation. In the last two years, California has added to this a major experiment with the compensated transfer of water from one user to another for drought management.

PROJECT SCOPE

The scope of this report is the role of voluntary, compensated water transfers in the management of water in California. These include both long- and short-term transfers as well as the major Drought Emergency Water Banks established by the State for the years 1991 and 1992. Forced, involuntary, or uncompensated transfers, such as might result from court actions or legislated reallocations of water are not addressed, except in a few significant cases where they have had a role in motivating voluntary transfer agreements.

In this report our focus is on the technical, planning, and operational aspects of water transfers. We also seek to identify the role of water transfers in comprehensive water resources planning and management. We have deliberately not preoccupied ourselves with the important third-party economic and environmental impacts of water transfers that have received so much attention in the literature and media. While we understand the importance of minimizing these impacts, we feel this report's contribution should be in the relatively neglected technical arena.

TRENDS IN TRANSFERS

Recent years have produced increased interest in the transfer of water and water-related facilities as part of a re-organization of federal, state, and local water infrastructures. Such interests in transfers have included the transfer of water and water-rights (Howe, *et al*., 1986), the transfer of water storage rights in Federal reservoirs (Johnson, et al., 1990), and the transfer of entire Federal projects to State or local water agencies (Diringer, 1992).

The primary motivations for such transfers have been to realign the operation of existing water infrastructure to new developments in water demand and to reduce the heightened costs of new water resources infrastructure. New developments in demand include growing urban and environmental water demands relative to traditional irrigation, navigation, and flood control concerns. The costs of additional water resource infrastructure have been increased in recent years owing to the lesser availability of good reservoir sites and conveyance right-of-way and heightened concerns for the environmental impacts of new water resource infrastructure.

Transfers have far-reaching implications for water resource planning and management. In addition to contributing to the "bag of tricks" available to water managers, transfers require a broader conceptualization of water management problems. In contrast with traditional supply augmentation and demand management measures, which can typically be accomplished by a single water agency, water transfers require the coordination of planning and operations between both the water transferor and transferee, with likely additional involvement of storage and conveyance facilities operated by third parties. While there may be advantages in cost and flexibility to such transfer arrangements, they can come at some cost of real or perceived loss of an agency's self-determination in water management.

Transfers also require a more explicitly economic perspective on the purposes of water resource operations. The purpose of water infrastructure becomes more than merely supplying a constant quantity of water, but becomes a means for creating wealth and well-being for water users generally. If one water user is willing to trade to another water user a quantity of water for a quantity of money, or some other incentive, obviously both parties (at least) would be better off for the transfer and the water system might better serve the users and the regions by facilitating the transfer.

The California drought can be seen as one experience where the transfer of water has played a vital role in the management of water during drought and appears to potentially have a significant role in long-term water supply planning and operations for Federal, State, and local water systems.

LEARNING TO USE TRANSFERS

Water transfers are often discussed in a very generic way. Yet the transfer of water can serve a number of different purposes in the operation and planning of a water resource system. The purposes which transfers can serve include various drought management objectives, reduction in the need for new water supply capacity (e.g., new reservoir capacity), and more efficient operation of a water resource system on a daily or seasonal basis. As events encourage us to ponder the use of transfers more seriously, we will doubtless find many other uses for water transfers as part of our water management policies and operations.

The process of learning to incorporate water transfers into our water resource systems will be long and interesting. In many ways we are still learning new ways to coordinate the use of conventional water sources, such as the conjunctive use of surface and ground waters or the coordinated operation of surface water reservoirs.

Droughts have historically been a major source of innovation in the water management profession, particularly in California. Until recently, California, despite an array of legislation designed to encourage water transfers, has lagged behind other Western states in the frequency of major water transfers (Gray, 1989). The last two years of the current drought has changed this situation, with water transfers becoming a major contribution to the water supplies of many urban and agricultural water systems.

Following this current California drought, water transfers seem likely to become almost a conventional tool in water resources management, just as reservoirs and water conservation became accepted after early experimentation and demonstrated utility during earlier droughts. As water demands continue to increase and diversify and water supplies become more constrained, water resources planning in semi-arid regions such as California can be expected to increasingly incorporate water transfers and drought management planning, together with now-conventional planning for water conservation, reservoirs, and conjunctive use of ground and surface waters.

The technical scope of water resources planning with water transfers requires greater coordination and cooperation in the planning and management of agricultural, urban, and environmental water supplies. With transfers, it is no longer possible, or even economically desirable, to plan for urban water supplies in the absence of coordination with agricultural and other water users.

The need for such coordination and cooperation will forge new alliances between water users, as well as new animosities. These will stem from the realization of the new trade-offs in water use that have increasingly weighted on water management professionals.

For the water management profession, water transfers must eventually result in a new way of professional thinking about the development and management of water supplies. This new thinking must be broader in technical scope and more integrative of the diverse water management measures and constituencies available.

Let us now take a glimpse into the potential future of water supply management, by examining this very recent experience with water transfers spurred on by the current California drought.

STUDY APPROACH

Through interviews, case studies of recent transfer activities, review of past transfers, and review of other drought management activities, we tried to discern the current and potential future role of transfers in short- and long-term water resources planning.

Extensive in-person and telephone interviews were made with a variety of Federal, State, and local officials, private water consultants, and long-time California water observers. These discussions were open-ended and sought primarily to solicit the thoughts and experiences of diverse perspectives. In selecting interviewees, we sought out primarily those in the water industry with a direct experience with transfers. We were interested in the perspectives of policy-implementors, rather than policy-makers or policy pundits.

The water personnel interviewed at all levels of government -- federal, state, regional, and local -- are pragmatic people and work for typically conservative agencies. The general impression gotten from these interviews is that transfers are useful and can be effective but cannot substitute entirely for new storage and conveyance facilities. A list of interviewees appears in Appendix C.

In addition to the interviews, we reviewed an extensive technical literature and media coverage of water transfers and drought management throughout the state. Much of this literature was suggested to us in the course of interviews, and a number of interviewees were suggested by reading the technical literature and media reports. We have made every effort to provide documentation through referencing written work.

Overall, in examining the use of transfers in California water management, we tried to focus on a few good examples rather that attempting to catalog all water transfers within the state. We hope that the result is a presentation more conducive to in-depth thinking about how water transfers can be used in water management.

It is commonly thought that it is impossible to study a drought as it occurs, owing to the lack of time available from water agency officials and the often highly-politicized nature of drought management activities. We had hoped this study would be conducted in the year following the current drought and began our interview work with some trepidation. However, we were extraordinarily pleased to discover an extremely high level of interest and cooperation on the part of almost all those interviewed. Perhaps this good fortune is due to the particularly visible role of water and drought in California and the long duration of the current drought. Still, the continuing nature of the current drought has impeded the use of documented sources, since there has not yet been much time for much drought-management documentation to be produced.

REPORT ORGANIZATION

The report is organized in three parts: Chapters 2, 3, and 4 set the stage; Chapters 5, and 6 present a description of past and current water transfer activity in California; and the remaining chapters present lessons from the California experience and draw conclusions about the role of water transfers in comprehensive water resources management.

Chapter 2 presents a brief overview of California's water resource system. Particular features such as storage and conveyance facilities, water uses, water law and institutions, drought management, and water development history (including the role of droughts) are presented. Chapter 3 reviews the hydrology and management chronology of the current drought. Some comparisons are made of this drought with the 1976-77 and the 1930s droughts.
Chapter 4 discusses some of the theoretical basis and limitations of water markets and water transfers, identifies different types of water transfers, and, presents generic discussions of technical aspects of engineering water transfers.

Chapter 5 reviews the 1991 and 1992 State Water Banks. The legal, economic, and technical basis for the Water Banks are discussed. The buyers and sellers are detailed. Chapter 6 reviews other water transfer activities during and immediately preceding the current drought.

By analyzing the lessons learned from the California water transfers experience, Chapters 7 discusses the integration of water sales and transfers in water resources planning at the federal, state, and regional levels. Chapter 8 assembles and briefly discusses a list of conclusions.

Appendix A includes descriptions of several water transfer case studies which provide background for the innovations described in the report. Appendix B contains examples of some typical water transfer contracts and agreements. Appendix C contains a list of those interviewed as part of this study. Appendix D contains a list of references.

Chapter 2

Overview of California's Water Supply System

Water supply in California is poorly distributed in both time and space. The principal sources of water are in California's northern and eastern mountain areas, whereas the greatest demands occur in the southern and western regions. Moreover, the climate is one of wet winters and dry summers, with runoff being dominated by snowmelt. The water related infrastructure, institutions, and legislation which have evolved, as well as the conflicts and antagonisms which have arisen over the years, can be traced to this unique imbalance of supply and demand. To control the annual floods from spring snowmelt and conserve water for agricultural, municipal and industrial, and other uses, federal and state water agencies, in conjunction with local agricultural and municipal water districts have designed and constructed one of the most extensive systems of dams, reservoirs, canals, pipe lines, power stations and pumping plants ever conceived. The physical and human infrastructure developed as part of the California State Water Project (SWP), the federal Central Valley Project (CVP), and the numerous smaller local projects has created a highly integrated and intricate water resources system which can store and distribute large quantities of water.

This chapter has two main objectives: 1) to present a brief overview of California's water resource system, including a description of water supply and demand, storage and conveyance infrastructure, water law, and institutional arrangements; and 2) to identify the importance of drought episodes in the evolution and development of the State's water supply system. More extensive presentations of California's water resource systems can be found in Bain, *et al*. (1966), the California Water Atlas (Kahrl, 1978), and recent editions of Bulletin 160 of the State Department of Water Resources (DWR, 1987).

WATER SUPPLY

California's water supply system arises from its particular climate which distributes water unevenly over the state and unevenly in time over the course of the year and between years.

Precipitation

Average annual precipitation in California is 23 inches, or approximately 200 million acre-feet (MAF). But, as indicated on Figure 2-1, it is poorly distributed throughout the state. Average annual precipitation ranges from over 50 inches in the north to less than 6 inches in the southern part of the state (DWR, 1987).

The precipitation is also unevenly distributed throughout the year. Winters are wet and summers dry. Most precipitation falls during the months of November to March, while the summer months are almost entirely without rain.

Runoff

Average annual runoff in California is approximately 75 million acre-feet, of which approximately 24 MAF flows directly to the ocean. But, like precipitation, runoff is also poorly distributed throughout the state, as shown on Figure 2-2. About 40 percent of the state's runoff occurs in the relatively small North Coast region (DWR, 1987). Historically, in about 40 percent of the years runoff is less than 75 percent of average.

Snowpack is important in assessing the State's water supplies because it provides an indication of how far into the summer runoff will continue. About half of the natural runoff from the Coastal and Sierra Nevada mountains occurs during the late spring and early summer months of April, May and June.

Source: DWR, 1983

Figure 2-1
Average Precipitation Distribution in California
(inches per year)

Source: DWR, 1983

Figure 2-2
Average Runoff Distribution in California

The Sacramento River Index (SRI) is used by the Department of Water Resources to classify water years into wet, above normal, below normal, dry, and critically dry. The SRI is the sum of the unimpaired water year runoff from the Sacramento River above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River flow at Smartville, and American River inflow to Folsom Reservoir. The 50-year average (1940-1990) is 18.4 MAF.

An important additional source of runoff for California is the Colorado River. California is allotted 4.4 MAF/year of Colorado River water, although until recently California has been able to use about 4.8 MAF annually (DWR, 1987).

Reservoir Storage

To control and distribute the state's runoff, over 1,300 reservoirs with total capacity of approximately 43 MAF have been constructed by federal, state, and local interests (DWR, 1987). One hundred and fifty-five of these are considered representative and are used by the Department of Water Resources for generating statewide statistics. These 155 reservoirs are known as the state's major reservoirs. Total storage capacity in the major reservoirs is approximately 37.7 MAF. Historical average storage has been 29.5 MAF, or roughly 78% of capacity. Table 2-1 lists the major reservoirs by hydrologic region. Reservoir construction peaked between 1940-1980. For a variety of reasons no major reservoirs have been constructed in California since the mid-1980's, although several are currently under study.

Only a few reservoir projects under study are supplied directly by streamflow (e.g., Auburn Dam on the American River). Most reservoir projects under serious study are off-stream storage projects, filled by pumping during periods of "excess" streamflow. Examples of these off-stream projects are Los Vaqueros (in Contra Costa County), Los Baños (in the southern San Joaquin Valley), and Domenigoni Valley (in Riverside County). Each of these sites have potential storage capacities of about one MAF.

Table 2-1
Major Reservoirs in California
(totals may vary due to rounding)

Region	Number of Reservoirs	Total Capacity (MAF)	Historical Average Storage (MAF)
North Coast	7	3.1	2.6
San Francisco Bay	18	0.7	0.5
Central Coast	6	0.9	0.7
South Coast	29	2.0	1.3
Sacramento Valley	43	16.0	13.7
San Joaquin Valley	33	11.4	8.4
Tulare Lake	6	2.0	1.3
North Lahontan	5	1.1	0.7
South Lahontan	8	0.4	0.3
TOTAL	155	37.7	29.5

Source: DWR, 1987

Groundwater Supplies

Groundwater provides approximately 16.6 MAF of water annually in the State, or almost 40% of the water applied for agricultural, municipal, and industrial uses (DWR, 1987). In addition to serving as a source of water, aquifers in many areas of the state function as reservoirs for both within year and overyear storage of water and as conveyance systems for making water available over large regions.

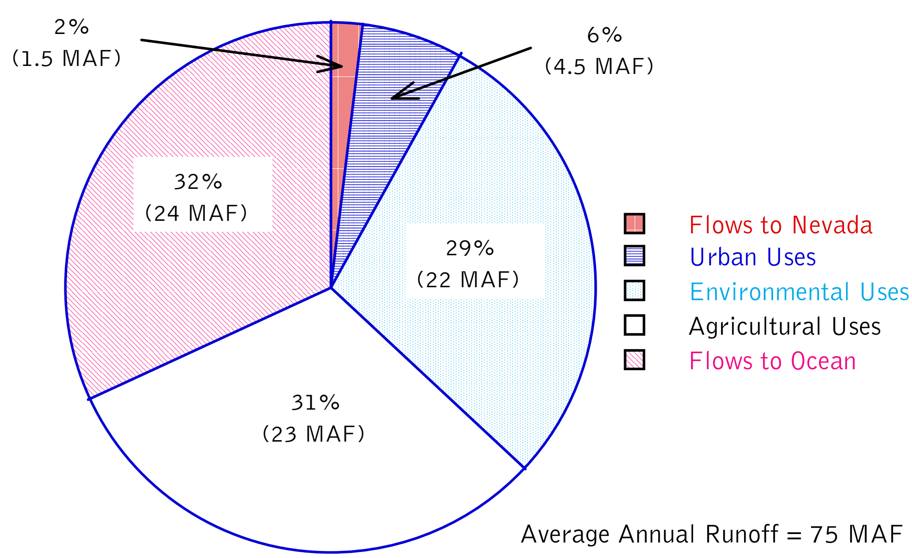
Statewide, groundwater withdrawals in normal years exceed inflows to the aquifers by about 2 MAF/year. This long-term depletion of groundwater storage is particularly significant in the San Joaquin Valley, due primarily to pumping for irrigation. Overdraft is also significant in parts of the Central Coast region from Santa Barbara to Santa Cruz Counties (DWR, 1987). Groundwater has an especially important role in drought management. During drought, groundwater is quickly sought as a partial substitute for reduced surface water supplies. Many of the effects of drought are mitigated by the use of groundwater, particularly for agriculture in the Sacramento and San Joaquin Valleys (Vaux, 1986). However, the long-term drawdown of the water stored in aquifers can lessen the availability of water during drought, increase its cost (by increasing the cost of pumping), and decrease its quality.

Many water agencies in southern California and the San Joaquin Valley have adopted complex conjunctive use schemes to make better use of the storage potential of aquifers for drought management (Vaux, 1986; Brooks, 1983). These schemes can involve making surface water available at rates that are less expensive than groundwater pumping costs, to encourage the retention of groundwater supplies until surface water is less available. Other schemes involve special artificial recharge facilities to store water during wet years so as to make it available during droughts.

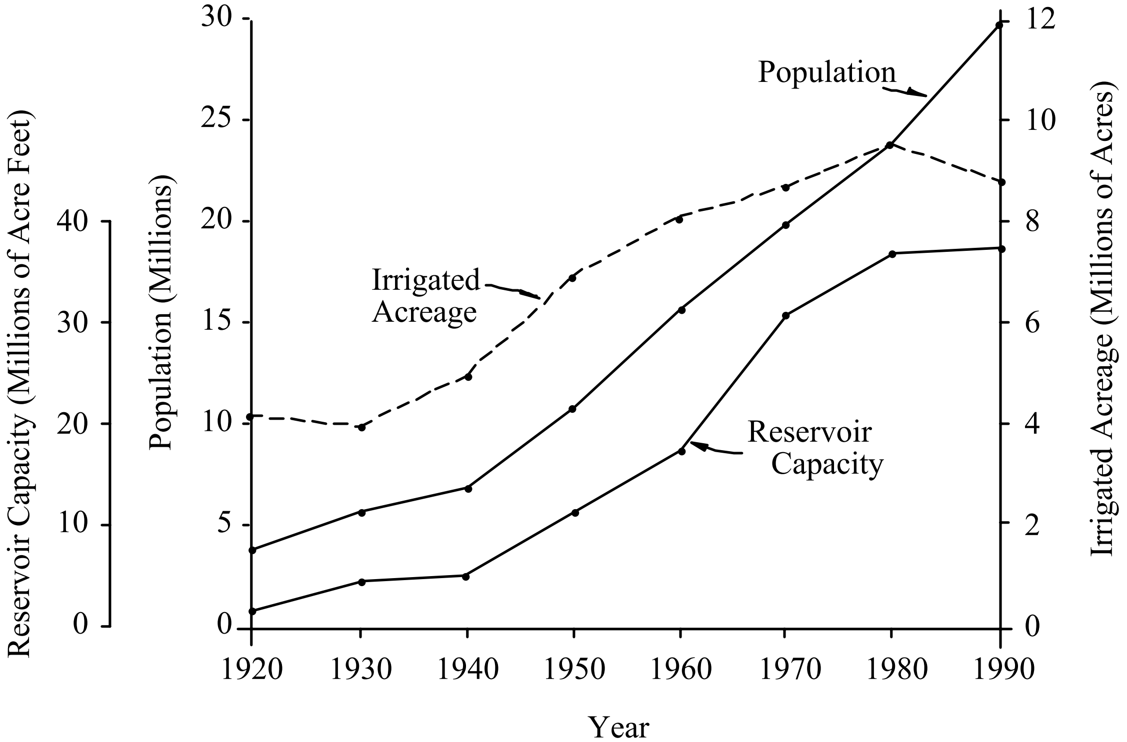
WATER DEMANDS

The major uses of water in California are for agricultural, urban, and environmental purposes. Figure 2-3 illustrates the final disposition of California's average 75 MAF of annual runoff (DWR, 1991a). Figure 2-4 summarizes the historical evolution of urban and agricultural water demands in California, compared with the development of reservoir capacity in the state.

Figure 2-3
Disposition of California's Average Annual Runoff



Source: DWR, 1991a



Source: DWR, 1991a

Figure 2-4
Historical Evolution of Water Demands in California

Agricultural Uses

Agriculture consumptively uses roughly 27 MAF of water in a normal year, roughly 79% of the state's consumptive use of developed water supplies. This usage has remained relatively steady over the last decade, declining slightly as a result of changes in cropping patterns and urbanization of agricultural land (DWR, 1987).

Agricultural water demands are overwhelmingly for irrigation, and vary considerably from month to month. The greatest irrigation water demands occur between April and August. During other parts of the year, particularly during the winter months, there is little demand for irrigation water. This implies that most of the water used for irrigation must come from water stored in reservoirs or aquifers, or directly from snowmelt which is released mostly during the months of March and April.

The water quality demanded for agricultural uses can vary considerably, depending on the crop and soil conditions and is generally a significant factor in the selection of agricultural water supplies. However, in most regards, agriculture is the most tolerant major water use in California, in terms of water quality flexibility.

Urban Uses

Urban water uses are approximately 5.6 MAF/year in normal years, about 16% of the state's consumptive use of developed water supplies. This usage has grown rapidly with the state's population. Between 1980 and 1985, population grew from 23.7 million to 26.1 million inhabitants, an increase of 2.4 million or 10% over 5 years (DWR, 1987). Almost all of this increase in demand is supplied by developed water supplies to urban areas.

Urban water demands are much more constant over the course of a year than irrigation demands. Still, spring and summer urban demands tend to be significantly greater, due to landscape irrigation during California's long dry season. This summer peaking is most pronounced for residential water demands, which account for about 65% of total urban demands (DWR, 1984). Almost half of residential water demands are for outdoor uses, primarily landscape irrigation (DWR, 1984).

While waters of most qualities can be treated for urban uses, such treatment can be expensive for some water quality constituents. Dissolved solids, in particular, are particularly expensive to remove. The cost of treatment is a major consideration in selecting a water source for urban water agencies.

Environmental Uses

Water used for fish, wildlife, recreation, and power plant cooling totals about 1.7 MAF/year, or about 5% of total consumptive use of the state's developed water. In addition to use of developed water, fish and wildlife are probably the largest direct beneficiaries of the 24 MAF of undeveloped water that flows into the ocean in the average year.

While environmental demands for water occur throughout the year, water is required for particular species and habitats at specific times of year for spawning, migration, or habitat availability. This punctuated aspect of environmental demands for water at key points throughout the year is a challenge to the operation of water management facilities.

The quality of water available for environmental uses is particularly important. The temperature, pH, salts concentration, dissolved oxygen concentration, and other quality characteristics of water used for environmental demands can be crucial.

WATER INSTITUTIONS

California has roughly 3,000 water suppliers, both public and private. These water providing institutions differ widely in scale, organization, and enabling legislation, and are often driven by divergent objectives. Ownership and control of facilities varies, as does operation and maintenance responsibilities. However, overall operation of the system is finely orchestrated through a series of operating agreements, contracts, regulations, and laws. It is common for the water supplied to an individual house or farm to have been contractually or physically handled by several hierarchically layered water supply agencies. Water from a state or federal reservoir is often contracted to a regional water wholesaler which may sell the water to two or three additional water districts before final delivery to the individual water user.

This section identifies the institutions and agencies which most strongly influence the operation, management, and development of California's water supply system. A complete listing of agencies involved in California water resources issues is provided in California Institute of Public Affairs (1991).

Federal Institutions

The Federal government has a major role in the management of water in California, acting primarily through the Bureau of Reclamation. The U.S. Army Corps of Engineers and the Environmental Protection Agency have a lesser, but, significant role in managing the state's water resources.

Bureau of Reclamation

The Bureau of Reclamation was established by the Reclamation Act of 1902 to help reclaim the arid West by providing irrigation water to stimulate settlement and economic growth. The Act authorizes subsidies to users of project water through low interest rates and deferred interest and principal payments. Many of these subsidies are effectively "frozen in time" because of the long duration of Bureau water supply contracts. (Typical water supply contracts are for 40 years.) The Bureau, via the Central Valley Project, the Colorado River Project, and numerous local projects, is the largest supplier of water in California. Water deliveries through these projects total over 11 MAF in normal years (DWR, 1987). Its role in the development and operation of the water supply system has been paramount, and it continues to be a major influence shaping California's future water supply.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (Corps) has a relatively minor role in the overall operation of California's water supply system, despite its ownership of over 2 MAF of reservoir capacity. However, the Corps does have primary responsibility for flood control in several of the state's major reservoirs and for maintaining navigation channels in inland waterways. The Corps has built flood control facilities, including levees, channels and reservoirs on numerous streams and rivers, often in conjunction with local water agencies. The Los Angeles County Drainage Area Project, for example, includes five dams, twenty-two debris basins, and almost 300 miles of improved channels.

The Corps also serves in a regulatory capacity because, under the Clean Water Act of 1974, it is responsible for reviewing and granting Section 404 Permits for construction in navigable waterways and in wetlands. The Corps is therefore a primary review agency for major water resources development projects in the State.

Environmental Protection Agency

The major roles of the U.S. Environmental Protection Agency (EPA) in California's water management are in establishing regulations and enforcing the Federal Clean Water Acts and Safe Water Drinking Acts. The Clean Water Acts have the potential to significantly affect the operation of the Sacramento-San Joaquin Delta for environmental purposes (Sacramento Bee, 1992). Federal Safe Drinking Water Act regulations also potentially affect the ability and cost of using Delta water directly for urban uses.

State Institutions

The State government of California has three sometimes conflicting roles in water management. The state regulates water use, is a major developer of water resources, and seeks to protect the natural environment. State activities in these potentially conflicting roles are split between three agencies, the Department of Water Resources, the State Water Resources Control Board, and the Department of Fish and Game.

Department of Water Resources

The Department of Water Resources (DWR) is responsible for formulating coordinated statewide plans for the control, conservation, and use of the state's water resources. DWR provides the basis for administration policy on the allocation of water supplies and priorities for expenditures by federal, state, and local governments for water use, conservation, and development through planning and investigative activities. Furthermore, DWR is responsible for supplying supplemental water for personal use, irrigation, industry, recreation, and fish and wildlife. It is also ultimately responsible for flood protection and protection against catastrophic failure of water supply facilities.

One of DWR's primary functions is management of the State Water Project (SWP). Its responsibilities include operation and maintenance of facilities and assuring that water is supplied to the 30 contracted users, described in a later section.

State Water Resources Control Board

The State Water Resources Control Board (SWRCB) was created in 1967 and is responsible for administering water rights and water quality programs. The Board has the legal authority to issue surface water rights and is responsible for protecting the quality of the State's surface, ground, and coastal waters, including Delta water quality standards contained in Decision 1485. In granting appropriative water rights the SWRCB specifies the type(s) of use, how much water may be taken, the place of diversion and point of use, the diversion schedule, and any necessary conditions and precautions which must be taken to protect the environment, the public interest, and prior users. The SWRCB also has the authority to revoke water rights if the conditions are violated.

In its role in protecting the state's waters, the SWRCB has vast authority in limiting changes to existing permits. This then can become a major impediment to the transfer of water or water rights in which the place or type of use will be changed.

Department of Fish and Game

The California Department of Fish and Game (DFG) is responsible for the protection, preservation, propagation, and enhancement of the state's wildlife resources. Specifically, the Bay-Delta Project is responsible for evaluating the impacts of the Central Valley and State Water Projects on fish and wildlife resources of the Sacramento-San Joaquin Delta. DFG also has been involved in protecting and securing additional water rights for instream fisheries.

Local Institutions

The vast majority of the thousands of water suppliers in the state are local. The roughly 1,000 publicly-owned water suppliers are formed under more than 40 different water district acts (Phelps, *et al*., 1978). Another 200 or so suppliers are privately-owned firms whose operations are governed by the State Public Utilities Commission (California Institute of Public Affairs, 1991). Another roughly 1,300 suppliers are mutual companies, voluntary non-profit cooperatives supplying cooperative irrigation services (Revesz and Marks, 1981).

The largest and most complex local water agency is the Metropolitan Water District of Southern California (MWD), which wholesales water directly to 27 subregional suppliers and indirectly to about 210 other local suppliers. The area supplied by MWD has a population of about 15 million people (Boronkay, 1990).

Institutional Coordination

The operation of California's water supply system is held together by an intricate set of detailed contracts and agreements between water agencies. These agreements are further structured by the nature of California water law, the subject of a later section. Perhaps the most important single agreement in the state is the 1986 Coordinated Operating Agreement (COA) between the State of California and the Bureau of Reclamation. The COA coordinates the operation of State and Federal water facilities for economic and environmental purposes (*Agreement* ..., 1986).

INFRASTRUCTURE

The principal water supplies of the state are summarized in Table 2-2. The State's major water facilities are located as shown in Figure 2-5. Together the Central Valley Project and the State Water Project provide approximately 30 percent of the state's surface water needs. Principal features of the SWP and the CVP are their reservoirs with total storage capacities of about 16 MAF (DWR, 1987), roughly 45 percent of the mean annual runoff of the Central Valley or almost 20 percent of the state's mean annual runoff.

Sacramento-San Joaquin Delta

The Sacramento-San Joaquin Delta plays a vital role in the management of the state's water resources. Essentially, all north-south movement of water must pass through or around the Delta. It is seen by some as the great bottleneck of the California water supply system.

Movement of water through the Delta can only occur when the Delta is in balanced conditions; that is, when releases from upstream reservoirs match delta water quality standards, Delta outflow, and export needs.

Table 2-2
California's Normal-Year Water Supplies
(MAF/year in 1985)

Water Source	Supply (MAF/year)	Percent of Total
Local Surface Water	9.2	27
Local Agency Imports (excluding Colorado R.)	1.0	3
Reclaimed Water	0.3	1
Groundwater Safe Yield	6.0	17
Groundwater Overdraft	2.0	6
Central Valley Project	7.0	20
Other Federal Projects	1.3	4
State Water Project	2.4	7
Colorado River	5.0	15
TOTAL	34.2	100

Source: DWR, 1987

Windows of opportunity for moving water through the Delta are becoming increasingly constrained because of more stringent water quality standards and a larger number of threatened and endangered species residing in the Delta, which must be protected. Since 1978 the average daily probability that the Delta is in balance on any given month ranges from 7 percent in January to 86 percent in July. The probability of the Delta being in balance is higher in dry or critically dry years (as classified by the Sacramento River Index), exceeding 80 percent in April and May and 90 percent in June. Balanced conditions occur 100 percent of the time from July through September (Howitt, *et al*., 1992).

Federal Infrastructure

Central Valley Project

The Central Valley Project (CVP) provides 21.7% of the state's water supply. The major features of the Central Valley Project include 20 reservoirs with a combined storage capacity of approximately 11 MAF; 8 power plants and 2 pumping-generating plants with a total capacity of roughly 2,000 Megawatts; and approximately 500 miles of major aqueducts and canals. The annual yield of the CVP is approximately seven MAF.

Among the impoundments constructed in California, the Shasta-Trinity complex in the Sacramento Valley plays a key role in regulation of the Central Valley's water supply. The Shasta-Trinity System as shown in Figure 2-5, is comprised of two major reservoirs: Lake Shasta, with a capacity of 4.5 MAF, and Trinity with a capacity of 2.4 MAF. In addition, this system includes three small regulating afterbays, Keswick, Lewiston, and Whiskeytown Reservoirs, three power stations, and interconnecting channels, pipelines and penstocks.

Firm yield for the CVP is based on the most critically dry hydrologic period of record in the Central Valley, which occurred from 1928-1934. Firm yield also assumes ultimate demand conditions which are defined as the level of development that would exist at full delivery of contract and water rights commitments (BuRec, 1992). Current estimate of firm yield for the northern portion of the CVP (Trinity River, Shasta, Sacramento River, and American River divisions) is estimated to be 8.3 MAF per year. (This estimate is currently being updated.)

There are three classes of CVP water supply contracts: long-term contracts for periods of 10 years or more, which can be renewed for a period not to exceed 40 years; short-term contracts, which cannot be renewed; and temporary contracts, which are short-term contracts covering periods of less than 5 years. Each contract, independent of class, stipulates the nature of the intended uses of the water (e.g., irrigation, municipal, industrial, environmental), provisions in the event of water shortages, acreage limitations, assures compliance with water and air pollution measures, and establishes rates.

Colorado River Project

The Colorado River project provides 4.4 MAF/year of relatively firm yield to California, plus one half of any Lower Colorado Basin surplus water. This water is withdrawn directly for use by some irrigation districts, conveyed by the Bureau of Reclamation's All-American Canal to the Imperial Irrigation District (IID), or withdrawn by facilities provided by other users, such as MWD's Colorado River Aqueduct. The division of Colorado River water between these users is governed by a series of agreements, contracts, and court rulings (Abbott, 1988).

Solano and Other Local Projects

In addition to the large projects, the Bureau of Reclamation also owns smaller independent projects throughout the state, such as the Solano Project, which supplies water to Solano County in northern California, and Lake Cachuma in Santa Barbara County in southern California. Altogether, they contribute several hundred thousand acre-ft/year of water yield. The Corps of Engineers operates several reservoirs in California of significant local importance. These total roughly 2 MAF of storage, but are operated largely for flood control.

While generally not of major statewide importance, these smaller facilities can have a major impact on local water management. This will be explored for the case of Solano County in Chapter 6 and in Appendix A.

State Water Project

The State Water Project (SWP) normally provides about 7.4% of the state's water supply. The SWP includes 18 reservoirs with a total storage capacity of roughly 5 MAF, approximately 550 miles of aqueducts and pipelines, 17 pumping plants, and 8 hydroelectric power plants. The primary component of the system is Lake Oroville on the Feather River, with a capacity of 3.5 MAF. Existing facilities have an annual delivery capacity of 2.4 MAF. Expansion of these facilities is anticipated, including major off-stream surface water and groundwater storage and additional conveyance capacity.

The SWP has water delivery contracts with thirty agencies statewide, although not all agencies are currently connected to the conveyance system. The majority of the contracting agencies represent urban water uses. The Metropolitan Water District of Southern California has a right to eventually receive roughly 2 MAF annually. The other major concentration of water demand for SWP water is for irrigation in the Central Valley, demanding roughly 1.2 MAF annually.

The SWP is particularly crucial to statewide water management because it is the only project capable of conveying water from the northern relatively water-rich area of California to populous and rapidly-growing southern California urban areas.

Local and Regional Systems

In addition to the two major systems discussed above, numerous smaller, but still significant water supply systems have been developed by cities, counties, irrigation districts, and other local or regional agencies. The two most notable systems are operated by the cities of Los Angeles and San Francisco.

Figure 2-5
Major Water Storage and Conveyance Facilities

Los Angeles Aqueduct
The Los Angeles Aqueduct takes water from the Owens Valley and Mono Basin to the City of Los Angeles and is owned and operated by the City of Los Angeles. The saga of Los Angeles' quest for water in the early years of this century and the eventual construction of the Los Angeles Aqueduct is well documented (Kahrl, 1982). The total amount of water supplied by this system is approximately 470,000 acre-feet/year, but is subject to annual variation.

Colorado River Aqueduct
The 242-mile Colorado River Aqueduct is owned and operated by the Metropolitan Water District of Southern California (MWD). The aqueduct began operation in 1941 with water contracts with the Bureau of Reclamation originally entitling MWD to 1.2 MAF acre-feet annually. The current aqueduct has a capacity of 1.2 MAF/year. However, several court decisions have reduced this allocation and may continue to reduce it in the future. Completion of the Central Arizona Project reduced MWD's allocation to approximately 400,000 acre-feet. Water claims by Southwestern Indian tribes might further reduce this supply.

Sierra Mountains to San Francisco Bay area Systems
The City of San Francisco and the East Bay Municipal Utility District (EBMUD) own and operate major storage and conveyance systems taking water from the central Sierra Nevada mountains to supply most San Francisco Bay area water demands. These systems have several East-West aqueducts and a total reservoir capacity of almost 1.4 MAF. Additional water for this metropolitan region comes from the SWP, direct pumpage from the Sacramento-San Joaquin Delta, local runoff, and groundwater.

Other Systems
In addition to the large systems described above, California contains countless local water storage and conveyance projects of significant local importance. These are owned and operated primarily by local irrigation and urban water supply districts, as well as by power companies and other private firms. Pacific Gas and Electric Company, the state's largest electricity distributor owns over 700,000 acre-ft of reservoir storage.

WATER RIGHTS
California's water rights system is referred to as a "plural system" because it is based on several doctrines to govern use of the State's waters. The two primary doctrines are the riparian rights doctrine and the appropriative rights doctrine (Attwater and Markle, 1988). Other less important doctrines used in California are contract rights, pueblo rights, prescriptive rights, and groundwater rights. The interaction between these many doctrines often leads to complexity, confusion, and ambiguity in application. This section briefly defines the water rights doctrines used in California and discusses their implications for water resources development and management.

Riparian Rights
The riparian doctrine holds that private water rights arise from the ownership of land bordered or crossed by a natural watercourse (Cox, 1982; Getches, 1990). No strict quantity limitations are placed on riparian water rights; rather the quantity used is based on the concepts of "reasonable" and "beneficial" use and non-interference with downstream riparian water users. The original riparian doctrine stipulated that riparian rights could not be lost because of non-use. However, in California this has changed, and now the nonuse of riparian rights for ten consecutive years causes the rights to revert to the State and become available for appropriation. Use of riparian water is restricted to the watershed bounds of the riparian land, and subdivided land cannot be

unified to acquire riparian rights lost in previous subdivision processes. Finally, there can be no seasonal storage of surplus water under riparian rights in California.

Riparian water rights typically have seniority over all other types of water rights. That is, riparian rights must be satisfied by available supplies before appropriative water rights can be met. Riparian rights are correlative, meaning that when supply is insufficient to meet all riparian demands, the shortage is shared equally by all water right holders.

The two characteristics of riparian water rights which most affect the viability and success of water transfers and water marketing are 1) the limitation that riparian water must be used on adjacent riparian land and cannot be transferred independently of the land to which they are attached, and 2) that riparian rights are "non-storable". This does not allow the transfer of riparian water rights in space (conveyance) or time (storage) so critical for state-wide water management in California. Riparian diversions from the Delta account for approximately 1.3 MAF annually (BuRec, 1992).

Appropriative Rights

The appropriative water rights doctrine is characterized by the phrase "first in time - first in right." This establishes an ordering of senior and junior water rights holders, determined by the date on which water use is first initiated. This ordering has major consequences during droughts, when junior water users must sequentially curtail and eliminate their consumption until the shortage is alleviated, leaving relatively senior right-holders unaffected. Appropriative rights are not based on the ownership of land, and are, therefore, not subject to place of use restrictions, like riparian rights. They are often used on lands removed from the watershed of origin (Gray, 1989; Getches, 1990).

Because appropriative rights are not tied to the land, they can in theory be a transferable market commodity. Transfers may involve changes in ownership, type of use, and place of use. However, a general constraint on the transfer of appropriative rights is that other appropriators, senior as well as junior, must not be adversely impacted by the transfer. The State Water Resources Control Board determines third-party impacts and must approve changes in the timing, place of use, and type of use for most water transfers.

Contract Rights to Water

The intricate web of contracts by which agencies, projects, and individuals sell water to each other forms another body of law which affects water management in California. This is particularly important since, a large percentage of all developed water supplies in California are sold by long term contract to other users. As noted earlier, the contracts by which water moves from its source to an individual user may be several layers deep (O'Brien, 1988; Gray, 1989; Sergent, 1990).

Other Types of Water Rights

Several other types of water rights exist in California water law. Pueblo water rights exist for some water used by settlements existing in accordance with Spanish and Mexican law since before California's statehood. Prescriptive rights exist, but have little significance in recent times. Federal reserve water rights are the final form of water rights in California. These reserved rights can lie dormant for many years before put to their original purpose (Getches, 1990; Sergent, 1990).

Groundwater

Groundwater law in California is far less structured than surface water law. This may be, in part, a result of most of the state's groundwater law being established by judicial decisions and precedence, rather than legislation. The doctrine of mutual prescription tends to be in effect for some cases (Getches, 1990), but has been found not to hold where groundwater users are public agencies or public utilities (Sergent, 1990).

The storage of water in aquifers has become popular in recent years. A number of court decisions support the use of aquifers for water storage by public agencies and support the right of public agencies storing water in aquifers to withdraw this water later. Kletzing (1988) reviews the adequacy of this body of law to support large scale conjunctive use of surface and ground waters.

As a result of California's groundwater law, groundwater is essentially unregulated and largely unregulatable in most of California. The exception to this is where basins have been adjudicated (Kletzing, 1988). These adjudicated basins tend to be intensively managed aquifers in southern California (DWR, 1975).

Synthesis and Effects on Water Transfers

Water law has wide ranging effects on water transfers (Gray, 1989). Water stemming from pueblo rights would seem to be non-transferable. Water supplies based on appropriative rights are generally transferable, but require that there be no injury to any other water-right holders and approval from the State Water Resources Control Board to change the place or purpose of water use. Riparian rights must be used on riparian land or for instream uses in the same basin. Groundwater rights are less regulated with respect to transfers.

ROLE OF DROUGHTS IN WATER RESOURCES DEVELOPMENT

Semi-arid regions like California are prone to severe and frequent variations in annual precipitation. The resulting droughts strongly influence the economic and social development of these regions. Like many natural hazards, droughts cannot be avoided, but can be managed to reduce their adverse impact. Historically, improvements in drought management have been made largely by assimilating and adapting management experiences from actual droughts.

Droughts have had an important role in the development of California's water resource system. Each drought episode has presented planners and managers with new and unique challenges and forced managers to adopt creative and long-lasting innovations. Response to the drought of the 1920-30s focused on the construction of new storage facilities, a management philosophy which continued well into the 1970's (Pisani, 1984). Water conservation was successfully implemented in response to the 1976-77 drought and has become an established part of almost all California urban water supply plans and operations (Gilbert, 1986). It appears that water transfers and water marketing will be a legacy of the current drought.

The management of drought is more than a purely technical exercise. It must also consider the socio-economic, legal, and institutional conditions of a region. As such, drought management requires an interdisciplinary perspective.

HISTORIC ROLE OF WATER TRANSFERS

Water transfers are not new to California and have often been used in managing California's water systems during drought events. As early as the drought of 1920, the C&H Sugar refinery on northern San Francisco Bay was forced to import water from Marin County, north of the City of San Francisco (Pisani, 1984). (This is ironic since in the 1977 drought, 57 years later, emergency water transfers went the other way across the Bay to Marin County in an emergency pipeline placed along the deck of the San Rafael Bridge.) As will be discussed in Chapter 4, the City of San Francisco permanently transfers about half its water supplies to neighboring suburban water agencies. Transfers have also long been an integral part of the operation of irrigation districts and major irrigation supply systems, being required to equalize for the effects of local, seasonal, and over-year variation in water demands and water supply availabilities.

Still, as urban and environmental water demands continued to grow in California after the 1977 drought and the economic value of agricultural supplies began to stagnate, many have looked to more structural and strategic water transfers as an alternative to the construction of new water sources and the expense and potential environmental harm such projects can generate. Seen in retrospect, the decade or so before the current drought consistently foreshadowed an increased role for water transfers in California's water supplies (Gray, 1990; Sergent, 1990). This potential role for water transfers in drought management and water supply planning is the subject of this report.

SUMMARY

California's unique hydrologic circumstances have given rise to an elaborate water resources system. The infrastructure that physically conveys and stores California's water is of almost unequaled statewide capacity and flexibility. This system is governed by a vast number of diverse water management agencies which, in turn, are governed by a complex set of laws, regulations, judicial rulings, contracts, and coordinating agreements. All levels of government are highly involved.

In truth, water in California is governed as much by human action as nature. Therefore, the ways in which we conceive water resources problems are of as much importance as the physical hydrologic regime. At no time is this more evident than during droughts, when nature has fixed its water bounty, and we must decide what to do.

Chapter 3

The Current Drought

1992 marks the sixth consecutive year of drought in California. By the end of the 1992 water year, storage in the state's major reservoirs was at the lowest level since the drought of 1977. (Even though the February 1992 rains caused local flooding and were sufficient to replenish most reservoirs in southern California, the state's major water storage facilities are located in the north.) Deliveries from both the State Water Project and the Central Valley Project had to be curtailed, and competition for water has become intense. The overall severity and impacts of the continuing drought cannot yet be known, but are none-the-less significant. This chapter briefly reviews the hydrologic and management chronology of the on-going California drought and some cursory comparisons with the droughts of 1976-77 and the 1930s.

HYDROLOGIC SUMMARY OF THE CURRENT DROUGHT

Drought events have very uneven spatial distributions and their effects can be highly localized. Thus, while some parts of the state may be suffering through the driest periods of record, others may be only slightly affected or even experience an unusually wet period. Several measures are used to classify droughts, including precipitation, runoff, and reservoir storage levels. Table 3-1 shows the values for these indicators on a state-wide basis, as a percent of normal conditions, for the period 1986-1992. Also listed is the Sacramento River Index used by DWR to classify water years.

Table 3-1
Summary of Statewide Hydrologic Data, 1977, 1986-1992
(percent of average) *

	Average	1977	1986	1987	1988	1989	1990	1991	1992
Precipitation	100	45	128	61	82	86	69	76	86
Runoff	100	20	140	48	47	72	45	43	43
Reservoir Storage	100	35	119	84	66	74	60	61	56
Sacramento River Index (MAF)	18.4	5.1	25.7	9.2	9.2	14.8	9.2	8.4	8.9

* As of October 1
Source: DWR (1991a)

Precipitation

As noted in Table 3-1, statewide average annual precipitation in five of the six drought years has been greater than 75 percent of normal; the lowest was 61 percent of average in 1987. Although statewide average precipitation in 1992 has been 86 percent of normal, most has been concentrated in southern California and not in the State's main water storage and supply regions in the north.

The management of the current drought has been particularly difficult due to uncertainties in predicting March precipitation. Many within-year water allocation decisions must be made in February, due to the logistics of irrigated farming in the state. Two of the recent drought years (1990 and 1991) have had a "March miracle" where March precipitation was several times greater than normal, reducing the shortages anticipated in February.

The "March Miracle" of 1991 turned a "desperate situation into a manageable one," and similarly, the rains of February 1992 convinced some jurisdictions that the drought was over. As their surface water supplies were replenished by the February rains, several counties and cities in southern California (such as Santa Barbara and Ventura County) formally declared an end to the drought, and others lifted mandatory water use restrictions. However, this wet period was not sufficient to provide a return to normal conditions, and statewide water supply conditions remained considerably below normal.

Runoff

While precipitation is a good drought indicator for much of the eastern United States, California's climate and reliance on irrigation make the runoff available for storage and diversion a more relevant indicator of hydrologic drought.

With the exception of the South Coastal region in 1992, runoff in this six year period has been substantially below normal statewide. In five of the past six years, runoff has been less than 50 percent of normal (in 1989 runoff was 72 percent of normal). As of September 30, 1992, statewide runoff was only 43 percent of normal, ranging from 35 percent in the North Lahontan Region to 112 percent in the South Coastal Region. Runoff in the two most important water supply basins, the Sacramento and San Joaquin Basins, averaged 47 and 41 percent of normal, respectively. Table 3-2 shows average annual runoff by hydrologic region.

Depth and water content of the snowpack in the Sierra and Cascade Mountains are important components of runoff. Above average spring temperatures can accelerate snowpack runoff and cause flooding (this was a major problem prior to the construction of reservoirs and flood-control levees and by-pass channels.) The spilled water is unavailable for beneficial use later in the year.

Table 3-2
Runoff by Hydrologic Study Area
(percent of Historical Average)
(as of October 1)

Hydrologic Study Area	Historical Average (MAF/yr)	1987	1988	1989	1990	1991	1992
North Coast	28.6	56	52	76	46	35	40
San Francisco Bay	1.6	25	26	45	23	28	35
Central Coast	2.5	19	20	19	9	43	53
South Coast	1.2	32	40	28	16	58	112
Sacramento Valley	22.4	49	49	78	49	45	47
San Joaquin Valley	7.9	33	38	60	40	50	41
Tulare Lake	3.3	45	42	50	34	56	37
North Lahontan	1.8	42	33	78	45	45	35
South Lahontan	1.3	66	56	58	42	49	47
Colorado Riv. Flow	0.2	93	58	41	39	63	51
TOTAL	70.8	48	48	72	45	43	43

South Coast combines Los Angeles, Santa Ana, and San Diego regions shown on figure 2-2.
Source: DWR, 1983; 1991a; 1992

Reservoir Storage

Reservoir storage at the end of the 1992 water year was below 13 MAF for the first time since the drought of 1977. Several reservoirs throughout the state went dry and others reached record low levels. Table 3-3 indicates storage levels for the State's major reservoirs, reservoirs of the State Water Project, and reservoirs of the Central Valley Project. The 200,000 ac-ft increase in storage during the 1991 water year was due to the large reductions in deliveries from the SWP and the CVP, not to an improvements in hydrologic conditions. Table 3-4 shows the variability of drought impacts on storage throughout the state, listing reservoir storage as a percent of normal for the different hydrologic regions.

Table 3-3
Statewide Reservoir Storage
(as of October 1, in MAF)

	Average	1977	1987	1988	1989	1990	1991	1992
155 Major Reservoirs	29.5	7.8	18.9	14.8	16.7	13.6	13.8	12.7
State Water Project	3.8	1.5	3.2	2.6	3.1	2.1	2.6	1.7
Central Valley Project	6.3	2.4	6.3	4.6	5.1	4.0	3.3	3.0

Sources: DWR (1978, 1991a)

Table 3-4
Reservoir Storage by Hydrologic Region

Region	Historical Average Storage (1000 AF)	Percent of Average (October 1, 1977)	Percent of Average (October 1, 1991)	Percent of Average (October 1, 1992)
North Coast	2,643	11	60	56
San Francisco Bay	500	57	73	89
Central Coast	698	33	39	52
South Coast	1,341	63	107	118
Sacramento Valley	13,701	31	64	60
San Joaquin Valley	8,386	18	65	43
Tulare Lake	1,274	16	67	28
North Lahontan	717	5	17	15
South Lahontan	274	56	89	75
TOTAL	29,534	26	61	56

Source: DWR (1992)

Groundwater Use

The shortage of surface water during a drought leads to considerably more use of groundwater than normal, especially by the agriculture sector. For example, in a normal year groundwater typically supplies approximately 40 percent of the State's water needs, but during the 1976-77 drought, groundwater supplied about 53 percent of total demands. A similar story holds for the current drought. During the first four years of the drought, increased groundwater pumping greatly reduced the drought's impact, particularly to the agricultural sector. However, by the fifth consecutive year of below normal precipitation and runoff and, consequently, higher than normal pumping rates, groundwater levels had been greatly reduced in many aquifers and there was widespread concern about depletion of these aquifers.

Groundwater storage in the San Joaquin Valley has decreased by an estimated 11 MAF because of overpumping and inadequate recharge during the past five years. Groundwater levels in several counties in the San Joaquin Valley are as low or lower than they were after the 1976-1977 drought (DWR, 1991a). The smaller, coastal groundwater basins can deplete quickly, but also tend to recharge much faster, as they did during the March 1991 and February 1992 rains. The decline in groundwater levels during the drought is illustrated in Figure 3-1.

Increased pumping of groundwater when the recharge potential is low reduces groundwater levels. Reduced groundwater levels increase pumping cost, increase potential for land subsidence, can deteriorate groundwater quality, and, along coastal regions, increase the likelihood of salt water intrusion.

Colorado River Supplies

The Colorado River is a major source of water for southern California, providing approximately 4.4 MAF annually. The Colorado River Basin has also suffered effects of the recent drought. Although reservoir storage in the Lower Colorado Basin was down 3.3 MAF, it was still at 93 percent of the historical average. There have been no reductions in deliveries through the Colorado Aqueduct and none were planned for the 1992 season (DWR, 1991a).

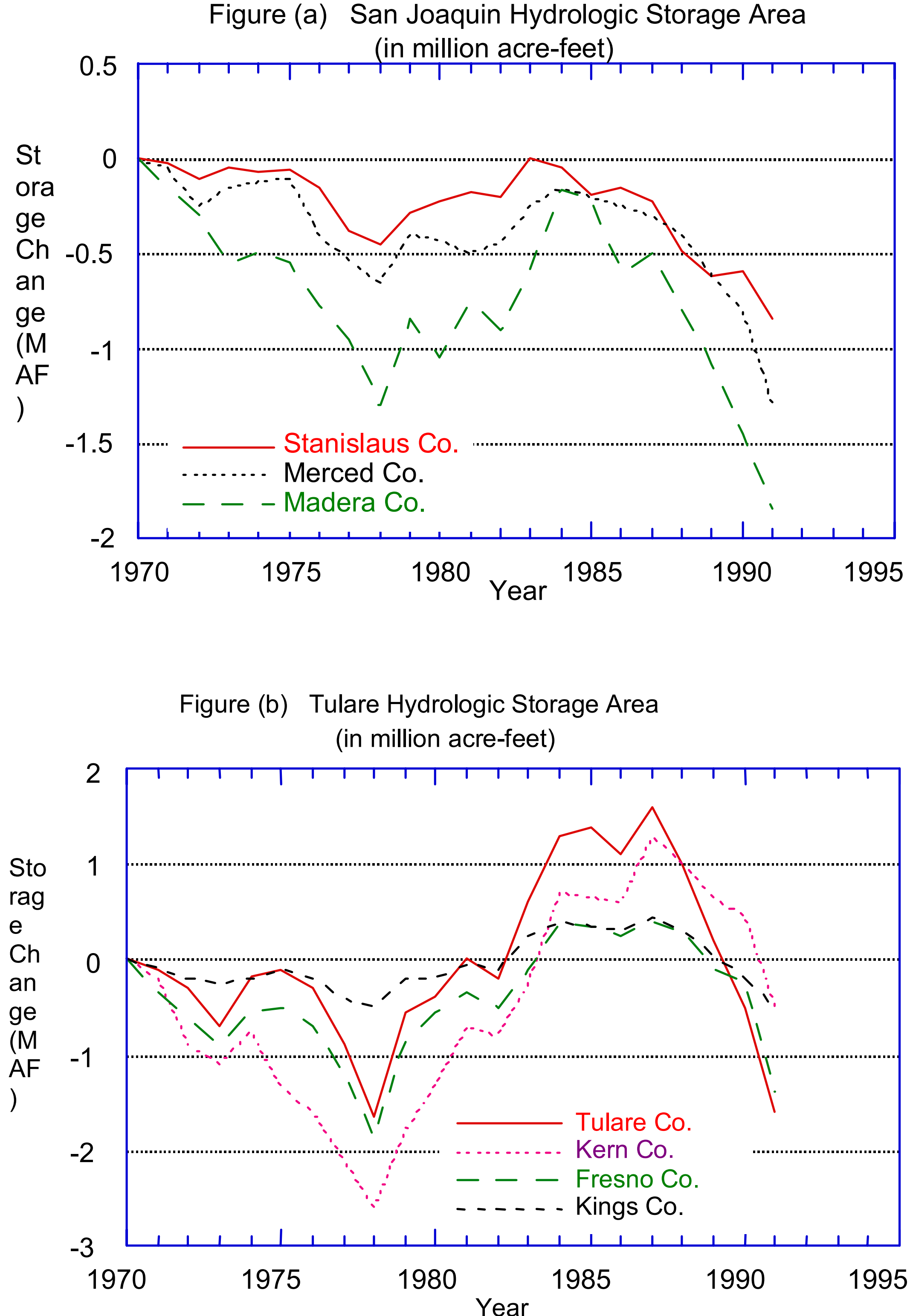
DROUGHT IMPACTS

Prior to 1990, the drought had minimal impacts because groundwater resources were able to compensate for reduced surface water supplies and significant surface water supplies remained in storage. The last two years of drought have changed this. Now the six years of cumulative drought conditions have affected all sectors of California. In 1990 the SWP reduced agricultural deliveries by 50 percent. In 1991, for the first time since it began operation, the State Water Project could make no deliveries for agricultural demands and reduced deliveries to urban areas by 70 percent. In 1991 the Bureau of Reclamation reduced deliveries from the Central Valley Project by 75 percent to most of its agricultural contractors and by 25 percent to others (DWR, 1991a). In 1992 deliveries from the SWP were reduced 55 percent and deliveries from the CVP ranged from 25 to 75 percent of requested amounts, depending on the type of contract. The impacts of these cutbacks and other drought-induced shortages are briefly summarized below

Agricultural Sector

Impacts of the drought on the agricultural sector as a whole were minimal for the first few years because "...the agriculture sector was in a strong financial position before the drought began and because it has been buffered by groundwater availability and the ability of farmers to alter planting patterns" (Gleick, 1991). In fact, in 1990 gross cash receipts for agricultural products reached record levels. However, individual farmers and some subsectors, such as dryland farming, were affected because of regional variations in groundwater supply and lack of precipitation for an estimated economic loss to agriculture of $455 million for 1990 alone. Since 1990 groundwater has become increasingly expensive to pump or is simply not a feasible source of supply because of quality problems. Also since 1990 deliveries from the two main agriculture water suppliers, the CVP and the SWP, have been reduced and competition for water from urban and environmental water demands has intensified.

Figure 3-1
Cumulative Change in Groundwater Storage



Source: DWR,

Urban Sector

Greatly reduced water supplies have forced numerous urban areas to implement mandatory water rationing programs, ranging from 25 to 50 percent. Many of these were implemented after voluntary reductions did not provide sufficient levels of conservation. However, except for communities dependent on isolated water systems, the effects of the drought have been manageable. Some municipalities have faced increased treatment costs because of reduced surface water quality, or increased energy cost because of lowered groundwater levels. The drought has also forced many to rethink their approach to water management. The costs of the drought to urban water users has not been systematically estimated, but has been especially great to the landscaping industry.

The drought has also affected energy production in the State. Hydroelectric power typically accounts for one-third of the energy used in a normal year and up to 40 percent in wet years. In 1990 this value dropped to approximately 13.5 percent. The drought has resulted in a roughly $2.9 billion increase in electricity generation costs during its first five years. (DWR, 1991a)

Environmental Impacts

Possibly the most severe and least quantifiable impacts of the drought have been borne by the environment. The following are some of the impacts (Gleick, 1991; DWR, 1991a):

• A wide range of endangered and threatened plant and animal species are directly threatened by low water conditions. For some species, the numbers have been reduced to such low levels that recovery to pre-drought levels may not be possible.

• Tree mortality in the Sierra Nevada has been extremely high. In some forest areas, 30 to 80 percent of the trees are dead or dying. Lack of precipitation has also increased the chances of forest fires and the cost of fire protection. This will likely cause substantial damage to the forestry and forest products industries, as happened with the 1977 drought.

• Federal and State wetland habitats were allocated only 25 percent of normal water supplies in 1991, risking large populations of waterfowl.

• Fisheries of all types have been severely impacted, particularly Coho and Chinook salmon, herring, and striped bass.

DROUGHT MANAGEMENT

Overview

Several approaches can be taken in planning for and managing droughts. The most traditional approach has been to size water supply capacity so that water demands can be met fully even under extremely severe and long droughts (Rippl, 1883). This approach has been modified in recent decades to try to modify the operation and interties of multiple reservoir systems to increase their yield during drought (Palmer, *et al.* 1982).

Over the last 20 year or so, the reduction of water demands has become another popular approach to drought management and planning (Gilbert, 1986). Water conservation has become an integral part of water supply planning in California since the 1977 drought, when a number of water utilities achieved water demand reductions in excess of 30% during the drought. Some utilities achieved demand reductions in excess of 50% (DWR, 1978).

More recently, water transfers have been explored as another approach to drought planning and management. Experience with this approach is a major result of the current California drought.

Management responses to the current drought can be separated into two distinct phases - early drought responses from 1987 to 1990, and recent response from 1991 to the present.

Early Drought Responses

In the early years of the drought, management strategies centered on standard practices in supply augmentation and demand management, with some new wrinkles. As conditions became more severe in 1991, drought response reached a critical stage and witnessed a fundamental, almost philosophical change in management. Responses to the first four years of the current drought are discussed in this section. More extensive discussion of early innovative responses to this drought appears elsewhere (Lund, 1991). Response to the past two years is the major focus of this report.

Supply Augmentation

Several supply augmentation methods used with varying degree of success in California are discussed below. These included the use of pumped storage facilities, groundwater, desalination, cloud-seeding, water reclamation, and system interconnections.

The San Luis pumped storage reservoir in the San Joaquin Valley has greatly heightened the flexibility of water operations within the state during the drought. Together with the state's conveyance facilities, the San Luis reservoir has enabled the SWP and CVP to store water that would otherwise have spilled to the ocean during the winter months and added flexibility to the operation of the CVP and SWP systems.

The greatest supply augmentation asset in the state is groundwater. Most of the surface water shortages during the first four years of drought have been made up from more expensive groundwater supplies, both naturally and artificially recharged.

The current drought has spurred the use of desalination technology for municipal purposes as well. Santa Barbara recently completed a 7.5 million gallon per day (mgd) reverse osmosis plant for use during emergency situations. The City of Morro Bay also recently finished construction on a 600,000 gallons per day (gpd) desalination plant. Desalination may be used more in the future as the cost of imported water increases and the costs of desalination decrease because of technological advances and economies of scale (DWR, 1991a). In the near future, however, desalinated water will most likely remain too expensive for most agricultural uses.

Currently there are twenty cloud-seeding, or weather modification, projects in California, sponsored in part by Solano County Water Agency, Los Angeles Department of Water and Power, the City of San Diego, and Southern California Edison Company. Both DWR and the Bureau of Reclamation are also investigating the feasibility of cloud-seeding projects. These programs are operated to augment local and regional water supplies and hydropower potential. Depending on the number of storms treated, estimates of increased annual precipitation range from two to fifteen percent (DWR, 1991a).

The early years of the drought spurred interest in water reclamation efforts. In many urban areas, reclaimed water makes up a small, but significant proportion of total water supplies, totaling over 51,000 ac-ft/year (45 mgd) statewide. Reclaimed water is used primarily for landscape irrigation, but has also been used for agricultural irrigation (DWR, 1991a).

Interconnections between adjacent water supply systems have been used to make water available to jurisdictions that face severe shortages. The San Francisco Water Department constructed a 45 mgd intertie to the SWP's South Bay Aqueduct. East Bay Municipal Water District (EBMUD), Contra Costa Water District and DWR are jointly pursuing the possibility of an interconnection between EBMUD's Mokelumne River Aqueduct and the Contra Costa Canal. The interconnection could be operational if 1992 is a very dry year. Interconnections have also been creatively employed to provide water from the State Water Project to the Santa Barbara region.

Demand Management

Demand management strategies have become traditional in California and great use of these has been made during the drought. Most major water utilities in the state have made extensive use of voluntary and mandatory water use restrictions. A large number of utilities have also developed programs in conservation retrofitting, industrial water conservation, and public education.

Water rationing is traditionally a water utility's most Draconian demand management measure, a last resort. However, the recent California drought has seen mandatory water rationing used as a major front-line approach to water conservation enduring for several years at levels between 10-25% (CUWA, 1991a; 1992). In a single year, some especially hard-hit agencies, such as Santa Barbara, have sought and attained water conservation rates of roughly 40%. EBMUD, the City of San Francisco, San Jose, and numerous smaller water providers have adopted various water rationing schemes for several years to maintain overyear storage for possible future drought years. This unexpectedly early and successful use of water rationing conflicts with traditional wisdom on rationing. Furthermore, the successful use of diverse rationing schemes points out how little is known about the design of water rationing efforts.

Given the rapid population growth of some areas in the state, the drought has resulted in restrictions and prohibitions on new connections and annexations to service areas in an attempt to forestall increased demands during the drought. This approach has been taken in some suburban Sacramento communities, Santa Barbara, and EBMUD.

Retrofitting of existing structures and landscapes to reduce water use has become common. As discussed in Chapter 6, many utilities now offer payments for adopting less water-intensive landscaping or ultra-low flow toilets.

Much of California's urban water use is for landscape irrigation. Partially as a result of the drought, water districts are encouraging local jurisdictions to enact ordinances establishing landscaping guidelines for new developments. Some of these guidelines restricted irrigation to drought-tolerant plants with drip irrigation systems. A more immediate drought response has been to prohibit lawn watering in some severely-affected areas, such as Santa Barbara (Hecht and Mayer, 1990).

During the drought, a number of utilities have provided expertise and visits to industrial sites to encourage and facilitate industrial water conservation. Often this conservation takes the form of re-use of industrial water within each industrial plant (CUWA, 1991b).

State Drought Measures

The State has developed several programs to assist in local drought management. The DWR Drought Information Center was established to serve as a clearinghouse for information about the drought. Its functions include the collection, verification, and dissemination of drought information; to provide assistance to water users and agencies in developing and sharing methods to conserve, exchange, and transfer water; and to coordinate all DWR joint drought actions with federal, state, local and private groups. Special financial programs have been set up by the Office of Emergency Services to assist individual farmers who suffered crop damage, counties in search of emergency water supplies or funds to repair or replace facilities affected by the drought.

Recent Drought Response

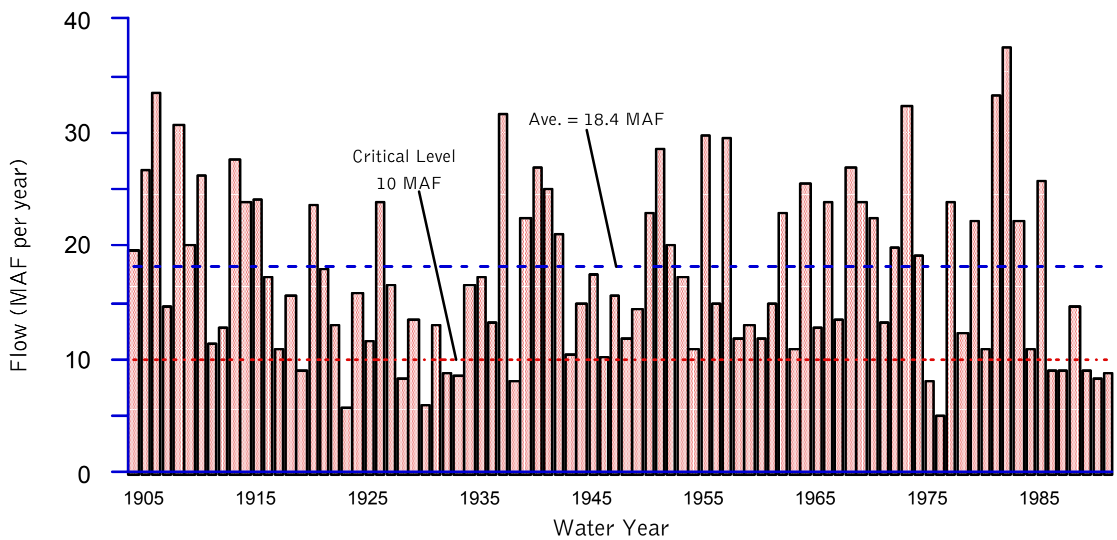
After four years of drought, when traditional supply augmentation and demand management measures served the state well, continued and increasingly severe drought conditions demanded more serious and experimental drought management measures. While much of the response to the continuing drought was to continue or intensify traditional supply and demand management measures, 1991 greatly accelerated the intensive and widespread use of water transfers for drought management state-wide. This followed a number of smaller-scale transfers over the preceding years, extending to well before the current drought. This will be the primary subject of the remaining chapters of the report.

COMPARISON WITH PREVIOUS DROUGHTS

Hydrology

California's two previous major drought events are 1929-34 and 1976-77. These periods can be seen on Figure 3-2, which shows the Sacramento River Index from 1905-1992. The driest six-year period of record in the Sacramento River basin is still 1929-1934, with average

Figure 3-2
Sacramento River Index (1905-1992)



Source: DWR, 1991a

unimpaired runoff of approximately 9.8 MAF per year, or about 53 percent of the 50-year average (18.4 MAF). The 1987-1992 average, based on May 1, 1992 estimates, is 10 MAF per year.

However, for some parts of California, including the central and southern Sierras and the San Joaquin River Basin, the current six year period is the driest on record. The year 1977 is driest year on record in California, and 1976 was the fourth driest year of record. Not surprisingly, this period constitutes the most severe two year drought of record in California. Precipitation, runoff, and reservoir storage values from the current drought are compared to those for the drought of 1977 in Table 3-1. The 1976-77 drought was a very short, very intense event. Its impacts were severe, but short-lived. Conditions quickly returned to normal as 1978 was a very wet year (DWR, 1978).

Management

Each drought in California's history has contributed new tools and management approaches for water resource managers. In the 1930s the solution was structural improvements in the form of reservoir construction (Pisani, 1984). In 1976-77, it was urban water conservation (Gilbert, 1986). For the current drought, water transfers and exchanges have found great use.

These new approaches to drought management are as much a reflection of prevailing social attitudes as they are technically correct and efficient. But, drought management also relies on past experiences. Lessons learned from previous droughts are embodied in the management plans for current and future dry periods. The 1976-77 drought showed that water conservation could be an effective form of drought management. But other findings were equally important. For instance, DWR (1978) makes the following recommendations, all of which have received considerable attention in the intervening years and have had an impact on how the current drought has been managed:

• "...a coordinated agreement between the [Bureau of Reclamation] and DWR is absolutely essential to assure that the federal CVP meets the same quality standards for the Delta... as the SWP does to protect existing water rights, anadromous fish, wildlife, and the productivity of the bay." The Coordinated Operating Agreement was signed by the Bureau and DWR in 1986 (*Agreement*..., 1986). It assigns responsibilities for maintaining Delta water quality and has been key in coordinating water transfers.
• "Groundwater will play a larger role in combating droughts in the future. Groundwater 'banks' need to be developed to store excess water during wet years for subsequent use during droughts." Future development of the Kern Water Bank and the Arvin-Edison-MWD exchange agreement, as well as other groundwater recharge projects statewide will likely be instrumental in reducing the impacts of the future droughts. However, these projects were not completed before the current drought.
• "...the Department pledges to continue its efforts in educating the public and in providing information useful in making more beneficial use of the water resource." The role of a well educated public cannot be underestimated in drought conditions. Many of the voluntary water restrictions were successful because the public already "knew what to do."

Although new approaches to drought management tend to become widely accepted as a result of new drought events, this is not to say that these new approaches have had their origins in these same droughts. Each new set of drought management innovations has been preceded by a long, and often controversial history of proposals, ideas, experiments, and legislation which has sought to introduce the innovation before the onset of drought (Pisani, 1984; Gilbert, 1986).

For water transfers, the current drought was preceded by over ten years of attempts to gain acceptance and use of water transfers in the state, including considerable legislation to make water transfers easier (Gray, 1989; 1990).

SUMMARY

The current California drought is but the latest in a series of drought events that have helped shape the development and use of California's water resources. Each drought has come at a particular period in the state's economic and social development, and brought with it motivation and opportunity for new innovations in water management throughout the state. The legacy of each drought to California water management has been experience with these new innovations.

The current drought has had significant economic impacts on most of the state. The drought also has had a significant impact on how water managers, political leaders, and the public think about water supply. Much of this management impact has been to refine the water management techniques implemented before the drought. In addition, and probably more importantly, the drought has motivated experimental implementation of relatively novel approaches to water management, such as water transfers.

Chapter 4

WATER TRANSFER USES AND THEORY

Water transfers are a common component of many regional water systems, but have come under increased consideration for meeting growing water demands and managing the impacts of drought. This chapter contains a review of common forms of water transfers, a brief review of the economic theory of water transfers, a summary of the different uses and types of arrangements for water transfers, and a description of some of the technical problems involved in effecting water transfers.

this study adopts the definition of water transfers as "the voluntary permanent or temporary change in the existing purpose and/or place of use of water under an established legal right or entitlement" (MacDonnell, 1990). Water transfers do not necessarily imply the transfer of water rights. It is much more common for water transfers to be an impermanent transfer of water itself, akin to the renting or lease of a water right, with the water right formally remaining with its original owner. Water marketing would be a subset of water transfers involving the sale of water.

COMMON EXAMPLES OF WATER TRANSFERS

While water transfers and water marketing are currently controversial in many parts of the country, it should be realized that there have been active water markets in most parts of the united states since early in this century. Most of these transfers are confined to within individual metropolitan areas or irrigation systems. These current examples of common water transfers show the degree to which water transfers are already a significant component of many water resource systems and some the ways in which transfers can be used.

Metropolitan Water Supply

Many metropolitan areas of the united states have some form of water market, where individual water utilities buy and sell water between each other on a relatively unregulated basis (Lund, 1988). Most of these transfers involve a single large seller, typically a large central city selling water to numerous large and small suburban cities and water districts. For example, roughly half the city of San Francisco's Hetch Hetchy system yield is used to supply the peninsula south of the city. The City of Seattle's mountain watersheds are the predominant supply for 34 suburban water districts with a larger combined population than Seattle, including Washington State's fourth largest city, Bellevue. This phenomenon is not restricted to the west coast, as shown in table 4-1.

The motivations for these sales arise out of some combination of the economies of scale of urban water supply acquisition, conveyance, and treatment and the historical legacy of central cities being the first to acquire most of the better, larger, and least expensive water supplies in many regions. It has been argued that both central city and suburban parties to these transfers and sales accrue significant advantages from this arrangement. These advantages are typically lower water supply costs, higher supply reliabilities, and greater capability and certainty in regional water supply planning. Still, there is often some degree of controversy and conflict between parties to these transfers (Lund, 1988).

Mutual Irrigation Companies

Water marketing and transfers within agricultural regions is an ancient practice. Maass and Anderson (1978) describe a very effective water marketing arrangement that has been in effect in one area of Spain since the before the time of columbus. In addition, there are almost countless water trades and sales between farmers throughout much of the western United States.

TABLE 4-1
PROPORTION OF SUBURBAN SALES FOR SELECTED U.S. CITIES

City	Metropolitan-Wide System Sales (Mgd)	Percent Sales To Suburbs (By Volume)
Atlanta	100	25
Chicago	1040	16
Dallas	170	16
Denver	168	29
Kansas City	75	13
Louisville	112	51
Miami	139	50
Milwaukee	154	14
Minneapolis	72	21
New York	1512	6
Phoenix	156	10
Portland	88	28
San Francisco	244	57
Seattle	122	38
St. Paul	47	18
Wilmington, Delaware	28	43

Source: After Capen, 1975

Mutual irrigation companies are common in the western united states. These districts are typically informally constituted cooperatives of farmers, with no governmental status. Each farmer has a share of the total amount of water available to the company. Water is then transferred by rental or sale of these shares to other farmers within the venture (Enright, 1989). It has been estimated that there are roughly 9,200 such mutual water companies in the western united states, with roughly 1,300 such mutual water companies in california (Resesz and Marks, 1981).

WESTERN WATER TRANSFERS

MacDonnell (1990) reviews recent transfers of water and water rights in six southwestern states between 1975 and 1984. This review found almost 6,000 change of water-right applications filed in these states during this period, primarily in Colorado, New Mexico, and Utah. The vast majority of these applications were approved by state authorities. There are untold additional cases where transfers have been effected without legal need for state approval. Water transfers within the Bureau of Reclamation's Central Valley Project (CVP) generally do not require state review, since the Bureau is the holder of a very general and flexible water right. Between 1981 and 1988, CVP contractors were involved in over 1,200 short-term transfers involving over 3 maf without state review (Gray, 1990). While water transfers in the arid and semi-arid west remain controversial, they are not necessarily unusual.

ECONOMIC THEORY OF WATER TRANSFERS

Although the economic theory of water transfers has been extensively addressed elsewhere (Howe, *et al*., 1986; Brajer, *et al*., 1989), it is summarized here. Three economic characteristics of market-based water transfers are considered particularly important: overall economic desirability, economic equity, and third-party impacts.

Overall Economic Desirability

Economists have long recommended making water a more transferrable commodity, based on economic and market theories. In theory, the market transfer of water improve the economic productivity of water and other resources in society.

In comparison to the absence of transfers, water marketing performs relatively well on six criteria for evaluating alternative mechanisms for allocating resources (Howe, *et al*., 1986):

1. *Flexibility*: Allowing water transfers provides greater flexibility in system operations and response to drought.

2. *Continuous resource use*: Allowing transfers ensures that water supply capacity is used maximally. For example, if a city were to construct a large reservoir with a yield beyond its current needs, allowing transfers makes it possible for this temporary excess capacity to be utilized by irrigation, hydropower, or other users. This encourages efficient use of developed resources and can can promote the earlier development of new water resources to be used by multiple users over time, rather than having each user construct their own water source (Lund, 1988).

3. *Users confront the real opportunity costs of water use*: When a water market is established, water users are faced with a comparison of the economic value of their use of water to the economic value of that same water to other users, represented by the market price.

4. *Predictability*: Water markets perform poorest in providing predictability to water allocations, compared to existing fixed long-term contracts and water rights. However, once a market is established, the outcomes should become rather predictable, as they are for other commodities distributed by market mechanisms.

5. *Perceived as equitable*: As discussed below, the voluntary nature of water markets ensures fairness between the two direct parties to a transfer. Regulatory efforts can be taken to reduce impacts to third parties. In a relative sense, market allocations of water can be seen as more fair than allocations traditionally based on mere historical precedence or political power.

6. *Reflection of public as well as private values of water*: Water markets do not consider explicitly public values of water, such as water quality and instream uses or economic impacts to third parties. Sometimes, these values can be represented in a market when, for instance, a private group or government agency purchases water for instream uses or wildlife or when economically affected third parties subsidize the purchase of water by specific water users. The performance of water markets on this criteria is somewhat better when it is compared with many traditional forms of water allocation, which allow minimal use of water for environmental purposes and do not consider the third party impacts of failure to transfer water.

While water market transfers are often desirable, the economic efficiency of water markets is likely to be imperfect when compared to the performance of an ideal market (Brajer, *et al*., 1989). The conditions required for perfectly efficient market conditions are difficult to attain, especially for a commodity such as water. Some problems particular to water are discussed below (Howe, *et al*., 1986; Brajer, *et al*., 1989):

- Water rights are often poorly defined, making ownership, transfer, and enforcement difficult.
- Water markets will often consist of relatively few buyers and/or sellers. This can change the market price for water from its ideal, marginal cost levels and change the use of water from its ideal, perfectly competitive market pattern. In extreme, but uncommon, cases the presence of few buyers or few sellers can lead to monopsonistic or monopolistic behavior in water markets.
- Water is often costly to convey between buyers and sellers, given pumping costs and the need for conveyance, storage, and treatment facilities. This reduces the number of potential buyers and sellers that can economically make use of transferred water.
- Legal barriers will likely further restrict the number of potential buyers and sellers, because some types of transfers will be legally prohibited or entail excessive legal expenses, delays, or uncertainties.

• Water transfers can have high transaction costs. The costs of legal fees, administration, monitoring, and mitigating potential third-party impacts can be high.
• Good information on potential buyers and sellers is often unavailable. Even for individual buyers and sellers, there may be little realization of the economic value of market participation. This consideration is probably much less significant once a water market has been established for some time.
• Communication between buyers and sellers may be difficult. Especially early in the development of a water market, it is likely that buyers and sellers will have difficulty in communicating and negotiating terms for water transfers. Neither party is likely to have developed an understanding of the other party's motivations and technical requirements for the transfers. Indeed the uncertainty involved regarding the long-term impacts of transfers on either party and third parties may further prolong, delay, or frustrate negotiations.
• Water transfers often involve third-party impacts. These impacts will be both positive and negative.

Economic equity

As Howe, *et al*. (1986) note, "Market transactions guarantee fairness between buyer and seller, by definition, since each must be made better off or one would refrain from trading." The consent of both parties to a voluntary transfer would seem to ensure a degree of economic equity between these parties.

Still, there is widespread concern for the equity effects of transfers on third parties. These are discussed below.

Third-party impacts or externalities

The transfer of water use from a seller to a buyer can significantly affect other, third parties. These impacts on third parties are also known as externalities. A list of potential third parties appears in table 4-2. More detailed discussions of the externalities of water transfers appear elsewhere (Committee On Western Water Management, 1992; Howe, *et al*., 1990; Little and Greider, 1983).

Third parties can be helped or harmed by water transfers. For water transfers from farms to cities, farm workers and farm service companies in the region selling water are likely to experience some economic harm. Yet, the purchase of additional water by the city will likely improve employment in some business sectors, such as the landscaping industry, nurseries, and manufacturers and sellers of lawn products. The relative magnitude of these impacts is often difficult to determine accurately, but their presence is undeniable.

More paradoxically, water transfers might aid members of a group in one region while harming other members of the same group in another region. Water transfers from one farming region to another will lower farm employment and demand for farming services in the selling region and increase farm employment and demand for farming services in the purchasing region. These changes in employment and local spending also have effects on the revenues and expenses of local governments, positive in the purchasing region and negative in the selling region.

Similarly water transfers of surface water from farms to cities can both help and harm fish and wildlife in the environment. By reducing application of water to farms, water quality downstream of the farm should be improved, to the benefit of fish. Yet, where the on-farm application of water served as habitat for migrating waterfowl, the removal of this water could harm these bird populations.

A number of mechanisms have been suggested to avoid or compensate third parties harmed by water transfers. Some of these mechanisms include (Committee On Western Water Management, 1992; CAN, 1992):

• Monetary taxing of transfers to compensate harmed third parties
• Requiring transferors to provide additional water for environmental purposes

- Providing state compensation to help economic transitions in water-selling regions
- Paying in lieu of taxes to jurisdictions from which water is exported
- Paying general sales taxes on transferred water to the exporting region
- Requiring regulatory approval of transfers
- Requiring third-party input or approval of transfers
- Requiring prior evaluation of third-party impacts of transfers, similar to an EIR
- Requiring formal monitoring of third-party impacts of transfers
- Public review of major transfer proposals
- Restrict transfers to "surplus" waters.

TABLE 4-2
SOME POTENTIAL THIRD PARTIES TO WATER TRANSFERS

Urban
Downstream Urban Uses
Landscaping Firms And Employees
Retailers Of Lawn And Garden Supplies
Rural
Farm Workers
Farm Service Companies And Employees
Rural Retailers And Service Providers
Downstream Farmers
Local Governments
Environmental
Fish
Wildlife
Those Affected By Potential Land Subsidence
Those Affected By Potential Groundwater Quality Deterioration
General
Taxpayers

INSTITUTIONAL FORUMS FOR WATER TRANSFERS

Water transfers can emerge from various forums: bi-partisan negotiations, multi-lateral negotiations, several forms of brokerage, several forms of bidding, and other means. The forum under which water transfers are developed, reviewed, and approved can substantially affect the number, type, and details of transfers that actually take place. The selection of a forum and process for establishing transfers is particularly important for the consideration of third-party impacts (Nunn and Ingram, 1988; Little and Greider, 1983).

Several forums that have been suggested appear in Table 4-3. There is of course potential to mix the use of different forums in the water transfer process, using one forum to set a price and quantity, with other forums performing technical and legal review of transfer proposals.

USES OF TRANSFERS WITHIN A SYSTEM

Once acquired, transferred water can be employed within a water system in a number of ways. Each use of transferred water within a system produces different benefits and sometimes produces different costs. Some of the operational benefits of using transferred water are summarized in Table 4-4.

TABLE 4-3
SOME INSTITUTIONAL FORUMS FOR VOLUNTARY WATER TRANSFERS

Forum	Authors
Free Market	Howe, *et al.*, 1986; Brajer, *et al*, 1989
Bidding Forums Industry Sponsorship Private Firms Special District Regional Agency State Or Federal Agency	Saleth, *et al.*, 1989
Water Banks And Pools Industry Sponsorship Private Firms Special District Regional Agency State Or Federal Agency	Howitt, *et al.*, 1992; rigby, 1990
Negotiated Two-Party Multi-Party	

Direct Use To Meet Demand

As described earlier, many urban water systems purchase water from other jurisdictions as their main source for meeting everyday water demands (Lund, 1988). Other cities, particularly in Arizona have used permanent purchases or other acquisitions of formerly agricultural water for direct use in their systems during normal years (MacDonnell, 1990). These are examples of permanent transfers to directly meet water demand in normal years.

During drought, when normal water supplies are deficient, transfers may be sought to directly meet demand only for the duration of the drought. This has been the case of much of the water acquired in 1991 and 1992 in the State of California's Drought Emergency Water Bank. These were typically temporary transfers used directly to meet demands still unmet after being reduced by drought water conservation measures.

Direct Use to Avoid Depletion Of Storage During Drought

If a water buyer wishes to hedge against the possibility of drought later in a year or in near future years, transferred water can be directly used to retain water stored in reservoirs. In semi-arid regions prone to over-year droughts, it is common to seek supplemental water supplies and drought water conservation in the early years of a drought, when ample water remains in storage so as to retain flexibility should potentially more severe drought years follow.

Overyear Storage During Wet Years

Transferred water acquired during wet years can be stored in overyear storage in reservoirs or aquifers. This enhances the yield of the system during drought years by increasing the amount of stored water available upon entering a drought. Overyear storage of transferred water is particularly well suited to acquiring water with junior water rights. Water with junior rights is typically less expensive than water with senior rights, but is only available during relatively wet years. The overyear storage of transferred water during wet years often requires additional surface or groundwater storage capacity, however.

TABLE 4-4
MAJOR BENEFITS AND USES OF TRANSFERRED WATER

Directly meet demand

Use transferred water to meet demand, either permanently or just during drought.

Lower costs

Use purchased water to avoid higher cost new sources.
Use purchased water to avoid increasingly costly demand management measures.
Seasonal storage of transferred water to reduce peaking capacity.
Use drought-contingent transfers to reduce need for overyear storage facilities.
Wheeling low-quality water for high-quality water to reduce treatment costs.

Improve reliability

Direct use of transferred water to avoid depletion of storage.
Overyear storage of transferred water to maintain storage reserves.
Drought-contingent contracts to make water available during dry years.
Wheeling water to make water available during dry years.

Improve water quality

Trading low-quality water for higher quality water to reduce water quality concerns.
Purchase water to reduce agricultural runoff.

Satisfy environmental constraints

Purchasing water to meet environmental constraints.
Wheeling water to meet environmental constraints.
Using transferred water to avoid environmental impacts of new supply capacity.

Another approach to producing overyear storage is to route excess surface flows controlled by urban users to farmers in wet years which can reduce farm use of groundwater. This increases or preserves groundwater storage during wet and normal years. In exchange, during dry years, farmers divert their own surface water rights to urban users and draw water largely from groundwater.

Seasonal Storage

There are sometimes opportunities to store transferred water on a seasonal basis to increase system yield during normal or wet years. Where within-year storage is available or can be economically constructed, the purchase of rights to water available during the wet season can make water available for storage during the wet season and use during dry parts of the year. This approach is attractive since junior rights to wet-season water are likely to be available at relatively less expense, yet will be available during most years.

Water Quality Improvement For Urban Users

By re-routing waters of different water qualities, the uses of different waters might be more economically matched with water users. This would typically involve exchanging high-quality waters to urban users and lower quality waters to agricultural users.

Satisfy Environmental Constraints

There are several ways to employ water transfers to address environmental concerns in system planning and management. By using transfers to avoid expansion of supply systems, the potential environmental impacts of any supply system expansion are avoided, or at least delayed. In some cases, it may be less expensive to purchase water from other users to meet instream flows rather than to reduce one's own use. By paying farmers to forego use of their riparian rights to water during drought years, more water becomes available for instream flows. This also makes more water available for downstream diversions for urban or agricultural uses.

TYPES OF WATER TRANSFER ARRANGEMENTS

There are numerous types of water transfers, summarized in Table 4-5. Each transfer form can have a different role in system planning and management and has different advantages and disadvantages for water buyers and sellers. Others have developed somewhat different taxonomies of water transfer types than the classification presented here (Committee On Western Water Management, 1992).

Permanent Transfers

In a permanent transfer, the buyer acquires the permanent right to use water from the seller. In the case of water sales from farmers to cities, this can involve reversion of the land to dryland agriculture, the immediate or gradual fallowing of farmland, the replacement of the farm's water supplies with a lower-quality water source (water less desirable from an urban use perspective), or the lease of the sold water back to the farmer during wet years. Permanent transfers are not uncommon in the west and can be accompanied by a lease-back arrangement in wet years.

Another form of permanent water transfer, common in Arizona, is to acquire water rights associated with recently-developed, formerly agricultural suburban lands. Some Arizona cities have made the provision of such rights to the urban water supplier a pre-requisite for annexation of new suburban developments to urban water systems (MacDonnell, 1990). This ties permanent changes in water use to changes in land use and does not require water rights to be severed from the land.

Long-Term Lease Of Water

Water right owners often wish to retain ownership of water rights, while entering into long-term lease arrangements with water users. Long-term arrangements would be long enough for a water user to rely on the transferred water almost as if it were a permanent water source. This might be a period of 20 or more years.

Leasing water allows water right owners to retain long-term investment flexibility in anticipation of potentially greater future values for water leasing or sale of a water right. For buyers of water, leases also can provide long-term flexibility where future water demands may not meet expectations. However, long-term leasing of water does entail risk for water buyers if water demands meet or exceed current forecasts.

Spot Market Transfers

Spot market transfers are short-term transfers or leases, typically agreed to and completed within a single water year. However, there is nothing to prevent a "futures market" for water where water is leased on a short-term basis for the following year.

Spot market transfers are typically established by some sort of bidding process, often with some of the conditions for transfer being fixed. However, spot market transfers can arise from negotiations between individuals or groups of buyers and sellers. A wide variety of bargaining rules for the operation of spot markets have been examined on a theoretical basis and through the use of simulation (Saleth, *et al*., 1991). These results illustrate the importance of bargaining rules when the numbers of buyers and sellers are small, less than about a dozen participants. For large spot markets, the effects of particular bargaining rules are quickly overshadowed by competition among buyers and sellers.

Water Banks

Water banks are a relatively constrained form of spot market operated by a central banker. Here, users sell water to the bank for a fixed price and buy water from the bank at a higher fixed price. The difference in prices typically goes to covering the bank's administrative and technical costs. Each user's response to the bank and involvement in the market is largely restricted to the quantity of water he is willing to buy or sell at the fixed price.

The California State Emergency Drought Water Bank (discussed in Chapter 5) is an example of a water bank or spot market where the terms and price of transfer were relatively fixed by the state acting as a banker, and participants primarily specifying how much water they wished to buy or sell. A similar phenomenon, on a smaller regional scale, is described for Solano County, California in Chapter 6 and Appendix A.

In agricultural regions, it is common for water banks or pools to exist within large irrigation systems. For many of these water pools, sellers only avoid the cost of purchasing water from the system's water wholesaler, with this cost, plus some administrative cost, being borne by the water buyer (Committee On Western Water Management, 1992; Wahl, 1989).

Contingent Transfers/Dry-Year Options

In many cases, potential buyers of water are less interested in acquiring permanent supplies than in increasing the reliability of water supplies during drought, other supply interruptions, or periods of unusually great demand. For these cases temporary transfers contingent on water shortages may be desirable.

Advantages of contingent transfers for the seller are the immediate infusion of cash, the potential infusion of additional revenues if the contingent transfer option is "called", an increased ability to predict the conditions and timing of any transfers, rather than relying on the vagaries of timing, price, and quantity on the water spot market. The long-term nature of contingent transfers also allows for a more thorough analysis and mitigation of potential third party impacts.

The temporal scale of contingent transfers is important. Long-term contingent transfer agreements can be established by negotiation between the two parties for a duration of 10-50 years. These long term transfers give each party long-term assurance of the terms and conditions of water availability. Such long-term agreements can help a water utility modify release rules for reservoir storage to maintain less drought storage than would otherwise be desired or reduce the need for long-term new source development.

Intermediate-term (3-10 year) contingent transfer contracts might be employed to help reduce the susceptibility of the buyer's system to drought during periods leading to the construction or acquisition of new supplies.

Short-term (1-2 year) contingent transfer contracts might be utilized by a system in the middle of a drought, with depleted storage, in preparation for the possibility that the drought might last a year or two longer. This type of short-term contingent transfer contract would enable the buyer to have committed water supplies under a possible condition when the system would be extremely vulnerable and allows the buyer to avoid some of the quantity, quality, and price vagaries of potential future spot markets.

A number of factors may be used to trigger contingent transfers. These include drought, interruptions of water supply due to earthquake, flooding, contamination, or mechanical failure, or unexpected increases in water demand. The appropriate time-horizon and conditions for a transfer agreement will depend somewhat on the particular source of unreliability that the buyer would like to eliminate. For example, the timing of the "call" mechanism for earthquake supply interruptions would likely be very different from the "call" mechanism for responding to drought.

Transfer Of Reclaimed, Conserved, And Surplus Water

Another form of water transfer involves the purchase of water made available from the reclamation of water or reductions in water demand.

Numerous urban water utilities have become involved in purchasing water back from their retail customers. Such schemes usually involve rebates to customers for installing low-flow toilets or removing relatively water-intensive forms of landscaping (DWR, 1988, 1991b).

Some cities have developed clever schemes where water transfers are made within their customer base. For instance, Morro Bay, California has a program whereby developers can receive water utility hook-up permits if they cause a more than equivalent amount of water demand reduction in existing customer through plumbing retrofits, landscaping measures, or other measures (*Wall Street Journal*, 1988; Laurent, 1992).

Finally, urban areas have taken an interest in financing the conservation of irrigation water to make additional water available for urban supplies. This has primarily been accomplished through the lining of canals. This approach can have additional benefits where agricultural seepage and drainage water has lead to water quality problems or high water tables, but can create additional problems where canal seepage is used to recharge groundwater (Gray, 1990; Sergent, 1990).

Wheeling And Exchanges

In the electric power industry, electric power is often "wheeled" through the power transmission system between power companies and electric generation plants to make power less expensive and more reliable. Water can similarly be "wheeled" or exchanged through water conveyance and storage facilities to improve water system performance. Again, such movement of water involves the institutional transfer of water among water users and agencies. There are a number of forms of wheeling water or water exchanges. Examples in California are discussed in Chapters 5 and 6.

Operational Wheeling

Sometimes the cost of conveying water or the losses inherent in water conveyance can be reduced by wheeling water through conveyance and storage systems controlled by others. An example would be the use of excess capacity in a parallel lined canal owned by another agency to convey water, rather than use of an agency's own unlined canal. Differences in pumping efficiencies might also motivate operational wheeling between conveyance facilities. Similar considerations might apply to decisions on where to store water during a drought, when different reservoirs have different seepage or evaporation rates (Kelly, 1986) or the distribution of hydropower heads is considerable for different storage options. These wheeling operations imply some sort of water exchange or transfer arrangement between agencies.

Wheeling To Store Water

A common form of wheeling is for cities to provide excess surface waters to farmers during wet years, with irrigators either using this water in part as a substitute for groundwater or for groundwater recharge. In exchange, the irrigators agree that the resulting stored groundwater will be available to the city during dry years or, more commonly, the city will contract to use the irrigators' own surface water rights during dry years, with the irrigators drawing more from the stored ground water. The Metropolitan Water District of Southern California (MWD) has pursued several such agreements, discussed in Chapter 6 and Appendix A.

Trading Waters of Different Qualities

water quality transfers are sometimes primarily exchanges of water made to improve the quality of water for one water trader. In many cases, historical happenstance has left agricultural users with rights to high-quality water for irrigation while new urban development is left with newer water sources with substantially degraded water quality. In such cases the costs of additional required water treatment for urban use of the low-quality water is much greater than the potentially slightly lower crop yields from agricultural use of the lower quality water.

Given reasonable conveyance costs, it therefore becomes desirable for water-quality based trades between agricultural and urban users. Urban users can often afford to make these trades on an uneven basis, trading more low-quality water for less high-quality water or providing a monetary inducement for a volumetrically even trade of water. Lesser quality waters might also be traded for environmental uses of aquifer recharge or habitat maintenance under some circumstances.

Seasonal Wheeling

Seasonal wheeling of water is common in agricultural regions where different sub-areas have complementary demands for water over time. This can provide opportunities for one water user to exchange water to another user during his low-demand season, with repayment coming in the form of additional water during the user's high-demand season.

Wheeling To Meet Environmental Constraints

By paying farmers not to use their riparian rights to water, the consumptive use from these flows becomes available for instream flows downstream. Another application of wheeling to meet environmental constraints could involve the use of storage facilities to release water when desired for instream flows while meeting demands before this time from other reservoirs or groundwater.

TABLE 4-5 MAJOR TYPES OF WATER TRANSFERS
Permanent Transfers
Contingent Transfers/Dry-Year Options
Long-Term
Intermediate-Term
Short-Term
Spot Market Transfers
Water Banks
Transfer Of Reclaimed, Conserved, And Surplus Water
Water Wheeling Or Water Exchanges
Operational Wheeling
Wheeling To Store Water
Trading Waters Of Different Qualities
Seasonal Wheeling
Wheeling To Meet Environmental Constraints

TECHNICAL ISSUES IN IMPLEMENTATION

Numerous substantive technical issues must be addressed in implementing water transfer agreements. Some of these are reviewed below.

Legal Transferability Of Water

The legal transferability of water is a major consideration in designing water transfers. The legal transferability of water will vary between states, and can vary within a given state over time as a state's water law evolves. In general, water rights typically specify the place of diversion, quantity of water, and use of water. Altering any of these may require regulatory approval. Different types of rights also have different transferabilities. Riparian rights, for instance are generally non-transferable from their initial location of use. Groundwater can be much more transferrable, in many cases because it is much less regulated (Kletzing, 1988). Much has been written elsewhere about the legal aspects of water transfers in California (Gray, 1989; O'Brien, 1988) and in other western states (MacDonnell, 1990).

Real Versus Paper Water

Where water transfers are motivated by real water shortages, the transfer of water on paper (e.g., by contract) must correspond closely with the transfer of actual water in the field. This is sometimes known as the distinction between real and paper water.

Tying quantities of paper water to real water is a difficult technical problem. In the case of transfers from farms, it is typical for farmers not to know exactly how much water they use or how much real water would become available if land were to be fallowed or cropping patterns altered (Ellis and Dumars, 1978). Even where such flow measurements are made, they are often inexact and of variable accuracy. In California, this farm water use estimation problem was addressed by per-acre water use factors for each major crop (DWR, 1992a).

Another problem with tying paper water to real water is establishing the hydrologic independence or interdependence of water sources. This is a common problem where pumped groundwater may actually be induced recharge from some surface water source.

Since water transfers typically also transfer water to another location and such transfers involve losses, less water should arrive at the buyer than was sold by the seller. The quantity of these losses can vary with the potential for seepage, leakage, or evaporation (especially of stored transfer water). Many water transfers in California must flow through the Sacramento-San Joaquin Delta, an estuary, necessitating a further conveyance loss due to the additional flows needed to move the salt water wedge seaward.

Particularly where there are a larger number of potential buyers and sellers of water, there would seem to be some need for standards or governmental involvement in tying real water to paper water transfers.

Water Right Seniority

In the west, under the appropriative doctrine, the purchase of water from senior rights brings with it a greater degree of reliability. The increased reliability of water from senior rights also typically raises its market value. This has several implications for how purchased water might best be used in the management of a system.

Drought-contingent contracts for water are probably best made with holders of senior water rights, since they are the least likely to be shorted during drought. However, if water is to be purchased with the intent to use or store it during wet years, it might be more economical to purchase water from more junior right-holders.

Conveyance, Storage, And Treatment

The mere purchase of water is usually insufficient to effect a water transfer. Transferred water must typically be conveyed and pumped to a new location, often stored, and commonly treated. Each of these activities implies substantial additional costs, which commonly exceed the initial water purchase price.

Since transfers are also usually a new use of existing water infrastructure, considerable work can be required to coordinate the use of conveyance, storage, and treatment systems. This can be particularly challenging because these facilities are often designed for very different operations. Occasionally, canals must be run backwards, water must flow backwards through pumps, and treatment plants must treat waters of a quality different from their design specifications.

Impact Evaluation and Monitoring for Third-Parties

Major water transfers might be required to provide an environmental impact statement regarding the potential for effects on third parties. The purpose of such a document would be to encourage more explicit consideration of potential externalities from major transfers. This can be a formidable and inexact estimation problem, involving difficult ecological and economic processes.

Another approach to third party impacts is to establish a monitoring program. Such a monitoring program might provide information on changes in local environments or economies that might result from the transfer of water to or from an area. The agreement on such a monitoring program and its implementation could involve much detailed technical work. In regions where there is substantial normal variability in the environment or economy, such monitoring might provide inconclusive results (Howitt, *et al*., 1992).

Contracts And Agreements

The legal transfer of water is typically effected by contract. The water transfer contract must specify a number of logistical and financial conditions of the transaction. The further physical transfer of transferred water typically also requires additional contracts or agreements with the operators of intermediate conveyance, storage, and treatment facilities.

Negotiated, bid, or fixed terms

Numerous approaches are available for arriving at a water transfer agreement (Saleth, *et al*., 1991, Nunn and Ingram, 1988). Terms can be negotiated, arrived at by any one of many bidding arrangements, or offered on fixed non-negotiable terms. The approach established for arriving at a water transfer agreement can have a significant effect on the final amount of water transferred and the economic efficiency of the transfer. Saleth, *et al*. (1991) develop a modeling study for different forms of bidding and negotiation rules for an agricultural basin. Nunn and Ingram (1988) examine the different forms of arranging water transfers from the perspective of consideration of third party impacts.

Water only

An agreement for the transfer of water must specify numerous logistical and fiscal details. Among these are: the location and timing of water pick-up from the seller, the fixed or variable price of the water, the fixed or variable quantity of the water, and potentially the quality of the water. The responsibilities for execution of the contract and liabilities for failure to completely execute the contract might also be included.

Conveyance

Where the transferred water cannot be conveyed directly between the buyer and seller, conveyance agreements are often required with third parties, either to make use of third-party conveyance facilities (pumps or aqueducts) or to coordinate the conveyance of transferred water through natural waterways within environmental limitations.

Storage

Similar to conveyance facilities, it will often be necessary to store transferred water in reservoirs or underground until it is to be used for drought, seasonal relief, or other uses. This will often require agreements or contracts for the storage of water with agencies which oversee storage facilities. When water is stored in aquifers, recharge and pumping facilities will be required, and legal arrangements with overlying landowners are common.

Treatment

Often the water that a water buyer has acquired would require additional treatment before being suitable for urban uses. In some cases, this treatment might be obtained from neighboring jurisdictions with compatible water treatment facilities and interconnected distribution systems. Such third-party treatment would require an additional water treatment contract or agreement. Some transfers of treated urban wastewater to agricultural uses require additional wastewater treatment.

TRANSACTION COSTS AND RISKS

The transfer of water often requires overcoming certain transactions costs. These costs include any legal fees, any costs for public agency review, the costs of any required technical studies, and any costs involved in settling claims from third-parties. MacDonnell's survey (1990) found that transaction costs averaged several hundred dollars per acre-ft of transferred perpetual water right, with averages of $380/ac-ft of perpetual right in colorado and $184/ac-ft of right in new mexico. These unit costs commonly decrease for larger transfers and increase with the controversy of a transfer. Still, transaction costs are highly variable between transfers. Where perpetual water rights are valued typically in thousands of dollars per acre-ft of yield, transaction costs are a substantial additional cost of water acquisition.

the risks of a transfer not being completed can also help dissuade potential partners in transfers. The risks of a proposed transfer being stopped entirely is particularly palpable where a substantial part of the transaction cost of a transfer must be expended before a transfer agreement is finally approved, or if there are high costs to delaying implementation of other water supply alternatives while transfers are being negotiated. This would be the case where large expenditures for technical and legal work must be made before final approval of a transfer is in place.

ROLES FOR GOVERNMENT

A number of roles for federal, state, and local governments can be found for facilitating water transfers. Government involvement can improve the prospects for water transfers by:

1. Improving the flow and reliability of information regarding transfers and transfer impacts,
2. Establishing a process for managing third party impacts,
3. Reducing the transaction costs of arranging and implementing water transfers, and
4. Increasing the probability that efforts between parties to arrange a water transfer will be successful and reducing the risks to parties from involvement with transfers.

Some particular roles for government in effecting these improvements are discussed below.

Technical

Perhaps the most appropriate role for government in water transfers is that of an arbiter of technical disputes and a regulator of the market. This role is needed in markets with many buyers and sellers to ensure a close tie between trades of paper water and real water and the coordination of the movement of transferred water with environmental regulations. Another role for government is in the arbitration of third-party impacts. Some role for state or regional government seems unavoidable under these circumstances.

Third Party Impacts

Government can take many roles in managing third-party impacts from water transfers. These roles include the technical role of providing information and standard methodologies for establishing the forms and magnitudes for third-party impacts. In addition, it is appropriate for government to provide guidance on the forums available for arbitrating or otherwise resolving potential third-party impacts. Without government involvement, the uncertainty and costs involved with real and potential third-party impacts will become more difficult to assess, more expensive to resolve legally, and constitute a greater barrier to transfers.

Banker

As will be seen with the California case, a state agency can successfully act as a banker of water, being an intermediate purchaser of most transferred water. A number of advantages for state water banks will be discussed in Chapter 5.

Regional governments can also act as banks in the formation of regional water markets, taking advantage of the regional hierarchy of governmental water jurisdictions commonly found in water management. Such a regional bank is examined for the case of solano county, California in Chapter 6 and appendix a.

SUMMARY

The use of water transfers in water resources planning and management is neither new nor simple. Actual employment of water transfers in real water resource systems is likely to employ a wide variety of transfer mechanisms and legal forms. These transfer arrangements can be arrived at through a number of negotiated and market means. The water acquired by these transfers can be put towards a variety of operational, environmental, and economic uses.

Overall, this abundance of forms of water transfers and their flexibility, combined with legal, third-party, and technical issues in implementing transfers, make water transfers one of the more promising, yet complex techniques for improving water management.

Chapter 5

California Drought Emergency Water Banks

The 1991 California Drought Emergency Water Bank was the first large water transfer program in the nation in which the State served as the predominant broker for water trades. It was created in response to the severe water shortages facing California in the winter of 1991. The Water Bank was established to provide water for critical municipal, industrial, and agricultural needs, preservation of fish and wildlife, and carryover storage as a precaution against yet another dry year. The 1991 Water Bank was considered largely successful not only because it was able to generate large quantities of water in a short period of time, but also because it was able to do so in a state where water trading and water marking has been especially slow to develop, relative to other Western states. Hydrologic conditions in California had not improved tremendously by the spring of 1992, and a similar but smaller water bank was established. This chapter provides a detailed examination of the 1991 and 1992 Drought Emergency Water Banks. This experience points to some roles and issues for using State or regional governmental brokers to manage or facilitate water transfers.

The California Drought Emergency Water Banks did not arise without precedence or long-term precursors. Some earlier water banks include the successful water bank sponsored by the Bureau of Reclamation for Central Valley Project (CVP) members during the 1977 drought and ongoing water pooling agreements within the CVP (discussed in Chapter 6). Similar water banks also exist elsewhere in the West, often as part of Bureau of Reclamation projects (Rigby, 1990). The establishment of the 1991 and 1992 Drought Water Banks were also facilitated by a series of items legislation items and technical studies conducted since the 1977 drought (Gray, 1989).

DEVELOPMENT OF THE 1991 DROUGHT WATER BANK

The 1991 Drought Water Bank was conceived as California entered the fifth consecutive year of drought conditions with very little promise of a return to normal water year levels. In February 1991, with only one month left of the traditional wet season, statewide precipitation averaged 28 percent of normal, most Sierra Nevada snowpacks were at less than 30 percent of normal, and runoff was about one-fourth of normal. Statewide reservoir storage was at 54 percent of the historical average, the lowest since the record dry year of 1977 (DWR, 1992a).

The Department of Water Resources (DWR) announced that the State Water Project (SWP) would deliver only 10 percent of the requests for water to urban areas and that no water would be delivered to agriculture. The U.S. Bureau of Reclamation (Bureau) announced similar, but less severe, cutbacks for its Central Valley Project (CVP): urban and agricultural CVP users would receive only 25 percent of their contract amounts and those with water rights settlements would receive 75 percent of contract amounts. Stringent water rationing, and severe cutbacks in agricultural production, as well as critical conditions for fish and wildlife were some of the widespread consequences of the water shortages (DWR, 1992a). Several counties had declared drought emergencies and the Governor had declared a state of emergency in Santa Barbara County.

On February 1, 1991, the Governor signed Executive Order No. W-3-91 which established the Drought Action Team. The team was established to (1) coordinate state efforts in mitigating the effects of the drought, (2) encourage local governments to develop drought emergency plans, and (3) to provide the Governor with reports and recommendations concerning drought management. The 1991 Drought Emergency Water Bank was established on February 15, 1991, as part of the Action Team's proposed drought plan.

The responsibility for organizing and implementing the 1991 Drought Water Bank was assigned to the Department of Water Resources. Staff members were redirected from other DWR programs and formed into teams to organize the operations that would establish the Water Bank. Teams were formed to negotiate purchase contracts for different regions of the state or for specific types of contracts, while others were assigned to work out the logistics and timing of water transfers. The Drought Emergency Water Bank was to be managed and accounted for separately from the SWP and other State contracts.

A Water Purchase Committee was formed to negotiate the terms and conditions of a model contract for buying water for the Bank. Committee members representing public agencies that might buy water from the Bank also aided in beginning negotiations and assisted in implementing water purchase contracts. In mid-February DWR began negotiating contracts to purchase water based on early estimates of critical water needs. At this time critical needs were estimated to be more than 800,000 ac-ft. These dropped to approximately 400,000 by mid-April. Sellers made water available to the Bank in one of three ways: (1) by fallowing farmland (not planting or irrigating a crop) and transferring the conserved irrigation water to the Bank, (2) by using groundwater instead of surface water, or (3) by transferring stored water from local reservoirs.

Prior to purchasing water, buyers had to demonstrate that they had made maximum use of current available water supplies, implemented a satisfactory degree of water conservation programs, and would be able to provide sufficient funding to cover their purchases from the Bank. There were additional criteria depending on the intended use of the purchased water. For example, municipal and industrial users were eligible only if available existing water supplies were less than 75 percent of their normal water demand. Agricultural critical needs had to pertain to supplying water for trees, vines, and other high-value crops. DWR reviewed all requests for fish, wildlife, and other critical needs on a case-by-case basis.

The allocation of water by DWR was prioritized based on 'Critical Need' to assure participants that those with the most urgent needs were met first. Allocations were made according to the following priorities (DWR, 1992a):

- Water to meet identified emergency needs, such as health and safety.
- Water for areas with critical needs, defined as: urban water users with less than a 75 percent supply, agricultural users who need water to assure the survival of permanent or high value crops, and fish and wildlife resources.
- Water for entities previously receiving allocations for critical needs and who need additional supplies to reduce substantial economic impacts resulting from reduced water supplies.
- Carryover storage for the SWP. SWP purchase of any remaining, unallocated Water Bank supplies provided the financial backstop for the program, with the remaining water saved in reservoir storage for later use should the drought continue.

A more detailed discussion on the prioritization of Water Bank allocations and critical need criteria is found in Howitt, *et al.* (1992).

Water Bank water was sold at a fixed rate. The price included all acquisition and administrative costs as well as costs incurred to satisfy outflow requirements for moving water through the Sacramento-San Joaquin Delta. The buyer was required to deposit 50 percent of the purchase price within seven days after enlisting in the Bank. Within 15 days, 75 percent of the cost had to be deposited. The balance was due prior to delivery of the water.

To protect the water rights of sellers and to encourage their participation in the program, several pieces of legislation were enacted to provide assurances to sellers. Assembly Bill (AB) 9 gives water suppliers explicit authority to enter into contracts with DWR or other water suppliers to transfer water outside their service area. AB 10 states that no temporary transfer of water for

drought relief in 1991 or 1992 will affect the standing of any existing water rights. Article 29 of the *Agreement Establishing a 1991 California Emergency Drought Water Bank* further specified several water rights assurances to sellers, including that transfers shall (Howitt, *et al.*, 1992):
• be deemed a reasonable beneficial use of water on the lands from which it was transferred;
• not constitute evidence of waste or unreasonable use;
• not affect or be a basis for any loss or forfeiture of rights to the transferred water or of rights of overlying landowners to pumped groundwater;
• not be evidence of the availability of surplus water or groundwater yield beyond the terms of the agreement; and,
• be in furtherance of state policies favoring voluntary transfers of water on an intermittent basis to help alleviate water shortages.

To further motivate early seller participation in the Water Bank program, the contracts contained a price escalator clause which assured that the seller would receive the higher price if prices increased or decreased in the future. The price escalator clause provided that if, by a specified date, the average price extended to a similarly situated seller exceeded the price in the contract by 10 percent, the seller would receive the higher of the two prices.

1991 WATER PURCHASE CONTRACTS

At the start of the Water Bank program, purchases focused on water from fallowed farmland for establishing a fair and workable price for acquiring the water. The intent was to offer a price that would yield a net income to the farmer similar to what the farmer would have earned from farming plus an additional amount to encourage the farmer to participate in the Water Bank.

After analyzing farm budgets, talking to potential sellers and buyers, and consulting with agricultural economists and others knowledgeable about crop water use, the acquisition price was set at $125 per acre-foot. Once negotiations began, it was difficult to change the established price. Relying on individual negotiations to set a different price would have caused unaffordable delays. Thus, the DWR paid $125 an acre-foot of water to all sellers, regardless of the source of the water or the crop not planted in the case of fallowing. Later in the year, after the surprisingly ample March rains and a mild summer, a more favorable water supply and demand condition allowed for the negotiation and purchase of 10,000 acre-feet at $50 per acre-foot and 10,000 acre-feet at $30 per acre-foot (DWR, 1992a).

The 1991 Drought Water Bank acquired a total of 820,665 acre-feet of water through 348 contracts (DWR, 1992a). The sources of the purchased water are listed in Table 5-1. The largest contribution to the 1991 Water Bank was from Yuba County, approximately 217,000 ac-ft, much of which was from the sale of water stored by the Yuba County Water Agency (157,200 ac-ft). Approximately 151,000 ac-ft was acquired in Yolo County, mostly through land fallowing. In all 51 percent of the acquired water came from 325 fallowing contracts; 32 percent from 19 groundwater substitution contracts; and 17 percent from four surface water contracts, as shown on Figure 5-1.

Fallowing Contracts

With fallowing contracts, sellers made water available to the 1991 Water Bank by agreeing to fallow their farmland (by not planting or irrigating a crop) and transferring the conserved surface water to the Bank. For the land to be eligible, it must have been farmed in the previous year, or set aside under the federal Farm Commodity program and planned for agricultural production in 1991. Verification of these criteria was based on acreage reports filed with the Agricultural Stabilization and Conservation Service (ASCS). Shallow groundwater levels in the Delta necessitated additional requirements for controlling excessive vegetation (e.g., weeds) to reduce water losses from subsurface seepage. If the seller breached the contract by irrigating with surface water, the seller was liable for liquidated damages equal to twice the price paid.

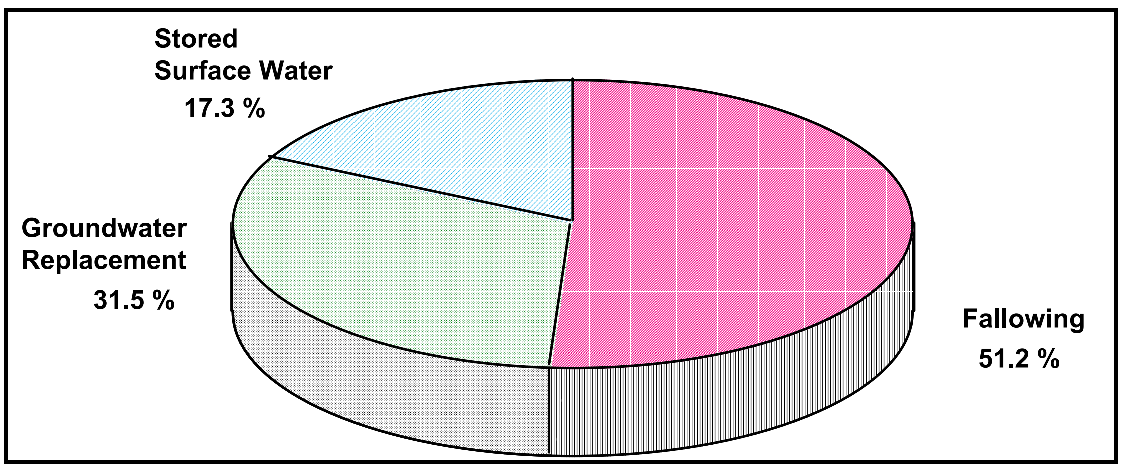
Just over half of the Water Bank supplies came from fallowing farmland. The crop acreages and locations are shown in Table 5-2. Of the 166,094 acres participating in the land fallowing program, corn acreage accounted for 35.7 percent. Wheat, pasture, alfalfa, and rice acreage accounted for 26.2 percent, 9.7 percent, 6.2 percent and 4.9 percent, respectively. The total acreage fallowed for the Water Bank is approximately ten percent of the field and vegetable acreage of the major counties, and is within the acreage fluctuations of the past four years, with the exception of corn in Yolo and Sacramento counties (Howitt, *et al.,* 1992).

Table 5-1
Sales to the 1991 Drought Water Bank
(acre-feet)

Region	Amount of Water Purchased
Above Shasta Reservoir	6,709
Sacramento River	76,730
Sacramento-San Joaquin Delta	338,688
non-Delta Yolo County	61,771
Yuba, Feather River, and Others	336,767
TOTAL	820,665

Source: DWR, 1992a.

Figure 5-1
Sales to the 1991 Drought Water Bank
(820,665 acre-feet purchased)



Source: DWR, 1991a

Table 5-2
1991 Drought Water Bank Crop Summary by County
(acres fallowed)

	Alfalfa *	Corn	Pasture *	Rice	Wheat *	Other	Total	% of Total
Butte County	0	0	0	1,158.0	1,455.7	458.5	3,072.2	1.8
Colusa County	0	0	0	2,231.0	0	92.2	2,323.2	1.4
Contra Costa County	678.0	6,500.0	1,482.0	0	1,344.2	576.0	10,580.2	6.4
Sacramento County	996.5	9,014.3	1,783.9	798.0	11,927.1	4,154.2	28,674.0	17.3
San Joaquin County	3,795.2	24,958.3	591.7	0	14,288.5	8,624.4	52,258.1	31.5
Shasta County	521.9	0	3,258.1	577.6	50.5	35.4	4,443.5	2.7
Solano County	913.8	5,471.7	3,208.5	0	5,859.9	3,097.3	18,551.2	11.1
Stanislaus County	0	136.0	0	0	0	0	136.0	.1
Sutter County	0	1,589.4	0	2,557.8	55.0	1,256.9	5,459.1	3.3
Tehama County	0	0	390.0	0	0	0	390.0	.2
Yolo County	3,313.6	11,606.6	5,473.3	857.8	8,602.9	10,351.8	40,206.0	24.2
Subtotal	10,219.0	59,276.3	16,187.5	8,180.2	43,583.8	28,646.7	166,093.5	100
Percent of total	6.2	35.7	9.7	4.9	26.2	17.3	100.0	100

* Crops planted but not irrigated.
Source: DWR 1992a

The total amount of water conserved by land fallowing was estimated as the net amount of applied water consumed by the crop. Information from a survey of crop water use conducted after the 1976-77 drought was used to calculate the amounts of water conserved by fallowing different types of crops. Crop consumptive use was estimated to be equivalent to the crop evapotranspiration assuming similar patterns of rainfall for the 1991 and 1977 growing seasons (Howitt *et al.*, 1992). A crop fallowing payment schedule identified the amount of water per acre that would be consumed by specific crops, as shown in Table 5-3. The price paid to fallow a specific type of crop was equal to the amount of water saved per acre multiplied by $125 per acre-foot. For example, the water conserved by fallowing an acre of sugar beets was estimated at 3.0 acre-feet; multiplying by $125 resulted in payments of $375 per fallowed acre. The estimates of crop water use were adjusted as the 1991 rainfall surpassed the 1977 levels.

Groundwater Substitution (Surface Water Replacement) Contracts

Sellers entering into groundwater contracts made water available to the Bank by substituting groundwater for surface water. DWR paid land owners to pump groundwater to irrigate crops and to allow the surface water they normally used to be transferred to the Water Bank. A few contracts were negotiated in which groundwater was pumped for direct transfer to the Bank.

Groundwater contracts involved the complex task of determining whether the pumped groundwater was "new" non-surface water. Water was considered "new" if it had been made available to the State’s supply system only because of actions undertaken as part of the Water Bank program. Well logs for each well entered into the program were reviewed to assure that the Bank received only new water.

Table 5-3
1991 Drought Water Bank Fallowing Payments for Selected Crops

Irrigated Crop	Sacramento Valley and Delta Upland		Delta Lowland (1)		Comments
	Crop Water Use, Acre-foot per Acre (2)	$/Acre	Crop Water Use, Acre-foot per Acre (2)	$/Acre	
Alfalfa	3.5	450	3.2	400	rounded amount
Dry Beans	2.1	263	1.7	213	rounded amount
Field Corn	2.5	325	2.0	250	rounded amount
Pasture	3.5	450	3.2	400	rounded amount
Rice	3.5	450	-	-	rounded amount
Sugar Beets	3.0	375	2.5	325	rounded amount
Tomatoes	2.5	325	2.1	263	rounded amount
Wheat, Barley (3)	2.0 1.5 1.0	250 190 125	2.0 1.5 1.0	250 190 125	prior to 3/1/91 3/1/91 - 3/13/91 after 3/13/91

(1) Slightly lower values were used for crops grown in lower elevations of the Sacramento-San Joaquin Delta due to the influence of seepage from surrounding channels.
(2) The crop water use numbers in acre-feet are the estimated consumptive crop water needs that were expected to be met by applied irrigation water. These amounts assumed minimum rainfall in 1991, similar to rainfall in 1977.
(3) Water savings for these crops depend to a large extent on rainfall. The initial value of 2.0 ac-ft per acre was progressively reduced over time due to the record rainfall throughout March 1991.
Source: DWR, 1992a

In many areas, the groundwater basin is the major regional source of agricultural and urban supply. Concerns were expressed that groundwater would be pumped for use outside the basin, potentially harming local areas. To address these concerns the groundwater contracts with landowners required that the seller meter the groundwater pumped. The local water district then released an equal amount of surface water to the Bank instead of the landowner. In this way, the pumped groundwater was used on lands overlying its source. To ensure that pumping did not harm local groundwater basins, monitoring programs were established in Yuba, Butte, and Yolo Counties. Yolo and Butte Counties also received a 2 percent payment on selected contracts to fund further development of their county water plans.

Reservoir Storage Withdrawal Contracts

Withdrawals from reservoirs accounted for 17 percent of the total water delivered to the Water Bank. The most significant acquisition of stored water involved an agreement with the Yuba County Water Agency (YCWA) which sold a total of 157,200 acre-feet of water stored in its New Bullards Bar Reservoir. Under the agreement, YCWA agreed to transfer 99,200 acre-feet in 1991 and 30,000 acre-feet would be stored in New Bullards Bar on behalf of DWR for release in 1992. In addition, DWR acquired 28,000 acre-feet on behalf of the Department of Fish and Game (DFG) to be applied for instream flow releases in accordance with shortage provisions of a 1965 agreement on stream flow releases between Yuba County and the DFG. This water was also used on wildlife refuges in the San Joaquin Valley. The water for DFG was purchased at a discounted price of $50 per acre-foot. Water for the Water Bank was bought at the usual $125/ac-ft.

ALLOCATIONS FROM THE 1991 DROUGHT WATER BANK

As of December 20, 1991, twelve entities had made purchases from the 1991 Water Bank, totaling 389,970 ac-ft (DWR, 1992a), compared with 348 entities selling to the Water Bank. Three jurisdictions -- Metropolitan Water District of Southern California, Kern County Water Agency, and the San Francisco Water District -- accounted for over 80 percent of the water purchased. MWD alone purchased 55 percent. Over 90 percent of the supplies allocated from the 1991 Water Bank were for municipal and industrial uses. The buyers and quantities purchased are shown in Table 5-4.

Table 5-4
1991 Drought Water Bank Allocations
(in acre-ft as of December 20, 1991)

Location	Amount Allocated	Percent of Total
Alameda Co. Flood Control & Water Con. District	500	0.1
Alameda Co. Water District	14,800	3.8
American Canyon Co. Water District	370	0.1
City of San Francisco	50,000	12.8
Contra Costa Water District	6,717	1.7
Crestline-Lake Arrowhead Water Agency	236	0.1
Dudley Ridge Water District	13,805	3.5
Kern County Water Agency	53,997	13.8
Oak Flat Water District	975	0.3
Santa Clara Valley Water District	19,750	5.1
Metropolitan Water District of Southern Ca.	215,000	55.2
Westlands Water District	13,820	3.5
TOTAL	389,970	100.0

Source: DWR, 1992a

Three factors help explain the difference between total Water Bank purchases (820,665 ac-ft) and total Water Bank allocations (389,970 ac-ft): 1) carriage water requirements for Delta water quality standards, 2) "technical corrections" for actual rainfall (i.e., March 1991) and technical fine-tuning of actual water savings, and 3) increased carryover storage (roughly 265,000 ac-ft.). To satisfy Delta water quality requirements, DWR must release more than one acre-foot of water from storage above the Delta to deliver an acre-foot to the Delta pumps for further delivery to southern California. The Delta carriage water requirement is typically 20-30 percent, but can be as high as 40 percent of the contracted sale. Storage and conveyance losses are the responsibility of the contracting member.

Selling Price

The purchase price for water from the Water Bank was $175 an acre-foot for water delivered as far as the SWP's Harvey O. Banks Pumping Plant at the entrance to the California Aqueduct. This price included DWR's purchase price of $125 an acre-foot, outflow requirements to move water through the Delta plus technical corrections, which reduced the net amount of water available for delivery, and the costs of monitoring and contract administration.

Most Bank water was delivered through SWP facilities. The costs of conveying the water through these facilities were negotiated in separate conveyance contracts. The SWP contractors who purchased Bank water paid primarily for the energy required to pump water to the contractor's area. Non-SWP contractors were charged an additional use-of-facilities fee, which consisted of a proportional share of the capital and annual operation and maintenance costs associated with SWP facilities used to make the transfer. Final delivery costs could be, and in many cases were, several times higher than the original purchase price.

The Conveyance Contract between DWR and the City of San Francisco (Appendix B) is an example of the additional costs that must be borne by a non-SWP contractor using SWP facilities to convey water purchased from the Water Bank. The contract stipulates points and rates of water delivery, as well as costs for using SWP facilities for conveyance and storage purposes, including, for example, a charge for the share of costs to offset fish losses resulting from pumping at the Delta; a California Aqueduct and South Bay Aqueduct use-of-facilities charge; a storage and regulation fee for use of San Luis Reservoir; and a monthly operation and maintenance fee. Some types of fees depend on the quantity of water transferred or stored, others are lump sum payments. In a separate agreement, San Francisco purchased 22,857 ac-ft of water from Placer County for delivery in 1991 and 1992. A separate contract with DWR was required for use of SWP facilities to wheel this water. The costs of conveyance, storage, and carriage water raised the total cost of water transfers by several hundred dollars in some cases. Additional discussion of the San Francisco transfers is provided in Chapter 6 and in Appendix A.

Operations

Enabling legislation for the 1991 Water Bank stipulates that use of State Water Project facilities by the Water Bank shall not be allowed to conflict with the operations necessary to provide water to SWP water supply contractors or to meet other SWP and State obligations. In other words, transferred water received lowest conveyance and storage priority in State facilities. This point along with the vast network of Bank water sources (351 contracts) required substantial coordination to match storage and delivery operations with the availability of Water Bank supplies. To minimize alterations in SWP and CVP operations and to maximize direct delivery of Water Bank supplies as they became available, water from the various sources was pooled and retained in the SWP-CVP system until the most opportune time for delivery. Both the SWP and CVP adjusted reservoir operations and Delta export pumping schedules to the greatest extent possible to accommodate deliveries of Bank water as well as to protect fisheries.

As originally proposed, Water Bank transfers would have increased Delta export pumping during July through October. However, analysis showed that pumping in July and August might harm substantial numbers of American Shad, Delta smelt, and striped bass at the Delta export pumps. Instead, during these months some deliveries of Bank water were met by releases from San Luis Reservoir which contained no Bank supplies. The water which was advanced from San Luis Reservoir was later replaced by Bank water stored in northern reservoirs and conveyed through the Delta in the late summer and fall, thus avoiding significant impacts to Delta fisheries.

As noted by Howitt *et al.*(1992), "(p)erhaps the most innovative operations of the SWP and CVP systems involved the acquisitions of water from holders of riparian rights who fallowed their lands." By law, riparian rights cannot be transferred, and yet the Bank was able to acquire water from holders of these rights. This was achieved by using transferred riparian rights to maintain the Delta water quality standards that must be maintained by the SWP and CVP. Prior to any export of water from the Delta, the SWP and CVP water supply systems must cooperatively maintain flows in the Delta to achieve minimum water quality, temperature, and flow requirements as specified in the State Water Resource Control Board decision, D-1485. To meet these water quality standards, the SWP and CVP must frequently release stored water. Riparian water right holders participating in the fallowing contracts forego consumptive water use and do not exercise their water rights, allowing the water to stay in the rivers and channels of the Delta. In doing so, the additional water retained in the Delta channels enables the SWP and CVP to decrease the amount of water released from northern storage to satisfy D-1485 water quality standards. This allowed the SWP and CVP to increase their available water supply for critical uses.

Monitoring

To ensure compliance with contract provisions, programs for monitoring land fallowing operations and groundwater pumping were developed. The monitoring program for Delta fallowing included two flyovers of the Delta and at least two detailed field evaluations or evaluation of aerial photographs, for each contract. The photographs were evaluated to assess the effectiveness of the fallowing program as well as contract compliance. Potential problems were dealt with on a case-by-case basis.

The groundwater monitoring programs were established in Yuba, Yolo, and Butte Counties. Where groundwater levels were of particular concern, data loggers were installed on a few wells to record well levels on an hourly basis. Elsewhere, water level monitoring equipment was installed in wells. Additional elements of the monitoring program included collection of water quality data and aquifer testing. The Yolo County program also included provisions for monitoring ground subsidence due to groundwater pumping. (See Appendix A.)

IMPACTS OF THE 1991 DROUGHT WATER BANK

Concerns about the possible effects of transferring water from other uses to the Drought Water Bank were expressed in many areas of the State. Some of the more pressing issues involve effects on local agriculture-based economies, groundwater basins, and the environment.

Howitt *et al.* (1992) analyze the effect of land fallowing in response to the 1991 Water Bank on county economies and the distribution of gains and losses from Water Bank activities. The impact of fallowing on the agricultural economy of a county was measured in terms of acreage or the value of output. Examination of the pattern of fallowing by crop and by county revealed that the majority of fallowing in 1991 was well within the fluctuations of agricultural activity of the counties. When compared with the total county economy, the estimated effects of Bank activities on local economies were relatively small. The Counties of Sacramento, San Joaquin, and Solano suffered the greatest net losses of county income and employment, which amounted to less than 1 percent of 1989 county personal income and 1989 county total employment even though all estimates neglected the benefit of the revenues from the Water Bank on the county's local economy. A detailed evaluation of the economic impacts of water transfer activities, particularly fallowing of agricultural lands, in Yolo and Solano Counties is being prepared by the Agricultural Issues Center of the University of California, Davis.

In a unique action, Yolo County, after performing their own estimates of the economic impacts to County welfare services from the water transfers and resulting unemployment (450 farm workers were laid-off), billed the State for $129,305 in compensation payments. The claim was rejected by the DWR, stating that there was no legal basis for such payments, and noting that the State had already contributed over $600,000 towards the groundwater monitoring program and more than $100,00 for water resources planning efforts (Davis Enterprise, 1992). In effect, DWR did not dispute that the Water Bank could have such impacts, and it encouraged Yolo County to file a claim with the State Water Resources Control Board. It is only through Board approval of such matters that DWR can legally make payment for damages.

The impacts of groundwater extraction were also considered. Such impacts included lowered groundwater levels, increased pumping costs or costs for deepening wells, potential subsidence, and decreased groundwater quality. Several extensive groundwater monitoring programs were conducted under the Water Bank program to collect data on aquifer characteristics and to aid local water managers charged with managing natural resources. As already mentioned, groundwater monitoring programs were established in Yuba, Yolo, and Butte Counties.

The effects of the drought on the Central Valley's fish and wildlife habitat were also of particular concern. Modifications to SWP operations, including Water Bank transfers, were made to minimize impacts on Delta fisheries. Although Water Bank operations were designed to have minimum impacts on fisheries and wildlife, not all impacts could be eliminated. To mitigate the indirect and cumulative impacts of water transfers on striped bass, DWR purchased an additional 300,000 yearling striped bass for release into the Delta (DWR, 1992a). DWR also purchased 28,000 acre-ft of water from Yuba County Water Agency on behalf of the Department of Fish and Game for meeting instream water quality requirements. Also, the fallowing of agricultural land stripped some waterfowl of temporary habitat and refuges.

Several groups including the Rand Corporation are currently evaluating third-party impacts of the 1991 Drought Emergency Water Bank.

1991 DROUGHT WATER BANK CONCERNS

To provide an independent evaluation of the 1991 Drought Emergency Water Bank program, DWR funded a study by private consultants to interview a representative sample of buyers, sellers, environmental organizations, and third party interests . The resulting report, "A Retrospective on California's 1991 Drought Water Bank" by Howitt *et al.* (1992) includes an overall evaluation and a general critique of the 1991 Water Bank program and offers some recommendations for future water bank activities. The following sections provide a summary of the issues and findings.

Concerns of Local Communities

Representatives from agricultural communities expressed concern about the potential impacts of water banking on their economies, particularly if water banking and trading happen frequently or are allowed to become permanent. They argued that many businesses could survive one year of loss, but not consecutive or frequent losses. It was recommended that evaluations of third party impacts carefully examine potential long term impacts on local communities.

Groundwater overdrafting, increased pumping costs to non-Bank participants, and subsidence are also of concern to local communities. The concern is that continuous or substantial groundwater pumping from Water Bank activities may result in these adverse effects. Many of the groundwater basins in the water selling regions are not heavily utilized. Hence, the hydrology between basins and surface water supplies are not fully understood. It was suggested that prospective Bank participants be required to fund studies to determine acceptable groundwater pumping rates and to develop long term water management plans.

Environmental Concerns

Representatives of fish and wildlife groups were concerned that no mechanism existed to allocate water for fish and wildlife. Although the cost of water sold included the cost of sufficient additional carriage water in the Delta (as required by Water Rights Decision 1485), and water was purchased specifically for fish and wildlife purposes, environmental representatives believed that the existing levels of protections were inadequate. Until the standards are upgraded, the environmental representatives did not want to see water transferred out of the Delta for water banking activities. Other concerns were that the rights to return flows were uncertain and that water banking would substantially reduce these flows. Many waterfowl habitats depend on return flows, particularly from agriculture, to provide their water supply. In addition, many migrating and resident birds use cultivated crops for food and nesting. Fallowing land for water bank participation would reduce both of these resources. It was noted that there was broad agreement among different interests that funds are needed for fish and wildlife protection, mitigation, and enhancement.

Legislation Issues

There was substantial concern and disagreement over the need for additional legislation at both the federal and state levels to promote water sales. The Warren Act, federal legislation enacted in 1959, in particular, was cited as one that discouraged development of water bank actions. The Warren Act does not allow federal facilities to be used to convey non-project water to non-project users. This restriction required parties to engage in complex agreements in 1991, which increased the costs and delayed the finalization of plans to acquire supplemental water involving the CVP system. The Warren Act was overridden by the Reclamation States Emergency Drought Relief Act of 1991 (HR 355).

Additional complexities arise when addressing the transfer of Bureau water or the use of Bureau facilities to effect a water transfer. These can arise from "the confusion concerning the nature of the relationships between the various parties, the ownership of water rights, and the source of governing law" (O'Brien, 1989). The Bureau does not define the relationships which exist between the end-users, who are most likely to suffer or benefit from the transfers, and the water districts contracting directly with the Bureau.

Water Bank Participation and Notice

Third party and environmental interest representatives complained that there was little or no opportunity for them to comment or participate in Water Bank operations or negotiations. Many felt that they should have been asked for informal comments. They expressed frustration that there was no easy way to influence the actions of the Water Bank.

Representatives of local communities expressed criticism that the water negotiations were kept secret. They felt that workers, particularly migrant workers and owners of farm-related businesses, should have been informed in a timely manner of a decrease in demand for farm labor and in production to potentially reduce third party impacts.

Criticisms Involving Uncertainty and Risk

Given the rapid rate at which the Water Bank was implemented, the levels of consumptive water use assigned to land fallowing and other such criteria were developed during negotiations. This created uncertainty for Bank participants as well as third party and environmental interests. Because DWR policy on implementing the Water Bank was changing, some sellers felt that there was insufficient information and lack of accessibility to available data to make an informed decision about whether or not to sell water to the Water Bank, to understand what was required to participate in the Bank, or to know the terms and conditions they could anticipate. Sellers stated that because of all the uncertainty about Bank operations, they would not have sold had they not received firm assurances by top DWR management that DWR would stand by their contracts once negotiated. (It should be noted that most initial agreements between sellers and DWR were concluded with a hand shake and a promise of written contracts in the future.)

EVALUATION OF THE 1991 DROUGHT WATER BANK

Most of those involved in the 1991 Drought Water Bank agree that it was surprisingly successful. In the matter of a few months, the 1991 Drought Water Bank acquired over 820,000 acre-feet of water through transactions with willing sellers. The large-scale water transfer program was implemented in less than 100 days and established important links with local water interests and local governments for future programs. The operational flexibility of both the SWP and CVP allowed conveyance of water through the Delta with minimal additional impacts to fisheries. That flexibility, excessive March rains, and the Water Bank enabled the State to meet all critical needs for water in its fifth year of drought.

Howitt *et al.*(1992) concluded that the trading of water through the Water Bank created substantial economic gains for both California agriculture and the statewide economy, although there were localized regions which suffered economically. By increasing the water available for agriculture, Bank allocations sustained the rural economy and rural employment in water importing regions of the state (especially in the southern San Joaquin Valley). The gain in employment in importing agricultural regions (1,153 jobs) exceeded the estimated job loss in exporting regions (162 jobs). The estimated income gain for agriculture in importing regions

($45 million) was over three times higher than the estimated loss of county income in exporting regions ($13 million) (Howitt *et al.*, 1992).

Water Bank operations provided some benefits to fish and wildlife that would not have been incurred under a "no-Bank" situation. Capture of juvenile fish in unscreened pumps and diversions in the Delta and Sacramento River was reduced since water diversions to farmland were reduced under the fallowing contracts. Fallowing lands also provided the opportunity to retain more water in reservoirs until later in the season. This helped to cool fall river water temperatures to benefit the fall run salmon. The reduction of irrigated acreage also reduced salts and chemical loading in return flows to the Delta.

There were criticisms and failings, however. Identified below are a few of the recommendations presented by Howitt *et al.* (1992) concerning the course of action for future water bank operations which would allow DWR to address some of the main criticisms of the 1991 Drought Water Bank, as discussed in previous sections. See Howitt, *et al.* (1992) for a more detailed discussion.

Early Notice

To maximize the participation of potential sellers, DWR should announce the formation of a water bank early enough so that growers can take into account the opportunity of water sales as they plan for an upcoming irrigation season. Notice should include the planned scope of Water Bank acquisitions, terms and conditions of contracts, and the nature of Bank operations.

Contracting Guidelines

The restricted number of different types of contracts limited the flexibility and efficiency of the 1991 Drought Water Bank. For example, for the evaluation of critical need criteria for environmental needs, DWR had to review all requests on a case-by-case basis. To implement more complex contracting strategies, it was suggested that DWR develop and publish formal contracting guidelines. This would serve to improve the administrative efficiency as well as the overall efficiency of the Water Bank operations. By publishing the guidelines, DWR would also avoid criticism concerning equal contract opportunities for all sellers.

The "contract guideline" document should be published no later than the formation of the Water Bank and should explain (Howitt, *et al*. 1992):

(1) the various types of contracts available to sellers;
(2) what a seller should expect to receive from each type of contract;
(3) the documentation needed under each type of contract; and
(4) how the water bank will administer each type of contract.

Dual-Class System of Contracts

Perhaps the most useful recommendation offered by Howitt, *et al*. (1992) is the use of a dual-class system of contracts consisting of early and late commitment contracts which would offer a mechanism for rewarding sellers and buyers who enter into early commitments with DWR.

As previously described, the price escalation clause provided an important incentive for sellers to participate in the 1991 Water Bank -- guaranteeing the seller the higher price should the water purchase price increase later in the year. Although this provides an incentive for sellers to commit early in the water year, there is no reward given to buyers for their early commitment.

The dual-class system would consist of early contracts or option-agreements arranged before some cut-off date (e.g. January 1), and late contracts, consisting of non-option agreements arranged after the cut-off date. Under the early contracts, the Water Bank would assure sellers a *reservation fee* to purchase the right to decide by a trigger date (e.g. February 15th) whether to buy the amount of water under the terms and conditions specified in the contract. The sellers receive the reservation fee whether or not DWR exercises its option to purchase water for the

Bank. In addition, if DWR acted on the option, it would pay the sellers a *water purchase price* based on the amount of water purchased by the trigger date.

Water acquired under early contracts would be placed in the early contract pool which would be allocated only to those buyers who make purchase commitments by the cut-off date. For buyers who commit to purchase water available under the early contracts, they have water supplies available under the locked-in water purchase price. They pay a reservation price which acts as an insurance premium enabling them to buy water at the locked-in price. If, for example, the water supply situation deteriorates, they have guaranteed water supplies at a lower price than buyers who did not purchase early contracts. If the water supply situation improves, they do not have to exercise their options to buy under the early contract conditions, and only to pay the reservation fee.

The water acquired under late contracts would be placed in a late contract pool which would be allocated to buyers who make a commitment to buy water under late contracts. The late contracts would contain only the water purchase price. The price would depend on the water supply conditions after the cut-off date.

In this manner, the dual-class system of contracts rewards sellers and buyers that commit early to the Water Bank and would enable the price escalation clause to be dropped from water purchase contracts.

Additional Recommendations

Additional recommendations deal with land fallowing issues, including the need to develop accurate and defensible crop water use patterns, the need to structure acquisition prices to reflect differences in yield from Delta fallowing contracts, and the need to establish limits on the amount of fallowed acreage permitted per region (Howitt, *et al.*, 1992).

Valuable experience was gained and many lessons were learned from the activities of the 1991 Drought Emergency Water Bank. This knowledge was instrumental in establishing and operating a modified Drought Emergency Water Bank in 1992.

DEVELOPMENT OF THE 1992 DROUGHT WATER BANK

The 1992 Drought Emergency Water Bank was initiated in March 1992 by the Department of Water Resources when it became apparent that California was entering a sixth consecutive year of drought. The 1992 Water Bank was undertaken with the same guiding principals and objectives as the 1991 effort. However, some significant modifications were made in implementing the 1992 Water Bank. A summary of 1992 Water Bank activities is presented below, followed by a discussion of the unique aspects of the 1992 Bank and how it differed from the 1991 Water Bank.

ALLOCATIONS FROM THE 1992 DROUGHT WATER BANK

In January 1992, prior to the February rains that filled many of the reservoirs in southern California, initial estimates of critical needs, as defined above, were as high as 500,000 ac-ft. When the Water Bank began operations in March, critical need demands had reduced to approximately 100,000 ac-ft. As of October 23, allocations from the Bank totalled 154,250 ac-ft. Buyers and their purchases are shown on Table 5-5. Agricultural purchases constitute approximately 62 percent of total Bank allocations. Twelve agricultural water districts participated in the 1992 Water Bank, but two, Tulare Lake Basin Water Service District and Westlands Water District, account for roughly 87 percent of all agricultural purchases.

Table 5-5
1992 Drought Water Bank Allocations
(in acre-feet as of October 23, 1992)

Purchaser	Amount Allocated	Percent of Total
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

Source: Department of Water Resources (1992)

Purchases by the State Department of Fish and Game (DFG) account for 13 percent and municipal and industrial demands represent approximately 25 percent of total purchases. Contra Costa Water District and MWD each purchased 10,000 ac-ft and the City and County of San Francisco purchased 19,000 ac-ft.

As of October 23, 1992, groundwater and conservation accounted for approximately 150,000 ac-ft of the water purchased by the Water Bank. The balance, roughly 35,000 ac-ft, came from direct surface water contracts. About 31,000 ac-ft had to be set aside to meet Delta water quality requirements. The contractors and the amount contributed to the Water Bank are shown on Table 5-6.

Table 5-6
Sellers to the 1992 Drought Water Bank
(in acre-feet as of October 23, 1992)

Contractor	Amount
Alhambra Pacific Joint Venture	5,000
Browns Valley Irrigation District	4,600
Conaway Conservancy	17,500
Davis Ranches	4,000
East Contra Costa ID	2,500
Los Rios Farms	15,000
Merced Irrigation District	15,000
Oakdale ID/South San Joaquin ID	50,000
Oroville-Wyandotte ID	10,000
Pelger Mutual Water Co.	1,500
Upper Swanston	995
West Sact./RD 900	1,500
Western Canal Water District	50,000
TOTAL	177,595

Source: DWR, 1992

The DWR purchase price of water for the 1992 Water Bank was $50/ac-ft. The selling price was $72/ac-ft, which includes $50/ac-ft basic purchase price and $22/ac-ft of additional costs for administrative purposes and Delta requirements. As in the 1991 Water Bank, separate contracts are drawn between the State and the Buyer for scheduling of deliveries, use of State facilities, and repayment of costs. Also,as in 1991, the SWP contractors who purchased Bank water paid primarily for the energy required to pump water to the contractors' point of delivery, since they are already paying for the facilities themselves. Non-SWP contractors were charged an additional use-of-facilities fee, which consisted of a proportional share of the capital and annual operating and maintenance costs associated with SWP facilities used in the transfer.

Participants of the 1992 Water Bank are permitted to carryover any undelivered Bank water for final delivery before December 31, 1995. However, carry over water receives the lowest priority in facilities owned and operated by the State and is subject to substantial storage costs. Carryover Bank Water can be lost by spillage if reservoir storage capacity is required for SWP purposes or other State needs.

COMPARISON OF THE 1991 AND 1992 DROUGHT WATER BANKS

Although conceived for the same general purposes, the 1992 Water Bank differed from the 1991 Water Bank in several key aspects, responding to some of the experiences with the 1991 Bank. Although 1992 was still a drought year, somewhat improved hydrologic conditions also influenced the scale, structure, and operations of the 1992 Water Bank. The major modifications to the 1992 Water Bank are the following:

1. The 1992 Water Bank is substantially smaller in volume than the 1991 Water Bank.
2. The 1992 Water Bank is primarily an agricultural water supply bank.
3. The 1992 Water Bank is completely underwritten by the buyers.
4. The fallowing of land as a source of water is not permitted in the 1992 Bank.
5. The 1992 Water Bank instituted a system of pools for allocating supplies.
6. The 1992 Water Bank uses Option and Purchase Deposits for water.
7. Water needs for wildlife interests were a key purpose of the 1992 Water Bank.

A Smaller 1992 Water Bank

The 1992 Water Bank is smaller than the 1991 Bank both in the quantity of water transferred and in total number of participants. Although there were twelve purchasers from the 1991 Water Bank and sixteen from the 1992 Bank, the number of sellers dropped considerably from 348 to eleven, and the amount of water purchased by DWR from 820,665 ac-ft in 1991 to about 177,595 ac-ft in 1992 (compare Tables 5-1, 5-4, 5-5, and 5-6.) Several factors may explain this.

In 1992 what precipitation there was came early, prior to establishing the Water Bank. The rains reduced critical needs from an estimated 500,000 ac-ft in January (comparable to the estimated critical needs at the onset of the 1991 Water Bank) to about 100,000 ac-ft in April. Total requests for water from the 1992 Water Bank were 154,250 ac-ft., compared to the 389,770 ac-ft allocated by the 1991 Water Bank. Less water was required to meet existing critical needs.

Because water demands were lower in 1992, so was the price that DWR was willing to pay for it. Following extensive analysis and much discussion in 1991, the purchase price for water that year was set at $125/ac-ft. In 1992 the purchase price was established at $50 per acre-foot. The low price may have kept prospective sellers from participating in the 1992 Water Bank.

The 1992 Agricultural Water Bank

The 1992 Water Bank was primarily a facilitator for the transfer of water between agricultural users. This year twelve of the sixteen water purchasers are agricultural users, and their purchases account for approximately 62 percent of all water allocated from the Bank, compared to about 20 percent in the 1991 Water Bank. The large urban users, such as MWD, San Francisco WD, Santa Clara Valley WD and Contra Costa WD, that dominated the Bank in 1991 (7 out of 12 purchasers were urban water districts), did not request significant amounts of water from the 1992 Water Bank. In fact, only MWD, San Francisco, and Contra Costa Water District have participated this year, for a total of 39,000 ac-ft.. The February 1992 rains were enough to replenish urban water supply reservoirs along the central and southern coast areas, reducing their needs for imported water. Agricultural areas which depend on groundwater for irrigation did not benefit as much from these rains, although they did serve to recharge aquifers somewhat. The lower price also made water purchase for agricultural use more economical.

1992 Water Bank Underwritten by Buyers

A major difference between the two Water Banks is that in 1992 the State did not assume the financial responsibility it had in 1991. One criticism of the 1991 Water Bank was that DWR purchased water on the basis of early demands, many of which did not materialize or were not followed with signed contracts. The drop in real demand from what buyers originally told DWR resulted in the over purchasing of water. The 1991 Water Bank ended up with a surplus of approximately 265,000 ac-ft as carryover storage in Lake Oroville, at a cost of about 45 million dollars. Howitt *et al.*, (1992) conclude that "the over-acquisition of water was an unavoidable consequence of the lack of negotiated agreements before the drought emergency and an understandable lack of knowledge about the supply and demand for Bank water." To ensure against repeating this behavior, no water purchases were made by DWR for the 1992 Bank unless there was a willing buyer who had previously entered into contractual agreements to buy water from the Bank. In this sense, DWR behaved as a true broker, matching supply to real demands.

Land Fallowing Not Permitted

Many of the problems and criticisms of the 1991 Water Bank were due to the land fallowing program. For instance, there was difficulty in establishing crop water use and, consequently, establishing a water purchase price. Also, there has been much debate about the economic and environmental impacts of the land fallowing program. To avoid many of these difficulties, the 1992 Water Bank did not purchase water conserved through the fallowing of agricultural lands. Only water acquired through groundwater exchange contracts and stored surface water contracts were accepted. This helped procedurally, environmentally, and politically.

It was possible to exclude land fallowing from the 1992 Bank because critical needs were much lower than they had been the previous year. In 1991, water from fallowed lands accounted for over 50 percent of Bank purchases. If demands this year had been higher, it is unclear whether DWR could have secured enough water to satisfy all critical needs without fallowing agricultural lands.

System of Pools

The 1992 Water Bank used a system of pools to record purchases and sales of water to and from the Bank. A Pool is defined in the contract documents as a portion of Bank Water sold to Members (contractors) at a single melded rate. The Pool Melded Rate is the total costs incurred by DWR to acquire water, including amounts paid to sellers of water; legal, administrative and financing costs; the impact of carriage water and other losses; refill impacts; and the costs of monitoring the impacts of water loss in the counties of origin, all divided by the amount of Bank Water in that pool available for delivery (DWR, 1992b). Each pool represented a specified demand to be met by the Bank. A new pool was created when supply and demand conditions changed; for example, when a contractor submitted a request for increased allocation, when new contracts for water were executed, or when the critical needs of a pool were satisfied. Although, the price for water from each pool was uniquely established for that pool, it did not necessarily have to change as a new pool was created. The 1992 Water Bank operated six pools, each at the same melded rate of $72/ac-ft.

The intent was that when a new pool was created, members of a previous pool with unmet critical needs automatically become members of the new pool. If for any reason the Water Bank was unable to secure enough water to meet all of the contractors' critical needs in any pool, the water available in the existing pool was apportioned in the following manner:

- 45% for municipal and industrial critical needs
- 45% for agricultural critical needs
- 10% for fish and wildlife critical needs

This distribution pertains to a specific pool at a specific price and is negotiated in the contract. If, for example, the price goes up and agricultural interests drop out a new pool is formed and the distribution could be different.

Option and Purchase Deposits and Contracts

Along with a request for water, contractors are required to submit a deposit for either the purchase or the option to purchase a quantity of water not to exceed their estimate of critical needs. Option deposits were $20/ac-ft and consist of $10/ac-ft paid to the sellers, $5/ac-ft Delta carriage water losses, and $5/ac-ft administrative surcharge. Contractors requesting options to buy must specify the month in which they would exercise their option. Once an option is exercised, the contractor must pay the prevailing pool melded rate for water. Purchase deposits are for the full cost of water, $90 per acre-ft (DWR, 1992b).

DWR developed several types of standard contracts to purchase water from different parts of the State under different circumstances, including contracts for the option to buy water. Some sample contracts for water transfers are included in Appendix B.

Wildlife Concerns

The water demands of fish and wildlife during the drought were a primary concern of the 1992 Water Bank. The Department of Fish and Game purchased 20,000 ac-ft of water for preserving fish and wildlife habitat. This represents a significant change from the 1991 Water

Bank, in which no direct purchases were made for this purpose, although purchases were made as part of the arrangements with the Yuba County Water Agency, as discussed above.

Other Differences

Coordinating operations were facilitated in 1992 because the Bureau was able to assume a more active role. Specifically, the Reclamation States Emergency Drought Relief Act of 1991 permitted use of federal facilities for the conveyance of non-project water. Also acreage limitations for use of federal water were waived, so it became easier to transfer federal water to both federal and non-federal entities.

STATE SPONSORSHIP OF WATER TRANSFERS

With the arrival of a fifth year of drought, there was little prior water trading experience in California and few candidates on whom the responsibility of the Drought Water Bank could rest. The urgency surrounding the need for the Drought Water Bank and the conditions under which the Drought Water Bank was established left little question that the State Department of Water Resources should be responsible for its operation and development. It is the consensus that only DWR was capable of organizing the emergency water trades on such a large scale as needed for the 1991 water crisis. Quick organization of the Drought Water Bank, within a few months, was essential for its success. Experienced personnel, knowledgeable in water transfers and in California water supply operations and distribution were needed to lead the development of the Drought Water Bank. To avoid a potential delay in the large-scale purchase of water, DWR was able to use funds from the State Water Project to provide the initial working capital. Few other agencies would have had such funding immediately available.

Another attribute of DWR managing the Drought Water Bank is the Department's position in the state's system of water institutions. Much of the logistics involved in the operation of the Water Bank are associated with the responsibilities already borne by DWR. As the agency responsible for the operation of the State Water Project, introducing water transfers into the water supply distribution network naturally falls under the agency's expertise and facilities. Also, essential to a water transfer program, DWR was able to obtain expedited approval of water transfers from the State Water Resources Control Board. Private parties would have encountered difficulty obtaining prompt approvals for the water transfers.

LESSONS LEARNED FROM THE STATE-OPERATED WATER BANKS

The experiences of the Emergency Drought Water Banks of 1991 and 1992 provide water managers and planners in California and elsewhere with numerous lessons for the operation of large-scale water banks and for the long-term management of water resources in general. Some of these are discussed below. Further discussion on the integration of water transfers in long-term water resources planning and management is provided in Chapter 7.

State-operated Water Banks have advantage.

The 1991 and 1992 Water Banks demonstrated that a centralized water bank can succeed, even in an environment where non-bank transfers are allowed and are actively pursued, as described in Chapter 6. The centralized banks have several advantages, in addition to those discussed in the previous section:

- Perhaps the most important attribute of the State-operated Drought Water Banks was the greater chance they provided for successfully completing a transfer for buyers and sellers dealing directly with the Bank. This was in part due to the relatively straight-forward nature of the contracting and negotiations processes, but also to the reduction in the likelihood of third-party interference in Water Bank transfers. This was supported by legislation waiving the need for environmental impact review of water transfers during

1991 and 1992. Potential third parties can greatly magnify the potential transfer costs of actual completed transfers and, thus, reduce their reliability.

• A centralized water bank, particularly one operated by the State, can substantially reduce the transaction costs of water transfers. By making a central water bank available, it became much simpler for potential buyers and sellers of water to negotiate transfers. Most of the terms of the transfers were standardized and communications contacts were clear; this would be unusual for many other forms of water transfers and was particularly desirable given the need to quickly arrange transfers within a particularly severe drought year.

All sectors are interested in purchasing water.

The Drought Water Banks demonstrated that parties in all major water-using sectors are interested in buying water. Purchasers of water included agricultural, urban, and environmental interests. It was also shown that some agricultural users are willing to pay very high prices for water during drought years. During 1991, significant amounts of water were purchased at $175/acre-ft by agricultural users, primarily those with high-valued and perennial crops. Still, most agricultural users could not have economically afforded these prices, and it is doubtful if even agricultural users that purchased water at $175/ac-ft could afford to do so on a continual basis.

There is a substantial interest in selling water in drought years.

The 1991 and 1992 experiences revealed that a substantial number of agricultural parties are interested in selling water, at least during drought years. Most of the water purchased in both years came from agricultural users. The remainder came from water agencies with surplus water supplies that largely would have gone unused. However, seller participation is price-sensitive. With the high price expectation created by the 1991 Water Bank (purchase price was $125/ac-ft), sellers were slow in agreeing to the $50/ac-ft price offered in the 1992 Water Bank.

Reservoir and conveyance operations are crucial for the success of water transfers.

The physical transfer of water through the State-sponsored Bank required supplemental agreements in most cases for the use of State aqueduct and storage facilities. In some cases, the operation and capacity restrictions of these facilities limited the timing of physical water transfers.

Special legislation may be required.

The two Water Bank were successful, in part, because many of the legislative and institutional constraints which hamper water transfers under normal conditions, were waived. No Environmental Impact Reports were required and the State Water Resources Control Board provided almost blanket approval of transfers involving the Water Bank. In the opinion of some, these waived restrictions support the belief that the 1991 and 1992 Water Banks were not a true representation of the potential for water marketing in California. This may be well enough for the State, which made it explicit when establishing the Water Banks that they were created to allocate water for emergency purposes only, and the water purchase contract shall not be regarded as a precedent. It is undertaken solely to assist in mitigating the impacts of drought conditions in 1992.

Transfers can also occur between water years.

Excess purchases in 1991 totaling approximately 265,000 ac-ft increased DWR's carryover storage for the State Water Project in 1992. This suggests a potentially useful role for future Drought Water Bank purchases for either recouping or maintaining overyear storage as a hedge against potentially worse drought impacts in future years of multi-year droughts. Such purchases, however, should be made only at a reduced price compared to purchases made for use in the same year.

Transfer arrangements improve with experience.

The 1991 and 1992 Drought Emergency Water Banks have provided the opportunity "to learn by doing" and "to learn from mistakes." Lessons derived from the 1991 Drought Water Bank were applied in the formulation of the 1992 Drought Water Bank. Lessons from both these experiences should be valuable both for any future State Drought Water Banks and for others interested in establishing Drought Water Banks or other types of water transfers.

Overall, the Water Banks made water transfers more acceptable.

The 1991 and 1992 Drought Water Banks, as well as other drought water transfer activities described in Chapter 6, involved many buyers and sellers of water with little previous experience with water transfers. The somewhat psychological and sociological precedence set by the 1991 and 1992 Drought Water Banks is likely to stir greater interest in and attention to water transfers of many different forms in California long after the current drought ends.

SUMMARY

California's State-sponsored Drought Water Banks of 1991 and 1992 were, literally and figuratively, a watershed in the development of water transfers in California. Within a few months of its establishment, the 1991 Drought Water Bank had been able to negotiate over 820,000 ac-ft of water purchases and almost 390,000 ac-ft of sales, with the remaining water going to instream flows in the Delta and overyear storage for the 1992 water year. In the course of arranging these transfers, 348 individuals, firms, and agencies had sold water; 12 agencies had purchased water; and most other major water users and suppliers in the state had become acquainted with the idea and the opportunities of water transfers. The extension of the Drought Water Bank into a second year demonstrates its overall perceived success, and the changes from 1991 to 1992 show some of the lessons learned from the first year's experience.

Overall, the California Drought Water Banks of 1991 and 1992 illustrate the advantages of government involvement in establishing water transfers at the local and regional level. The unique contributions of State involvement were to firmly demonstrate State support for water transfers as part of water resources management, increase the probability of success for individual transfers, lower the transaction costs of transfers, facilitate coordination of transfers with other water movements in the state, and temporarily waive some environmental impact reviews. The experience of the 1991 and 1992 Drought Water Banks will likely encourage the independent pursuit of transfers by individual agencies in the future and serve to establish water transfers as a water management technique even if the State never sponsors another water bank. However, as will be seen in Chapter 6, there were a great number of water transfers taking place outside of the State-sponsored water bank during this period.

Chapter 6

Other Water Transfers and Exchanges

The State administered Drought Emergency Water Banks of the past two years have drawn widespread attention and have been hailed by some as a new and innovative approach to water resources management in California. However, water transfers and exchanges are not a new or particularly original form of water management, even in California. Although, water markets and transfers have been slower to take hold in California than in other western states, they have been used successfully under both normal and emergency conditions. This Chapter presents some examples of water transfers and exchanges which have occurred in California independent of the State Drought Emergency Water Banks.

The transfers discussed here are organized primarily by the major sponsoring agency. Usually this is the purchasing agency, but it is sometimes a selling water right-holder or an intermediate regional water resource agency. By presenting the discussion from the perspective of the sponsoring agency, this section should provide a flavor for the types of water management strategies to which water transfers can be applied. The latter part of the chapter identifies several additional types of water transfers and exchanges which have been successfully used by various institutions throughout the state. This discussion will illustrate the diversity of forms that water transfers can take and the flexibility that these transfers can add to individual and regional water systems.

TRANSFERS INVOLVING THE METROPOLITAN WATER DISTRICT

Almost two-thirds of the water used within the Metropolitan Water District of Southern California (MWD) is imported from three separate supply sources: the State Water Project bringing water from northern California, the Colorado River Aqueduct, and the Los Angeles Aqueduct bringing water from the Owens Valley and Mono basins. The balance is provided by local surface and groundwater sources (see Chapter 2). The volume of water supplied by the three aqueduct systems varies substantially over time and is not seen as sufficient to meet the MWD's long-term water demands. In addition, MWD faces decreasing Colorado River water supplies, once the Central Arizona Project is completed.

To increase the reliability and yield of its water supply system, MWD has long pursued alternative sources of water supply, including water transfers, exchanges, and innovative wheeling arrangements. Some of the more notable examples are discussed below. The planning strategy taken by MWD is discussed further in Appendix A.

Imperial Irrigation District-MWD Transfers

The transfer of water between the Imperial Irrigation District (IID) and MWD involves a 35-year contract for MWD payments for canal lining and other system improvements in IID's irrigation infrastructure in exchange for the water saved by these improvements. The savings are estimated at 100,000 acre-ft/year of water from IID's Colorado River water supplies.

The IID's motivation for the agreement stems from a 1980 petition filed with the California State Water Resources Control Board by a farmer with lands bordering on the Salton Sea. The Salton Sea is supplied by excess drainage and return flows from IID's service area. The suit alleged that the farmer's land was being flooded by these excess flows and that this constituted an unreasonable use of water by IID. The Board agreed with the farmer, and took a position that threatened IID's rights to the use of this quantity of water.

To resolve this issue, MWD attempted to establish an agreement with IID to fund water conservation measures within IID in exchange for the conserved water. Negotiations began in 1984 and continued intermittently until 1988 (Sergent, 1990; Reisner and Bates, 1990). Final agreement was reached three months after the State Water Resources Control Board ordered IID to conserve 20,000 acre-ft by 1991 and 100,000 acre-ft by 1994. The settlement, which was endorsed by the Board, helped preserve IID's original water rights at little cost. Indeed, rights to the 100,000 acre-ft/year of water to be supplied to MWD remain with IID (Gray, 1990).

Under the agreement MWD will pay approximately $92 million for the capital costs of irrigation system improvements, over $3 million/year in operation and maintenance expenses, and up to $23 million in liability for indirect costs (Gray, 1990). At a 5% real (inflation corrected) discount rate and an infinite amortization period, these costs total about $90/acre-ft of water or $1,750 per acre-ft/year of firm yield.

Coachella Valley Water District and Desert Water Agency Exchanges

In 1967 the Coachella Valley Water District and the Desert Water Agency entered into long-term exchange agreements with MWD. There are three main reasons for the success of these agreements:

1) Coachella Valley Water District and Desert Water Agency have entitlements to water from the SWP but have no means of getting this water directly from the SWP. By exchanging their SWP entitlements for a portion of MWD's Colorado River entitlements, both water agencies could utilize their SWP entitlements.

2) Coachella Valley WD and Desert WA typically use groundwater for irrigation and municipal and industrial purposes. They are concerned about long-term impacts of over pumping their groundwater aquifers. Use of Colorado River water should alleviate this concern.

3) MWD can improve overall water quality and reduce treatment costs because SWP water acquired from Coachella Valley WD and Desert WA is lower in salinity than water from the Colorado River.

The exchange agreements were amended in 1983 and are now valid until 2035. The actual exchanges began in 1973, and have been interrupted only by the 1976-77 drought. The Coachella Valley WD-MWD exchange is for up to 61,000 ac-ft annually. The Desert WA-MWD exchange varies depending on the status of Desert WA's entitlements from the SWP, which increase to a maximum of 38,100 ac-ft by 2035. Because they involve Colorado River water, these water transfers do not fall within the jurisdiction of the State Water Resources Control Board.

A supplemental agreement allowing MWD to make advance deliveries of Colorado River entitlements to the water agencies was signed in 1984. The advanced deliveries of up to 600,000 ac-ft are stored in groundwater basins for later use. In this manner, MWD is at liberty to take full delivery of its Colorado River entitlements, as well as the SWP entitlements if they feel conditions warrant such actions, during droughts for example. During these periods Coachella Valley WD and Desert WA draw from the groundwater bank.

Gray (1990) describes these exchange agreements as "...successful examples of how water transfers, conjunctive use of alternative supplies, and water banking can expand the efficiency and supply capacity of the systems that, considered in isolation, are at their physical limits."

This agreement enhances the reliability of both parties' systems at relatively little cost. Like the IID agreement, it is not a sale of water or water rights, but rather an exchange of water. This agreement also has an important water quality component in that it allows MWD to trade lower-quality Colorado River water for higher-quality water from the SWP.

Arvin-Edison Exchange Agreement

The Metropolitan Water District and the Arvin-Edison Water Storage District (AEWSD) have filed a request with the State Water Resources Control Board for a long-term water exchange contract between the two Districts. During wet years up to 135,000 ac-ft per year of MWD's entitlements from the State Water Project would be delivered to AEWSD, which could use this water for recharging their aquifer or directly for irrigation. In dry years, AEWSD would use groundwater in lieu of their surface water entitlements to the Central Valley Project. Thus, up to 128,300 ac-ft (AEWSD entitlements to the CVP) would then be available annually for MWD to use during these dry periods (Gray, 1990).

SWP facilities would be used to deliver CVP water to MWD. SWP deliveries to AEWSD would use SWP facilities and the locally-owned Cross-Valley Canal. The proposed exchange agreement requires that the point of diversion for the Bureau's water rights be amended by the State Water Resources Control Board to include the Banks Pumping Plant at Clifton Court Forebay (entrance to the SWP aqueduct), and that MWD be added to the Bureau's service area. The exchange agreement would extend from 1995 to 2035 and remains under review.

Exchanges During the 1976-77 Drought

During the 1976-77 drought, MWD increased its deliveries from the Colorado River and relinquished a total of 400,000 ac-ft of SWP entitlements. The San Bernadino Valley Municipal Water District, Coachella Valley Water District, and the Desert Water Agency also relinquished entitlements to SWP supplies totalling 35,279 ac-ft. Thus, DWR had 435,279 ac-ft of water for water-short areas (DWR, 1978).

DWR used this water to supply farmers in the San Joaquin Valley, who without the exchange would have received only 40 percent of their entitlements. With the exchange the farmers received 89 percent of their supplies. Some of the transferred water also went to urban users in the San Francisco Bay area, namely, East Bay Municipal Utility District, Contra Costa Water District, and Marin Municipal Water District (DWR, 1978). DWR also contributed to the Water Bank established by the Bureau of Reclamation in the Central Valley (discussed below).

TRANSFERS WITHIN THE FEDERAL CENTRAL VALLEY PROJECT

The transfer of water between contractors of the Bureau of Reclamation's Central Valley Project has been an integral component of the project's operating and management philosophy since its inception. The vast network of storage, pumping, and conveyance facilities has been used to transfer surface and groundwater to maximize project supplies, to minimize project costs, and to improve the timing and efficiency of deliveries to project contractors. The primary purpose of transfers within the CVP system has been to equalize variations in water demands between farms and water districts. This has included both seasonal exchanges of water and special transfers for drought management.

Because of the unique nature of the Bureau's water rights for the CVP, which specify the entire Central Valley as the source and place of use, these water transfers have, with few exceptions, not been subject to the regulatory mandates of the State Water Resources Control Board. The only transfers which must be reported are those that propose to change the type of use of the water, e.g., from agriculture to municipal and industrial uses. But since the majority of the transfers occur between agricultural users, they do not need to be reported. The majority of the transfers have occurred by *ad hoc* agreements between individual contractors.

This section discusses the routine transfer of water between individual CVP contractors, the special pooling arrangements that exist between two groups of contractors, Bureau transfers which involve the State Water Project, and the federal water bank established to ameliorate the impacts of the 1976-77 drought.

Routine Water Transfers

In the past decade alone, over 1,200 transfers totaling roughly 3 MAF have been effected. Individually these transfers have ranged from a few acre-feet to over 100,000 acre-feet. The primary purpose of these transfers is to accommodate fluctuations in water needs during the year due to changes in cropping patterns and weather. The Bureau imposes six basic restrictions on the transfer of water between individual contractors (Gray, 1990):

1. The transferor must have excess water available under its allotment.

2. Transfers are applicable only for the water year in which the agreement was established and all transfers must be completed within that year.

3. The transferee must have a contract with the Bureau for a use of water authorized by the transferor's contract. Otherwise the transfer constitutes a change in the water right and must be reported to the SWRCB.

4. The transferee's intended use must not violate reclamation law, e.g., acreage limitations.

5. Price of the transferred water is subject to review by the Bureau to ensure that transferors do not profit from the transaction.

6. Transfers between field divisions are not permitted. This effectively limits water transfers across the sensitive Sacramento-San Joaquin Delta.

Similar arrangements for establishing a water market within the State Water Project have also been proposed (Curie, 1985).

Permanent Pooling Agreements

Several Bureau contractors, the Sacramento River Water Contractors Association (SRWCA), the Tehama-Colusa Canal Authority (TCCA), and the Arvin-Edison Water Storage District have established permanent pooling agreements whereby members deposit water into a pool when there is surplus and make withdrawals in times of shortage. The SRWCA pool was established in 1974 and the TCCA pool in 1981. Participants in these pools are restricted from transferring surplus water to non-participants, and may only purchase water from non-participants if the pool has insufficient supplies. All deposits and withdrawals are reported to the Bureau and subject to its review, although, for all practical purposes, the pools are managed independently by SRWCA and TCCA (Gray, 1990).

The SRWCA pool has historically operated with a surplus. The excess deposits are returned to the Bureau for redistribution to non-SRWCA members. Total annual water use by SRWCA members is approximately 938,000 ac-ft, but only a small percentage comes from the pool. From 1983-1988, the pool provided about 0.3 percent of total supplies, and total deposits were about 10 times greater than withdrawals. However, the TCCA pool typically operates at a deficit, and routinely receives deposits from the Bureau and non-TCCA members.

Since 1970 the Arvin-Edison Water Storage District (AEWSD) on the east side of the San Joaquin Valley has operated a water exchange pool among its farmers (Wahl, 1989). Exchanges within the pool have been as high as 7.6% of the district's firm water demand. Offers to buy and sell water are made during the winter. Water is purchased at the normal district rate and is not set by a market. Exchanges are also limited to within the district's boundaries.

These pools provide an efficient means for offsetting short-term imbalances between supply and demand, and are perceived as highly beneficial by their members.

Transfers Involving State Water Project Facilities

Under the 1986 Coordinated Operating Agreement between the Bureau and DWR, excess capacity in the SWP California Aqueduct is available for the Bureau to transfer water from the Delta to contractors in the San Joaquin Valley when there is no capacity in the Delta-Mendota Canal. These transfers require SWRCB approval because they represent a change in the point of diversion for the Bureau's water rights from the Tracy Pumping Plant (entrance to the Delta-Mendota Canal) to the Banks Pumping Plant (entrance to the California Aqueduct).

From 1985 to 1989 ten applications were made to the SWRCB, all of which were approved. Nine of the ten wheeling requests, some of which were made by the Department of Fish and Game, were for environmental purposes, e.g., to support salmon spawning and migration, to provide greater instream flows in the Delta, or to supply water to wildlife refuges in the San Joaquin Valley. A total of 425,500 ac-ft were wheeled through the California Aqueduct for environmental purposes. The tenth transfer request was for 12,800 ac-ft and went to the Santa Clara Valley Water District. Details of the transfers are provided in Gray (1990).

These transfers demonstrate how the coordinated operation of the Bureau's CVP and the State Water Project facilities can result in more efficient use of existing water supplies and increased benefits to contracting entities.

1977 Bureau of Reclamation Water Bank

The year 1976 was the fourth driest year on record in California. 1977 was the driest. On April 7, 1977, Congress passed the Emergency Drought Act which granted the Secretary of Interior, acting through the Bureau of Reclamation, the authority to establish a water bank to assist agricultural water users in purchasing water from willing sellers. Prices were established such that no undue profit or benefit would accrue to the sellers. Interest-free loans were made available to purchasers, with a repayment period of five years (Wahl, 1989).

The Bureau established a priority system for the allocation of water supplies among the purchasers: 1) survival of permanent crops; 2) maintenance of crops necessary to support foundation dairy and cattle herds and other breeding stock; and 3) irrigation of other crops (DWR, 1978).

The Bureau secured 46,438 ac-ft of water through seven contracts, one of which was with DWR. The other sellers were CVP contractors. The water transferred by DWR was part of the water acquired through the exchange agreement with MWD discussed above. Bureau purchase price for water ranged from $15/ac-ft to about $84.50/ac-ft, depending on the source of water and cost incurred by the selling party. A list of the sellers and the purchase price is shown on Table 6-1.

Twenty-seven water agencies paid an average of $61 an acre-foot for water from the Bank. Selling price ranged from $44 to $142 per acre-foot, depending on the pumping and conveyance costs. A total of 42,544 ac-ft were sold. The difference was due to conveyance losses and to return flow losses from land left fallow. The 1977 Federal Water Bank was able to meet all requests.

Table 6-1
Water Supplied to the 1977 Bureau of Reclamation Water Bank

Seller	Amount (acre-feet)	Unit Cost ($/acre-feet)
State Department of Water Resources	8,185	84.51
Pleasant Grove-Verona Mutual Water Company	15,752	70.00
Chaplin-Lewis-Lewis	1,279	35.00
Reclamation District No. 108	5,000	25.00
Pelger Mutual Water Company	4,425	25.00
Natomas Central Mutual Water Company	6,000	15.00
Sacramento River Water Contractors Association	5,797	15.00
TOTAL	46,438	

Source: Wahl, 1989

EAST BAY MUNICIPAL UTILITY DISTRICT'S EXPERIENCES

The East Bay Municipal Utility District (EBMUD) has made several attempts at water transfers. While some of these transfers have given the agency greater flexibility in managing drought, EBMUD's transfer experiences have not been altogether positive. These transfers are described in greater detail in Appendix A.

EBMUD attempted three transfers during the recent drought. The first was an innovative attempt to pump low-quality water from the Delta roughly 200 feet to the Comanche Reservoir, where it would be used to satisfy downstream flow requirements. This would make an equivalent amount of high-quality water available for EBMUD's urban uses and could have supplied as much as 58 million gallons per day (mgd) of additional high-quality water, roughly 25% of normal-year water demand for EBMUD. Changing the point of use for this water required the approval of the State Water Resources Control Board (SWRCB), however. The application was rejected by the SWRCB primarily due to the potential for introducing new species and diseases from Delta waters into Comanche Reservoir and the Mokelumne River. The exchange was strongly opposed by downstream users (Gray, 1990).

In a second attempted transfer, EBMUD tried to purchase water from water users downstream of its reservoir system to reduce required releases and make more water available for EBMUD's urban demands. Offers of roughly $50/acre-ft. were made, but no purchases seem to have been completed (Contra Costa Times, 1988; Committee on Western Water Management, 1992).

Finally, EBMUD successfully purchased 60,000 acre-ft of water from the Yuba County Water Agency in February, 1989 for $45/acre-ft for potential direct use in EBMUD's service area (Melton, 1989), as was done during the 1977 drought. However, due to heavy March rains, this water was not used. Much of the water was later re-sold to the State Department of Fish and Game and Grasslands Water District for wetland uses, at substantially lower prices.

EBMUD's experience points to the wide variety of creative transfer forms available to water agencies and the still-formidable barriers that can exist to transfers, even during drought. EBMUD's water quality exchange and downstream water purchase proposals were highly innovative ideas, which may have required a longer period of negotiation and refinement to be successful and accepted.

TRANSFERS IN SOLANO COUNTY

Solano County, in northern California, is the primary example where a water bank, similar to the State Water Banks, has been established to facilitate water transfers within a region. Water transfers within Solano County are by no means new, as described in Appendix A. However, when the shortages of 1991 threatened the majority of water supplied to cities by the State Water Project while farmers relying on an independent Bureau project benefited from relatively abundant water supplies, generated incentives to effect a relatively large water bank for the region.

In this bank, the Solano Irrigation District (SID), supplying primarily farms, and the Solano County Water Agency (SCWA), supplying mostly cities, made arrangements for up to 15,000 acre-ft to be exchanged from county farms to cities. Cities would pay $200/acre-ft for the water, of which $170/acre-ft would go to farmers in exchange for the fallowing of fields. A constant 3 acre-ft of water per acre of land was assumed. The remaining $30/acre-ft went to payments to SID and the Bureau as well as administrative costs. A copy of the standard exchange agreement appears in Appendix B.

The Solano County example illustrates that having previous, small-scale experience with water transfers can facilitate larger-scale transfers to accommodate droughts and the ability of local regional water agencies to foster transfers with relatively little State or Federal involvement. This case is described in more detail in Appendix A.

TRANSFERS INVOLVING THE SAN FRANCISCO WATER DEPARTMENT

The San Francisco Water Department (SFWD) has purchased water from several agencies and their experiences draw attention to the numerous technical constraints and impediments facing water transfers. These are discussed below and described in greater detail in Appendix A.

In September 1990 SFWD purchased 15,000 ac-ft from Placer County (Lougee, 1991). This water was to be released down the American River and flow into the Sacramento River. From there, actual delivery to SFWD would be made through a set of water exchanges involving the SWP's San Luis and Del Valle Reservoirs. Final delivery to SFWD required construction of an emergency turnout from the State's South Bay Aqueduct.

The implementation of this physical transfer of water was complicated by water quality problems in the Delta and the Sacramento River. These factors, combined with a 30% carriage water requirement for all flows through the Delta reduced final SFWD deliveries to about 7,600 ac-ft, slightly more than 50% of the original purchase.

A transfer to SFWD from Modesto Irrigation District of 12,000 ac-ft of water suffered a similar fate. This water was pumped into the Toulumne River and wheeled to the State's South Bay Aqueduct for delivery to SFWD. Because of environmental and capacity constraints, the final delivery to SFWD was only 4,890 ac-ft.

The purchase price for Placer County and Modesto ID water was approximately $45/ac-ft. However, wheeling charges through federal and state storage and conveyance facilities were between $250-350/ac-ft.

In 1991 SFWD purchased 50,000 ac-ft from the State Water Bank, after subtraction of carriage water, at $200/ac-ft. This amount was more than the capacity of SFWD's turnout from the South Bay Aqueduct and surpassed the ability of SFWD's treatment plants to blend low-quality water from the Delta with its own high-quality waters from the Hetch Hetchy system. Furthermore, the transfer contracts required delivery of the water by December 1991. Only between 30-40 mgd could be used, but diversions were approximately 80 mgd. SFWD decided to store approximately 13,000 ac-ft of the purchase in San Luis Reservoir. SFWD had to quickly remove its water from San Luis Reservoir when flood waters entered the reservoir and reduced deliveries to MWD threatened to displace the 13,000 ac-ft of SFWD water stored there. Under the storage contract, transferred water is the first to be spilled from storage. Of the original 50,000 ac-ft purchased, approximately 78% arrived at SFWD's system (Lougee, 1991). In 1992, San Francisco purchased 19,000 ac-ft from the State Drought Water Bank.

The SFWD transfer case illustrated the importance of coordinated movement of transferred water through conveyance and storage systems operated by third-party agencies and constrained by environmental, contractual, and physical limitations.

WESTLANDS-KERN COUNTY EXCHANGE

In a 1989 agreement between two agricultural districts, the Kern County Water Agency (KCWA) agreed to exchange up to 55,000 ac-ft of its SWP water with the Westlands Water District (WWD) to help the WWD through a dry year. This water is to be repaid within ten years from WWD's CVP contracts. 45,000 ac-ft were actually delivered in 1989 to WWD through this agreement (DWR, 1990).

This water was made available within the KCWA because the ongoing drought and anticipated curtailment of SWP supplies early in 1989 had prevented many farmers served by the KCWA from obtaining the financing needed for farming. When the heavier than normal March precipitation arrived that year, the KCWA then found itself with surplus water. The original intent was to store this water in underlying aquifers for later years.

However, WWD was able to negotiate an agreement with the KCWA where WWD would pay KCWA $20/ac-ft for this temporary surplus, with an additional $12/ac-ft for conveyance. In addition, Westlands would return an equal amount of water to KCWA within ten years. This return part of the exchange would cost WWD about an additional $17/ac-ft. However, if WWD makes these returns during dry years, the KCWA will pay WWD between $5-15/ac-ft for the returned water. (Gray, 1990)

YUBA COUNTY WATER AGENCY SALES

The Yuba County Water Agency (YCWA) has been the largest individual seller of transferred water throughout the current drought. This has occurred because the YCWA developed its New Bullards Bar Reservoir, with a storage capacity of almost 1 MAF, well in advance of irrigation demands in the YCWA service area. Consequentially, the YCWA has substantial amounts of surplus water in most years, which is available for sale for use elsewhere in the state. Until the current drought, transfers from the YCWA remained at a level of a few thousand ac-ft/year (Gray, 1990).

However, during the first four years of drought YCWA sold roughly 290,000 ac-ft of water to other water users (exclusive of carriage water). These are enumerated in a later section. The YCWA then sold 157,200 ac-ft to the State's Drought Water Bank in 1991. There were no sales from YCWA to the 1992 Drought Water Bank.

After years of permitting the water sales, the State Water Resources Control Board (SWRCB) in 1991 called into question the quantity of Yuba County's water rights. This was due to the Board's feeling that Yuba County's right should be curtailed due to lack of diligence in putting this water to use within the agency's designated place of use, a requirement for beneficial use under the State Water Code. This case has yet to be resolved ("Yuba County ...," 1992).

The case of YCWA's transfers illustrates the potential benefits and risks to water supply developers of developing supplies prior to the expansion of water demands within their service area, if a market can be found for the temporary excess in water supply yield.

The principal water agencies involved in water transfers and exchanges in recent years were identified above. The remainder of this chapter focuses instead on different types of transfers and exchanges which have been employed by various water institutions throughout the state.

INTERAGENCY STORAGE PROJECTS

A number of interagency storage projects have been planned recently that facilitate water transfers, in addition to their direct purpose of improving the yield and reliability of California's water resources systems. Interagency storage projects, by their nature, involve the type of conveyance and storage facilities required for water transfers. The efficient operation of these storage projects is likely to be aided by water transfers, particularly during drought periods.

Kern Water Bank

The Kern Water Bank is a conjunctive use project in the San Joaquin Valley developed as part of the SWP. The intent is to store surplus water in wet years as groundwater in the Kern County area and to allow depletion of this storage during dry years. The effective groundwater storage of this site might be as high as 1.0 MAF, increasing the yield of the SWP by as much as 0.14 MAF/year (Andrews, 1989). A further advantage of this site is that it lies south of the Sacramento-San Joaquin Delta and thus avoids much of the environmental constraints on operations associated with this estuary.

The development of this underground facility for the SWP requires coordination of the water demands and SWP operations with 24 overlying water districts. SWP plans to operate several large recharge sites and modify deliveries to its customers as part of the water storage scheme. The project has required detailed technical and modeling studies of the region (Andrews, 1989). Such an arrangement necessarily involves coordinated water transfers or exchanges between local water agencies. These coordinated exchanges are difficult technically and politically, but appear to offer one of the more promising and least expensive additions to current firm supplies (Sergent, 1990).

Sacramento Regional Cooperation

A similar conjunctive use scheme has been proposed for part of the Sacramento metropolitan region. The City of Sacramento has excess water entitlements to surface water from the American River. However, neighboring suburban water districts, using groundwater, have been faced with declining groundwater tables and occasional groundwater quality problems. The idea proposed is to attempt to employ the unused portions of the city's surface water entitlements to supply selected suburban areas during wet years. During dry years, when surface water would be less available, these areas would revert to groundwater supplies. This would improve the reliability of all systems and reduce groundwater depletion (Metcalf and Eddy, 1985). Such an arrangement would necessarily involve water transfers or exchanges between local water agencies.

Pumped Storage

A number of large off-stream pumped storage reservoirs are currently being planned south of the Delta. In some of these cases, the reservoirs might be jointly operated by several agencies. However, in any case, the addition of large amounts of off-stream storage south of the Delta would greatly enhance the ability of water users in this region to participate in water transfers, since it would facilitate increased pumping of water through the Delta when it is "balanced," allowing storage of this water until it is needed by water users.

The Los Banos Grande site is located just south of San Luis Reservoir. It would be developed by DWR as part of the SWP and have a storage capacity of 1.73 MAF. The estimated cost is $740 million ($428/ac-ft storage), not including recreation and environmental mitigation costs. The facility may be jointly operated with the Bureau of Reclamation. The project currently faces a number of environmental challenges (DWR, 1990).

The Los Vaqueros Reservoir site has a capacity of about 1 MAF of storage and is located just southwest of the Delta. The Contra Costa Water District (CCWD) is interested in developing 100,000 ac-ft of storage at this site to store water from the Delta during high Delta flows, when water quality is superior. This stored high-quality water would then be blended with lower quality water during low Delta flow periods to maintain acceptable water quality in CCWD's distribution system.

The MWD is planning a pumped storage facility of about 800,000 ac-ft in the Domenigoni Valley, east of its service area. This capacity would be devoted to overyear storage for drought and other supply interruptions (MWD, 1992).

TRANSFERS OF CONSERVED URBAN WATER

The City of Morro Bay, in southern California, as adopted an innovative twist on the transfer of conserved water. Since 1985 when the city was facing limited water supplies and expensive expansion alternatives, it has required that new real estate developments install water conservation measures in existing structures to more than match the water requirements of the new development.

Water conserved by retrofitting existing development is applied to new development, with developers paying the costs of water conservation. For an urban system, it has the advantages of both encouraging water conservation in new development, facilitating water conservation in existing structures, and providing finance for these activities (Reed, 1990).

The original target for water conservation by developers in existing structures was to be twice the water to be used by the new development. Any excess of conserved water in practice was to go to the City. However, actual water conservation in this program in 1987 was estimated to be only 86% of the new water demanded by new development. This has led to some modifications to the program and some changes in the way conservation is calculated (Laurent, 1992, *Wall Street Journal*, 1988). While still in its early stages, this program is an interesting analogy to the trading of conserved water for the costs of conservation seen in the IID-MWD water transfer.

A somewhat different form of transfer of conserved urban water has been the unofficial, unmanaged, and uncompensated transfer of conserved urban water to agricultural uses in some agricultural regions of California. In Yolo County, for instance, urban users have reduced groundwater consumption by over 10% in most years of the drought through fairly standard water conservation programs. This water, which in the case of Yolo County is roughly 2,000 ac-ft/year, becomes available to supply nearby agricultural groundwater use and reduce agricultural pumping heads. Yolo County agricultural groundwater use during severe drought years can be as much as 300,000 ac-ft/year greater than that in normal wet years (Jenkins, 1992). Thus, the impact of these relatively small unmanaged transfers is virtually imperceptible in many cases.

PAYMENTS FOR WATER CONSERVATION

Several western urban water utilities now offer payments to customers for taking specific measures to reduce water demand. The most common offer is payment to install low-flow toilets (1.6 gallons/flush). The cities of Tucson, Arizona (Tucson ..., 1992) and Santa Barbara, Santa Monica, and Los Angeles, California (DWR, 1991b) offer rebates between \$80 and \$100 per toilet (Argent, 1990).

If low-flow toilets are used to replace typical (3.5 gallons/flush) toilets and each toilet is flushed an average of 10 times per day, 6,900 gallons are saved per year. This implies that 47 toilets must be replaced to produce 1 acre-ft/year of conserved water. If rebates are \$100/toilet, this would imply a cost of \$4,700 per acre-ft/year of yield, or an amortized cost of \$235/acre-ft at a 5% real discount rate and an infinite amortization period.

The City of Glenndale, Arizona offers similar rebates for adopting landscaping with low water requirements (DWR, 1988). EBMUD has considered offers up to \$300 per single family household and \$5,000/multifamily unit to install water-saving landscaping meeting district-set criteria (EBMUD, 1991). North Marin Water District has developed a "Cash for Grass" program where residents are paid to reduce the amount of their yards kept in lawn, with maximum payments of \$310 per house (DWR, 1991a). The Metropolitan Water District of Southern California offers to pay its local customer agencies 50% of the initial costs of water conservation or \$150/ac-ft of conserved water (DWR, 1991a).

PAYMENTS FOR ALTERNATIVE WATER SUPPLIES

In some cases agencies or firms have been paid to use alternative sources of water during drought periods. This has been common in the Suisun Bay area of the Delta when State project operations have reduced the availability of water of sufficient quality at some of the diversion structures in the western Delta. Under these conditions the City of Antioch and the Contra Costa Water District (CCWD) have been paid by the SWP for the cost of using substitute water supplies. All of these averted diversions are replaced with water from the CCWD's Contra Costa Canal.

By paying to replace these diversions, which have relatively senior water rights, the SWP can increase its ability to withdraw water from the Delta. Additional releases by the SWP to the ocean through the Delta would be needed to preserve a low salinity level at these diversion points. The effect of this scheme is to transfer water withdrawals to another location (CCWD's Contra Costa Canal) and to consequently increase the amount of water available for other users in the state.

These agreements with the City of Antioch and CCWD are longstanding, having been established in 1967 and 1968, respectively. In the 1988-89 water year, payments from the State totalled \$18,700 for 12,000 ac-ft for CCWD (\$1.56/ac-ft) and \$219,900 for 1,229 ac-ft for the

City of Antioch ($178.9/ac-ft). Similar arrangements have been made with industries withdrawing water from this same area (DWR, 1990).

INNOVATIVE WHEELING

The legal, institutional, and economic will to effect water transfers and exchanges is not always enough. Successful transfers also require tremendous amounts of cooperation and coordination among numerous agencies. Many of the transfers discussed in this Chapter succeeded because there were some innovative schemes involved to wheel the water from its place of origin to its place of use. Wheeling arrangements can be crucial in emergency situations, but they are also very important for helping to meet water supply needs under normal conditions in a timely and cost-efficient manner. Several such wheeling arrangements are described below.

Wheeling CVP Water

To increase the water supply yield of the combined CVP and SWP projects, the SWP has been involved in wheeling CVP supplies to Bureau of Reclamation contractors. In 1989, this wheeling totalled about 370,000 ac-ft (DWR, 1990).

Santa Barbara

The Santa Barbara region is normally considered to be hydraulically isolated from the rest of the state's water resources. However, during 1991, Santa Barbara County was able to take delivery of 3,600 ac-ft of SWP water through a complex series of wheeling and exchange agreements with neighboring coastal counties. Through these arrangements and use of the California Aqueduct, water was ultimately conveyed to Castaic Lake (DWR, 1991c). The Santa Barbara region was severely affected by drought in 1991, and sought 45% reductions in water demand in that year.

OTHER CONVENTIONAL WATER TRANSFERS

A number of other conventional water transfers are summarized below for completeness. These are listed for each year of the drought:

1987

• DWR purchased 37,000 ac-ft of water at $21/ac-ft from the YCWA to increase overyear storage in the SWP. The purchased water was released from YCWA's Bullards Bar Reservoir for downstream use by SWP contractors. This preserved an equivalent amount of storage in the SWP's reservoir system (DWR, 1988b). This transfer was essentially an interagency "space rule" since it allowed the relative storages in two nearby reservoirs to be made more equal.
• Napa County Flood Control and Water Conservation District received 7,700 ac-ft of water from the Solano Project using SWP facilities (DWR, 1988b). 3,500 ac-ft were similarly delivered in 1986 (DWR, 1987).

1988

• DWR purchased 116,000 ac-ft of water from the YCWA to increase overyear storage in the SWP, as was done at a smaller scale in 1987. This water was purchased at $12/ac-ft (DWR, 1989).
• Napa County Flood Control and Water Conservation District received 1,600 ac-ft of water from the Solano Project using SWP facilities (DWR, 1989).

1989
• 4,000 ac-ft of YCWA water was sent to the Napa Valley Flood Control and Water Conservation District using the SWP's North Bay Aqueduct (DWR, 1990). $45/ac-ft was paid to the YCWA for the water transferred (Gray, 1990).
• 17,000 ac-ft of YCWA's water was delivered to the Santa Clara Valley Water Agency (SCVWA) using SWP facilities. This water was formally purchased by the SWP for its contractor, the SCVWA (DWR, 1990). The SCVWA paid $45/ac-ft for this water (Gray, 1990).
• 54,000 ac-ft of YCWA water was delivered to agricultural users in the Tulare Lake Basin Water Storage District using SWP facilities. This water was formally purchased by the SWP for this SWP contractor (DWR, 1990). The Tulare Lake Basin users paid DWR $30/ac-ft for the water (Gray, 1990).
• The State Department of Fish and Game bought 30,000 ac-ft of water from YCWA. This water was to have been used by EBMUD, as described above. The water was delivered through SWP facilities with payments to EBMUD of $5/ac-ft and payments to DWR for conveyance of $8.75/ac-ft (Gray, 1990).

1990
• Through negotiated agreements, DWR facilities were used to convey water to satisfy several Bureau delivery contracts, including, 66,570 ac-ft delivered according to the three-way Cross Valley Canal contracts, and 6,200 ac-ft delivered to Buena Vista Water Storage District to meet U.S. Fish and Wildlife Service requirements (DWR, 1991c).
• 6,373 ac-ft of YCWA water was sent to the Napa Valley Flood Control and Water Conservation District using the SWP's North Bay Aqueduct (DWR, 1991c); 62,204 ac-ft were purchased by DWR and delivered through SWP facilities to Santa Clara Valley Water Agency and to Tulare Lake Basin Water Storage District
• 150,000 ac-ft of entitlement water delivered to the Kern county Water Agency for storage in the Kern County groundwater basin (DWR, 1991c).
• 9,262 ac-ft of SWP water and 182 ac-ft of CVP water was conveyed for recreational use and fish and wildlife enhancement in various locations throughout the state (DWR, 1991c).

SUMMARY

The State's Drought Water Bank has not been California's only water transfer mechanism. A variety of non-water Bank transfers are summarized in Table 6-2. Water transfers have occurred in the state in a bewildering variety of ways. Each transfer has occurred because it has been to the substantial advantage of each side, even though money has not been exchanged in many cases and the prices paid for water have been arguably well below market value. While the motivations for many trades often have been directly financial, there have also been other important motivations for participating in water transfers or exchanges, including:

- improvements in seasonal and drought reliability,
- improved water quality,
- reduced operating costs,
- retention of water rights,
- growth control, and
- avoidance of new water supply facilities

These examples illustrate the great diversity of purposes and mechanisms for water transfers within the framework of managing water supply systems, as well as their widespread applicability in a variety of settings.

Table 6-2
Significant Non-State Water Transfers

Metropolitan Water District (MWD)

IID transfer: MWD pays for conservation of irrigation water, MWD receives 100,000 acre-ft/year of the conserved water for 35 years, IID maintains legal rights to all water

Coachella Valley WD/ Desert WA Exchange: Trading Colorado River water for state project (SWP) water, Both sides make full use of their water rights, almost 100,000 acre-ft/year, MWD gains water quality and drought storage in irrigation districts

Arvin-Edison Exchange: Storage of wet-year flows in an agricultural district, In dry years mwd gains surface water and Arvin-Edison uses groundwater

Bureau of Reclamation CVP Transfers

Routine transfers	Permanent regional pooling agreements
1977 water bank	Wheeling water through state facilities

East Bay Municipal Utility District (EBMUD)

Attempts to trade low-quality water for high-quality water; Attempted dry year options

City of San Francisco

Independent purchases from Placer County and Modesto Irrigation District
Complexity and cost of effecting the physical transfer of legally transferred water

Solano County

County-sponsored 1991 drought water bank, 15,000 acre-ft; Long-term inter-agency exchanges, up to about 40,000 acre-ft/year; Role of transfers in county-scale water resources planning

Westlands-Kern County Exchange

Overyear exchange between agricultural users with financial incentives

Yuba County Water Agency

Largest individual seller of transferred water throughout the current drought

Interagency Storage Projects

Groundwater and/or surface water storage

Transfers Of Urban Conserved Water

City Of Morro Bay: New development supplied by conserved water from existing structures

Payments For Conserved Urban Water

Customers are paid for reduction of landscaping and toilet retrofits

Payments For Alternative Supplies

Paying users to adopt another supply that increases yields for the payee's system

Innovative Wheeling

Central Valley Project and Santa Barbara cases

Chapter 7

Integrating Water Transfers into Water Resource Planning

Like any other measure or approach for managing a water resource system, successful implementation of water transfers requires their integration with traditional water supply and demand management measures. In addition, successful use of water transfers also will require a host of institutional modifications at the local, State, and Federal levels. This chapter reviews the motivation for adding water transfers to the inventory of approaches available to water resource engineers and discusses several engineering and institutional aspects of integrating water transfers into larger water resource systems. These are presented as sets of lessons for "water transfer engineering" based on the recent California experience.

THE VALUES OF WATER TRANSFERS IN SYSTEM OPERATION

There are many reasons for exploring the integration of water transfers into existing water resource systems. Beyond providing water almost on demand during emergency situations, water transfers offer numerous opportunities for improving the overall economic and physical operation of water supply systems. The recent California cases of water transfers cited in Chapters 5 and 6 demonstrate that water transfers can be used for:

- augmenting water supplies during a drought;
- reducing, avoiding, or delaying the need for additional water supply capacity;
- improving the quality of water available for urban water users;
- increasing the reliability and firm yield of the water systems owned by both parties to a transfer, especially during drought conditions;
- sustaining environmental uses of water during droughts; and,
- facilitating and improving conjunctive use management of surface and groundwater supplies.

Water transfers can take a wide variety of forms including permanent transfers, dry-year options, spot-market transfers, exchanges, wheeling, and other forms. When integrated with traditional water supply and demand management measures, each form of water transfer can play a somewhat different role in overall water resource system management.

INTEGRATING WATER TRANSFERS WITH TRADITIONAL APPROACHES

If water transfers are to become a significant long-term component of water resources planning, they must be integrated with traditional water supply augmentation and demand management measures. Some hints of how this integration should take place are offered by the recent California experience. During California's current drought, both traditional supply infrastructure and demand management strategies have continued to have an important role in water management. However, this role has changed somewhat due to the presence of water transfers. The operation or construction of water conveyance and storage facilities, for example, takes a somewhat different form when water transfers must be incorporated in the planning process.

Any long-term arrangements for water transfers would likely be accompanied by efforts to contract for the conveyance and storage of such contingent water supplies with the operators of the State's major conveyance and storage systems, the State Water Project (SWP) and the

Central Valley Project (CVP). This might imply some greater analysis and negotiations over the operation of the State's water infrastructure under transfers, compared with the pragmatic and expedient approach taken in 1991 and 1992, where water transfers were essentially last in priority in the operations of the SWP.

Demand management is also an important component of water transfers, since much of the water transferred comes from conserved agricultural and urban water uses, as described in Chapter 6. One requirement for urban water purchases from the 1991 State Drought Water Bank was that purchasers implement at least 25% reductions in water use. The use of agricultural water conservation as the source of water for transfer is illustrated by the IID-MWD agreement. Water conservation also remains useful for reducing the need to purchase additional water.

The integration of water transfers with capacity expansion and demand management techniques is likely to mirror the integration of urban water conservation with capacity expansion measures seen in California after the 1977 drought. The addition and integration of water transfers will be somewhat more technically difficult, and much more institutionally burdensome since it requires the coordination of transfers of both wet and paper water between multiple parties.

INTEGRATION OF AGRICULTURAL, URBAN, AND ENVIRONMENTAL WATER USES

Perhaps the most important implication of water transfer planning is the necessity of increasing integration between diverse water users. Since most water for water transfers must economically come from agricultural users, and much of this water will go to urban and perhaps environmental users, any planning for water transfers implicitly integrates urban, agricultural, and environmental water supplies. With water transfers being common, it will become less possible, and less desirable, for individual urban or agricultural water districts or regions to plan and operate their water supplies independently. This necessary coordination of planning and operations between functionally diverse water agencies will imply potentially protracted and probably controversial negotiations, at least for long-term transfer arrangements, such as water exchanges for overyear storage or dry-year water purchase options.

Even without a significant component of long-term water transfer arrangements, a repeat of major short-term Drought Water Bank-type transfers also serves to integrate urban, agricultural, and environmental water users and planners. There is now a common perception that given the successes of the 1991 and 1992 Drought Water Banks, there will be future State Drought Water Banks or other forms of spot-market transfers available during drought years. Agencies of all types are likely to plan on these markets being available for either buying or selling water. The existence of spot-markets and water banks during droughts provides incentives for urban water suppliers to rely somewhat less on more expensive forms of conventional water supply capacity expansion and urban water conservation in planning and perhaps provides incentives for different forms of facility construction and operation. For agricultural water districts, the existence of water banks and spot markets during drought has implications for the wording of water supply contracts and the management of water during the drought.

The potential sale of water by farmers during drought affects the need for groundwater management and the special operation of conveyance and storage facilities. The ability of farmers to sell water might also affect the operation rule curves used by agricultural water suppliers for allocating water from storage to farmers over multi-year droughts. Should more water be retained in storage to hedge against potentially more severe droughts in future years, since farmers will be less affected economically by shortages when they can sell scarce water. Perhaps additional hedging or overyear storage by agricultural water suppliers, by creating a greater scarcity of water during most drought years, will increase farm incomes more than adherence to current reservoir operating rules. Similar issues relate to the overyear use of groundwater storage, though for groundwater in California, overyear regulation is legally much more difficult.

DROUGHT PLANNING EQUALS WATER SUPPLY PLANNING

The increasing likeness of water supply planning and drought planning is a long-standing phenomenon which would be accelerated by the use of water transfers. California's increasing water demands and its tendency to experience overyear droughts imply that the impacts of these droughts on economic activities will become increasingly more severe and frequent. Under these circumstances, planning for droughts becomes more than just contingency planning. Planning for droughts must play a major role in the planning and operation of water supplies in every year.

The equivalence of drought and water supply planning can be seen in the planning emphasis of many water agencies on long-term water conservation measures and water reclamation. While these activities reduce net water demands in all years, wet and dry, they also help retain water in ground and surface water storage so that these systems are better prepared when shortages in runoff and precipitation occur.

This increasing equivalence of drought and water supply planning is also evident in discussions of water transfers. The emphasis of many agencies on using water transfers during wet years to recharge overyear surface and ground water storage links water planning and operations in every year to that in drought years. The effects of the current California drought on water management in California are likely to be long-lasting and affect water management decisions every year.

DESIRABILITY OF LONG-TERM TRANSFER ARRANGEMENTS

The State Water Banks have significantly accelerated the acceptance of spot water market transfers in California. However, the State Water Banks have, in some circles, displaced thoughts of transfers based on longer-term transfer arrangements. Such arrangements can include dry year options, water exchange and wheeling arrangements, and even permanent transfers. While spot markets for water have several advantages, this section dwells on the desirability of transfers based on long-term arrangements between parties, including perhaps third parties.

Predictability has been suggested as a desirable feature for water allocation mechanisms (Howe, *et al.*, 1986). Most agencies and individuals involved in water planning and management are traditionally conservative by professional nature, preferring to have too much water with certainty rather than having a risk of shortfall. Therefore, predictable transfers, resulting from long-term transfer arrangements, would seem to be desirable for all parties.

There are also a number of practical reasons for preferring transfers based on long-term arrangements. These long-term contracts or arrangements give each party to the transfer, as well as third parties, the opportunity to plan for the magnitude and frequency of transfers. Farmers and harmed third parties know how much water will be transferred in the worst case, and will be able to determine roughly how frequently these transfers will occur. There should be fewer surprises.

Transfers based on long-term arrangements can also benefit from longer term evaluation and design than spot-market transfers. This is particularly true for third parties, which must often quickly evaluate transfers and act politically on spot market transfers. Given the conservative nature of water interests, it could be argued that spot market transfers encourage third parties to over-react to transfer proposals, perhaps halting transfers that would be more acceptable to them if proposed in a leisurely time-frame.

The relatively leisurely time-frame for negotiating long-term transfer arrangements also gives all parties ample opportunity to bargain, inform, and perhaps cooperate. Such multi-party negotiations, which cannot be accommodated in a spot market framework, may have a greater chance for successful completion and be more acceptable to all parties involved. These arrangements also facilitate the coordination of water transfers with other water management activities during wet and dry years. In California, the on-going three-way negotiation involving urban, environmental, and agricultural interests is an attempt to resolve some of the water priority and allocation issues, including identifying the role and impact of water transfers for each interest group.

Difficulties with Long-Term Arrangements

While long-term transfer arrangements give all parties greater opportunity to compromise and find common ground, they also give parties greater opportunity to entrench. Those opposed to any transfer or willing to accept transfers only on inflexible terms can find greater opportunity to politically or legally support their positions. Where such opposition is based not on ideology, but on interest, these opposing positions may be seen as actually starting positions in negotiations.

Water agencies often wish to remain as independent as possible in managing and supplying water used in their systems. It is sometimes difficult for these agencies to accept long-term coordination with others unless motivated by drought conditions or other dire circumstances. This position is common for both potential buyers and sellers of water, as well as potential third parties.

The California State Water Banks succeeded in part because special drought legislation waived requirements for examination of environmental impact review and prior examination of third party impacts. This would not be true of many potential long-term transfer arrangements. These additional requirements might stymie consideration of some such transfers, especially if a more systematic means of assessing and evaluating third party impacts is not developed. In anticipation of stricter environmental requirements for long-term transfers, several California water agencies, including MWD, Kern County Water Agency, and Solano County Water Agency, collectively known as the Authority for Environmental Analysis of Water Transfers, have joined to prepare what they consider to be a generic, or baseline, environmental impact report for water transfers involving the Delta. This document would form the basis for more detailed, transfer-specific environmental reports which may be required.

Under the guidelines of the Drought Water Banks established thus far, water transfers have received the lowest priority for use of storage and conveyance facilities. For example, transfer water was to be the first water spilled from SWP facilities when storage capacity was reached and the last to be allocated capacity in conveyance facilities. The lone exception was water deemed necessary for "extreme critical needs." This is an important issue to consider with regards to long-term transfer agreements which, in California, will rely extensively on SWP or CVP facilities, two systems with increasingly limited capacity.

THE ROLE OF GOVERNMENT

California's recent experience in using water transfers for drought management and water supply planning provides several potential lessons for Federal, State, and local agencies with regional water planning and management responsibilities. In California, state and federal government has an unavoidable role in water transfers. This essential governmental role arises from the involvement of state and federal agencies in water rights and water rights regulation. Furthermore, federal and state agencies own and operate the major water conveyance and storage facilities. Therefore, a significant part of the State's involvement in water transfers is due to its necessary technical role, required by its operation of major conveyance and storage facilities and its requirements and responsibilities under various environmental regulations, particularly those regarding Delta outflows. The various technical requirements for supporting water transfers are discussed later in this chapter.

In California, State involvement was essential in the process of establishing water transfers as an accepted form of water management. The State's presence in matters of water transfer has steadily increased since the 1977 drought, with several items of legislation enacted in recent years to facilitate the transfer of water and water-rights (O'Brien, 1988; Gray, 1989; 1990). Still, it required five years of severe drought conditions to motivate more influential and accelerated State involvement in water transfers. This was manifested through the establishment of the 1991 and 1992 State-sponsored Drought Emergency Water Banks. Active State involvement and support in arranging and implementing the legal and physical transfer of water was essential for many Water Bank transactions. It also facilitated, physically, legally, and morally, many other water transfers within the State.

State sponsorship of the drought water bank was required because of 1) the physical and environmental complications of state-wide water conveyance; 2) the need for statewide accounting of supply and demand (wet vs. paper water); 3) the need for a ready and knowledgeable staff; 4) the need to better coordinate the activities of private, local, state, and federal water agencies; and 5) the need to accomplish significant transfers within a few months of the program's inception. The California Department of Water Resources (DWR) became the "umbrella" agency for water transfers under the 1991 and 1992 Drought Water Banks. No other agency or private organization could have fulfilled all these desirable traits on such an urgent basis. On a smaller regional scale, in 1991 the Solano County Water Agency and Solano Irrigation District jointly fulfilled a similar role in Solano County in sponsoring their County Water Bank.
The role of government in the California and Solano County water banks was not independent of economic market forces for water. The prices set for the purchase and sale of water had to be at such a level that the amount of water offered by sellers would roughly equal the amount of water sold. The establishment of these prices is a complex process.

The success of the State's banking efforts should not detract attention from other forms of water transfers or the formation of quasi-governmental water banking, pooling, or exchanging institutions and arrangements. Such institutions, for example, are found within many Bureau of Reclamation projects in California and exist in many other irrigation and metropolitan water supply contexts.

Private, non-government sponsors may also succeed in implementing water transfers where capacity can be arranged in the conveyance system. Existing state and federal legislation permits the use of SWP and CVP facilities for conveying transferred water. Individual agencies have their own agendas and will continue to pursue short- and long-term contracts regardless of the existence of government-sponsored water banks. However, government involvement can greatly accelerate the development of water transfer agreements by initial sponsorship of transfers through the establishment of water banks or by other means. The development of transfers as part of a region's water resource system is likely to continue after government sponsorship of water banks has ended.

LEGAL AND ECONOMIC CONCERNS

California has strong statutory directives to promote water transfers, including (Gray, 1989; Sergent, 1990):

• Legislation declaring that voluntary water transfers are an "established policy" of the State;

• Legislation specifically supporting the transfer of surplus or conserved water;
• Authorization for DWR to facilitate water transfers;
• Support for the use of available State conveyance and storage capacity to facilitate water transfers;
• Legislation supporting various forms of temporary water transfers;
• Authorization of all local and regional water supply agencies to "lease, sell, exchange, or otherwise transfer water that is surplus to the needs of the agency's users for use outside the agency;"
• Legislation stating that the "transfer of water or water rights, in itself, shall not constitute evidence of waste or unreasonable use." This supports the ability of a seller of water to retain water rights used in a transfer under the state's appropriative doctrine.

However, most transfers which occurred in California during the 1980's were not directly linked to these statutes (Gray, 1990), and, overall, legal constraints still pose a significant threat to water transfer activity. As noted in Chapter 5, additional special legislation was passed to facilitate transfers in California during the 1991 and 1992 drought years.

In general, short-term, emergency water transfers can gain relatively easy approval and rapid implementation, given sufficient flexibility in the conveyance and storage system and sufficient professional flexibility and readiness on the part of water managers. Legislation often exists which reduces or eliminates barriers to transfers during drought or other emergency conditions. Droughts further increase the disparity in the economic values of different water uses, e.g., urban vs. agricultural, thereby increasing the potential financial motivation to participate in water transfers by both sellers and buyers. Long-term, planned transfers, such as dry-year option contracts and permanent water transfers typically face more difficult legal and economic constraints. The costs, delays, and risks involved in overcoming these constraints can induce agencies not to consider or participate in water transfers. Some of these are discussed below.

Water Rights Constraints

The legal aspects of water right transfers have been discussed extensively elsewhere (Gray, 1989; O'Brien, 1988). For the purposes of this report, it is sufficient to note that legal authority, limitations, and regulations regarding water transfers are very important to their eventual implementation. Legal considerations are particularly important when a proposed transfer involves changes in conditions stipulated by the original water right, such as changes in type of use, place of use, or timing of withdrawals (i.e., most types of water transfers). In addition, many of the longer term transfers involve the storage of surplus water during wet years. The storage of surplus water can also involve complex legal issues (Getches, 1990), particularly for groundwater storage (Thorson, 1978; Kletzing, 1988). However, as the examples in this report illustrate, many forms of water transfers are available to help overcome these substantial legal constraints.

In California, many water transfers are regulated by the State Water Resources Control Board. However, many proposed transfers, such as those involving groundwater, water from the Colorado River, or within large state or federal projects, do not fall under the jurisdiction of the Board and are relatively unregulated. In fact, many of the transfers that have occurred in California have involved these less regulated cases (Gray, 1990).

Contracts

In California, most surface water use is governed by water supply contracts established between water users and suppliers, as well as contracts between hierarchically organized water agencies. Thus, it is common for the water used by an individual user to be regulated by several water supply contracts, depending on the number of overlying agencies through which water is routed. Many of these contracts stipulate that any water not used by the contractor is to revert to the contractee. Many water use contracts also stipulate that water cannot be transferred outside of a district and can only be transferred within a district at cost. These types of provisions reduce the ability and incentive of lower-level contractors to sell surplus or conserved water (Sergent, 1990; Gray, 1989; O'Brien, 1988). Many of these contract provisions were waived by drought legislation for 1991 and 1992.

Prices and Costs

As demonstrated by the 1991 and 1992 California Drought Water Banks, both sellers and buyers can be quite sensitive to the price established for water. At lower prices, there are fewer willing sellers and a greater demand for water from agricultural water users. Higher prices encourage sellers and come closer to matching the value of water for municipal demands, but tend to exclude most potential agricultural buyers. The price set by the market, through negotiations, or by a governmental water banker has important implications for the character and number of resulting transfers.

The cost of water to a user includes more than its purchase price. Much of the work in establishing beneficial transfers of water lies in arranging for the conveyance, storage, and perhaps treatment of the transferred water. In addition, there are often carriage losses due to seepage, evaporation, and environmental demands on transferred water. In many cases, the costs of these activities and water losses exceeds the cost of the water itself. However, these costs can often be reduced by innovative wheeling arrangements, involving creative use of storage, conveyance, and treatment facilities.

Third Party Impacts

The real and potential third party impacts of water transfers will continue to have major effects on the development of water transfers as an accepted component of water resource management plans. The concern for third party impacts is felt by the legal and administrative challenges to proposed transfers and in the political and legislative climate of water management.

There are a number of approaches to managing and compensating for third party impacts, as identified in Chapter 4. However, agreement on the proper handling of potential third party impacts may require protracted negotiations, education, and perhaps legal action. Federal, state, and regional water agencies might exercise some leadership and set precedence in establishing methods, guidelines, and standards for examining and resolving third party impacts. This will be a difficult task, both technically and politically. In the meantime, third party impacts will continue to hamper those seeking to use water transfers as an integral part of water planning and management.

LOGISTIC AND ENGINEERING DIFFICULTIES

Water transfers involve much more than legal and economic issues. Indeed, it is especially easy for engineers to comprehend the range of logistical difficulties involved in the physical transfer of water.

Conveyance and Storage Constraints

The physical and environmental ability to transfer water posed significant challenges to many recent California water transfers. The difficulties encountered by the San Francisco Water Department, in particular, illustrate the traditional engineering limitations and concerns with the use of water transfers in system operations and planning.

These types of engineering considerations resulted in significant transaction costs for most water transfers in the state. Environmental concerns resulted in a requirement that approximately one-third of all transferred flows through the Sacramento-San Joaquin Delta be devoted to carriage water and be made available for flow to the ocean. Additional environmental concerns for riparian ecology and threatened and endangered species restricted the timing and amounts of transferred water that was conveyed by rivers. As environmental conditions in the Delta Estuary and upstream riparian habitats worsen, such environmental constraints on the conveyance of transferred water are likely to become more numerous and stringent. Such environmental limitations helped defeat EBMUD's attempt to trade low-quality downstream water for high-quality upstream water.

Pumping and rental of aqueduct facilities required to convey transferred water to its new place of use imply additional costs, beyond the purchase price. Further, in some cases, given the timing of both environmental constraints and operational constraints associated with conveyance facilities, storage facilities were needed to allow transfers to be conveyed part way to their destination and stored until the constraints were relaxed and the transfer could be completed. A variety of innovative water wheeling techniques were required in several cases to overcome environmental and physical constraints to transport transferred water to its final destination. Construction of additional conveyance interties was required in a few cases.

Despite the conveyance difficulties apparent in some California transfers, the success of water transfers in California is largely due to its extensive system of conveyance and storage facilities and their effective coordinated operation. Water transfers in other parts of the United States with less developed regional water infrastructure are likely to suffer from greater conveyance and storage constraints than are apparent in California.

Water Quality Considerations

In several cases, the quality of transferred water constrained physical conveyance. For example, San Francisco's water treatment plant capacity was unable to accept more than a limited rate of transferred water from the Delta. This limitation forced much of the transferred water to be stored, at a substantial cost, in State-owned facilities and slowly released into San Francisco's treatment plant. EBMUD faced similar limitation on the treatability of transferred water, which, combined with other difficulties in effecting transfers, led EBMUD not to use transferred water and to rely more on urban water conservation measures.

Coordinated Operation of Facilities

The California water supply system is so complex, institutionally and physically, that one agency cannot act in isolation. The involvement of three or more water agencies in many transfers has been the norm in California. In many cases the number of agencies is held to three only because of the extensive SWP project facilities used and the State's simultaneous involvement as sponsor of the Drought Water Bank.

The coordination and physical completion of water transfers will be made more difficult, and perhaps impossible, if agencies controlling major components of a region's water conveyance and storage system choose not to participate in transfers, are legally restrained from participating, or participate only in a highly constrained manner.

TECHNICAL SUPPORT FOR TRANSFERS IN WATER SUPPLY PLANNING

There is little doubt that the arrangement and implementation of water transfers is as technically demanding as conventional water supply augmentation and demand management engineering measures. It is especially demanding technically because to effectively engineer water transfers requires the integration of water transfers with conventional water management measures and the coordination of operations among formerly independent water agencies, as discussed above. These technical issues are especially important because they are of concern to more than one agency. Water transfers require interaction between parties, and this requires some level of technical agreement. Several specific areas of technical concern for water transfers are discussed below.

Wet vs. Paper Water

A large part of the engineering of water transfers is to establish the correspondence between paper (legal) water and wet (physically present) water. As water moves through a complex conveyance and storage system, such as California's, there are seepage and evaporation losses, withdrawals by other users, return flows from other users, and flows downstream. All these factors complicate the estimation of how much water is physically available to the receiver of a water transfer, given that the sender of a water transfer has relinquished use of a given amount.

There is a need for a common statewide basis for establishing the relationship between an amount of water sold with an amount of water received. Without such standard accounting, amounts of paper water are likely to exceed amounts of wet water available, leading to excessive withdrawals by water users to the detriment of those users who are not party to transfers. This will be true for transfers of both consumptive and instream uses. Litigation and calls for greater regulation of water transfers would be the likely result. In 1991 and 1992, DWR largely established the correspondence between wet and paper water and was able to enforce this accounting through its control of the Delta pumping and conveyance facilities used for implementing water transfers.

Agreements Needed to Support Transfers

The California experience illustrates the common need for water transfers to be supported by contracts and other agreements for the physical transfer and actual use of transferred water. These include agreements that allow the conveyance, storage, and perhaps treatment of water in facilities owned by third parties and the coordination of transferred water movements with other water movements and environmental constraints.

This coordination of transferred water with other water movements and storage can require significant engineering, as illustrated by the case of San Francisco's transfers. This technical task of transferring water can be especially demanding when it takes place on a spot market or water bank basis, where there is less opportunity for planning the movement of large amounts of water. One advantage of long-term arrangements for water transfers is that they would allow establishment and study of longer-term arrangements for the physical transfer of transferred water together with other water.

Third-Party Impacts

A great deal of technical work is required to establish and manage third party impacts from water transfers. There is currently little technical work supporting the absence, presence, or magnitude of physical, environmental, economic, and social impacts from water transfers. Less is known about how these impacts would vary with different specific transfer cases and mechanisms and how effective different approaches to managing third-party impacts might be.

Some of the technical issues in managing third party impacts are illustrated by the case of Yolo County. Farms in Yolo County were the source of about 150,000 ac-ft. of water for the 1991 Drought Water Bank. Much of this was transferred surface water, most of which was replaced by increased groundwater pumping. Yet the County does not employ a water engineer or groundwater specialist dedicated to county-wide water supply problems who can assess and manage the long-term impacts of these transfers (Jenkins, 1992). There is also little legal authority for counties to assume this role. Furthermore, there is little expertise in rural county governments to estimate the economic impacts of different types of transfers. Without an understanding of the economic and physical effects of water transfers, water exporting regions are likely to be suspicious of and somewhat resistant to the implementation of water transfers.

This same lack of a technical basis for assessing and managing water transfers takes on a more important role at the state-wide level where water transfer policies are made. Technical studies are needed to support policies and perhaps specific cases should be investigated of when and how water transfers are made and how any third party impacts should be managed. This is particularly urgent for the management of instream flows in and through the Sacramento-San Joaquin Delta, and its implications for the coordination of transfers and other flows through this region. A better understanding of the hydrodymanic, chemical, and biological behavior of the Delta would support carriage water requirements for water transfers and perhaps increase water yield from this system.

A Role for System Modeling

A major conclusion of this work is that to be most effective, water transfers must be integrated with other more conventional water planning and management techniques. Given the complex nature of California's water resource systems and the wide variety of different possible water transfer designs, it seems apparent that some form of water supply system computer modeling will be required to achieve this integration of water transfers with other water management measures.

Most major water supply systems in the state already possess significant conventional water modeling capability. However, most of these models are specific to individual water systems, in accordance with the needs of traditional water supply and water conservation measures which can be implemented by a single system. The integration of water transfers will likely require significant modifications to these single-system models to allow more explicit examination of long and short term water transfers and exchanges. The economic nature of water transfers also encourages more explicit consideration of the economic nature of water supply operations in system modeling. System models for examining water transfer options together with supply source and water conservation expansions and modifications might usefully provide economic measures of performance (component and net costs) to their traditional technical measures of performance (e.g., yields and shortages). Various agencies and academic researchers have already begun such efforts. Such coordinated operation models have also been developed and successfully applied in the development of other river basins in the United States, in the absence of explicit water transfers, notably for the Potomac River (Palmer, *et al.*, 1982).

The economic nature of the design of water transfers and their integration with other water supply management measures encourages the use of optimization models, where the model itself suggests promising combinations of water transfers, construction, and water conservation. While technically more difficult and still somewhat inexact, optimization modeling can aid in identifying promising solutions, which can then be examined in more detail with simulation models.

WATER TRANSFERS AND PUBLIC PARTICIPATION

The rise of public participation in water planning and management has been one of the greatest changes and advances in the field in the last 20 years. While additional public participation, including participation by many different government agencies, may have slowed water planning processes, it should be recognized that water planning has rarely been fast-paced (Pisani, 1984). Public participation has been essential, in many cases, in improving the design and operation of water projects and improving the integration of water projects with other societal concerns. Some forms of arranging water transfers could threaten the now widely accepted role of public participation in water planning.

As discussed in Chapter 4, water transfers can be arranged under a variety of institutional forums, such as bi-partisan and multi-lateral negotiations, and several forms of brokerage and bidding (see Table 4-3). Each forum has somewhat different implications for how third-party impacts are handled and for the flow of competitive market information between potential buyers and sellers in the water transfer market. These different forums also allow different amounts of public participation. In most cases, forums with the greatest opportunities for public participation also provide potential buyers and sellers with the most market information and provide the greatest opportunities for third parties to become involved.

Under relatively laissez-faire forms of arranging water transfers, individual water users and agencies can seek each other out and negotiate transfer arrangements. Under the relatively imperfect market conditions which will characterize most water transfer situations, there may be either a few major buyers and/or a few major sellers of water. Under this rather oligopolistic situation, it is to the advantage of any party to be secretive in its negotiations and contacts, so that other potential buyers and sellers are not aware of the true value placed on water by that party and of the transfer conditions desired. If this degree of confidentiality is attained, public participation becomes stymied and deferred, perhaps, to the approval of a "done deal." This could be something of a movement away from the more multi-party approach to water planning that has been evolving in California and elsewhere over the last few years.

The State Drought Water Bank type of forum has a very mixed set of effects on public participation. While the process is much more public and subject to essentially annual review and modification, the rules for each year’s Bank must be firmly established at the outset, implying that opportunities for public participation are limited for the duration of each year's Water Bank activities. Most public participation in water transfers and the integration of water transfers into overall water planning must be in the early planning stages of establishing Water Bank rules and early in the planning of individual agency's and district's decision to participate in the Bank.

As discussed throughout this report, there are an enormous number of different types of water transfers and a similar number of approaches for arranging water transfers. It is unlikely, and probably undesirable, that only one form of transfer and one form of arranging transfers be available within a state or region. Still, in arranging water transfers, buyers and sellers should be conscious of the impacts of their negotiations on public perceptions of water transfers. In the past, it has been argued (Kahrl, 1982), secretive transfers of water rights and heavy-handed water development have provoked public and legislative restrictions on water development. It would be a shame if the means by which desirable water transfers are arranged result in an eventual overburdening of water transfers with regulations, constraints, and suspicion. Some more secretive forms of arranging water transfers, while expedient, might prove to have a more long-lived "dark side."

CALIFORNIA'S EXPERIENCE INTEGRATING WATER TRANSFERS

The current California drought has greatly increased the acceptance and reality of water transfers, despite continued controversy. There seems little alternative to the use of water transfers for maintaining the economic use of water throughout the state, as urban and environmental water demands continue to increase. One consequence of the use of transfers and increasing water demands in a climate like California's is that drought planning and water supply planning, traditionally somewhat divorced, are becoming the same. This becomes especially evident for the many water transfers that involve the transfer of water in wet years for water in dry years and the long term storage of water in wet years for use in dry years.

The widespread use of water transfers in California will require increased coordination in the design and operation of water systems. Increased coordination will be required within individual water systems, where water transfers will need to be planned and implemented in concert with traditional water source expansion and water conservation measures. Water transfers will also imply increased coordination between water users, since some water users are now relying on water transferred from other water users.

State and Federal governments have unavoidable and positive roles in the establishment and implementation of water transfers in California. The control of much of the state's water infrastructure by State and Federal agencies makes their involvement in transfers unavoidable. The need for technical support, standards, and water accounting, particularly regarding environmental and other third party impacts, also require some involvement from higher levels of government.

The management of water in California with water transfers will require large amounts of technical work. In particular, technical work is needed

- to form the basis for linking paper transfers of water to physical transfers of water,
- to coordinate the operation of water conveyance and storage facilities for effecting water transfers,
- to assess and manage third party impacts, and
- to provide the modeling capability needed to most effectively engineer water transfers into state and local water supply systems.

While the integration of water transfers into California's water resource system is by no means complete, it has been greatly furthered by the current drought, the sustained, creative, and motivated activities of water agency personnel, and the diverse water infrastructure, water demands, and water resources of the state.

Chapter 8

Conclusions

Ten major conclusions are discussed below and summarized in Table 8-1. These conclusions have implications for the local operation of individual water systems, the technical profession of water resource system planning and management, and the role of Federal, State, and regional governments in inter-jurisdictional management of water resources.

1. Water transfers can be useful for enhancing the performance and flexibility of existing water resource systems.

The California case provides examples of many ways that water transfers can be beneficially used in the planning and management of water supply systems and the socio-economic systems that these water resources support. The major benefits of water transfers include:

• *Increasing the beneficial use of existing supplies.* Numerous examples have been provided where several forms of water transfers have increased the yields of water resource systems at state and regional scales.

• *Favorable net economic and employment impacts.* While the third party impacts of water transfers are an important issue, it is almost without dispute that water transfers can substantially improve the net economic and employment impacts of water resource systems. This net positive impact should also hold true for net revenues to government agencies, in most cases.

• *Add flexibility in drought management.* By enabling drought managers to more economically distribute shortages due to drought, water transfers add flexibility to the management of drought conditions. This form of economic distribution of shortages among users financially benefits those relinquishing water as well as those gaining water through transfers.

• *Help avoid capacity costs.* For many water suppliers, the purchase of transfer water can be less expensive than the construction of additional water supply capacity. Water transfers are not necessarily a complete substitute for supply capacity expansion, but can either defer or reduce the need for capacity. Only in some cases will transfers be able to alleviate all need for additional water supply capacity.

• *Provide a better match of waters of different qualities with different water demands.* By water transfers or water exchanges, urban areas can sometimes receive waters of higher water quality, which reduces treatment costs, health risks, and water taste problems, by exchanging waters of lesser quality that are more than sufficient for agricultural uses.

2. Water transfers must be integrated with traditional supply and demand management approaches.

Water transfers alone will rarely resolve a region's water supply problems in an economical manner. Typically, a more integrated management approach, employing traditional supply and demand management measures, integrated with water transfers, will provide better results in terms of cost, technical performance, and institutional feasibility. There are several reasons why transfers must usually be pursued conjunctively with other water management techniques:

• As elaborated in the next conclusion, modification or expansion is often required in conveyance, storage, and treatment facilities to make the best use of transferred water, including transporting the water to its new user.

• Modifications or expansions of traditional supply and demand management measures are often responsible for creation of transferred water. In many of the California cases, the water

transferred by sellers was made available by expansions in water conservation programs, modifications of storage operations, or modifications to groundwater use.
• To gain political or institutional acceptability, transfers must often be accompanied by other water management measures. Perhaps the best example of this is the requirement of the State Drought Water Bank that urban buyers have already implemented at least a 25% mandatory water conservation effort in their service areas prior to participation.

3. Modification and expansion of water resources infrastructure is often required to take best advantage of transfers.

Modification or addition to conveyance, storage, and treatment facilities may be required to make the best use (or any use) of transferred water. In addition, the operation of existing conveyance, storage, and treatment facilities is likely to require significant changes to facilitate water transfers. In many California cases, the water transferred can only be made useful if it is stored for dry periods, necessitating new surface water reservoirs or additional use of groundwater storage. Conveyance restrictions, both from physical aqueduct capacities and environmental limitations, are also amply evident in the California case.

The case of water transfers involving San Francisco is an example of this, where limitations on storage, conveyance capacities, and treatment facilities all shaped the use of transferred water. New conveyance capacity was required, and the operation of all these facilities required substantial modifications.

Overall, California is relatively well suited to make use of water transfers. The state's "plumbing system" has extensive conveyance and storage facilities, with many major urban users possessing some flexibility in water treatment operations. Still, even with these facilities, the implementation of transfers required significant thought and logistical coordination.

4. Water transfers can take many forms, each serving a different operational purpose in a water resources system.

The California case illustrates the many forms that water transfers can take and the diverse uses for different types of transfer arrangements. Each form of transfer, when utilized for an individual system, can fulfill a different operational purpose and accommodate different legal or third-party considerations. Water transfers can take the forms of permanent purchases of water rights, long-term leases of water, options to purchase water during dry years, short-term purchases on a spot market, government-sponsored water banks purchases, exchanges of water arranged between two or agencies, purchases of conserved urban water, as well as other forms. The contractual agreements that support each of these different types of transfer also can take variable forms. This feature adds immense flexibility to the engineering of water transfers.

5. Appropriate use of water transfers will likely vary between systems, reflecting local conditions.

Each system is somewhat unique, in terms of its supplies, water demands, operation, costs, and alternatives. Different water supply systems will find somewhat different uses for water transfers. For example, some water supply systems will not need or be economically able to employ water transfers. Individual systems with access to relatively little overyear storage capacity would probably find dry year options more useful than long-term continuous water transfers. And, regions with a diverse range of water uses, such as Solano County, might pursue a permanent spot market or water bank arrangement over long-term transfers. This variation in individual water system needs helps explain the diverse ways and degrees that water transfers have been employed in California.

6. Water transfers require a broader scope and scale of thinking about water resources management.

The examples water transfers in California demonstrate that a broader scope and scale of engineering is required to employ water transfers than is common in most water engineering planning and management studies. The use of water transfers in water management implies a regional and inter-regional integration of different water users and supplies. The differences between the demands of urban water systems and irrigation systems are the reason why transfers can be successful to both parties. Water transfers are usually successful when they can better coordinate the water demands of multiple users, combined with payments of other inducements to participate in an economic manner. This is a very different perspective from that of traditional water planning.

This new and broader view of water planning requires:

• coordination of the water demands of multiple water users of different types, whereas traditional water planning examines only the supplies and demands of one water users at a time,
• an economic perspective on the benefits and costs to each party of various transfer arrangements,
• a familiarity with the various contractual and operational forms that transfers can take,
• a familiarity with approaches to managing and compensating potential third party impacts of water transfers; and,
• an integration of the traditionally economic and legal perspectives of water transfers with more traditional supply and demand management engineering measures. This will likely require a more economic perspective from engineers, and more of an engineering perspective from economists and lawyers involved in water planning. It will require more interdisciplinary communication and coordination.

The implementation of this broader perspective on water planning will require significant changes in the operation of water planning departments of major water agencies at the local, state, and federal levels.

7. Environmental, legal, and third-party considerations are important political, planning, and operational considerations in developing and implementing water transfers.

Although not the primary focus of this study, the environmental, legal, and third-party aspects of water transfers were consistently brought up during our interviews and research. Cases of water transfers, both in California and elsewhere, demonstrate the very high degree of importance of environmental, legal, and third-party impact issues in the development and implementation of water transfers. These impacts can come in a variety of forms. Environmental and third-party impacts, in particular, can be both positive and negative and vary across regions. While these issues are formidable, they are not insurmountable.

There are numerous approaches for accommodating, compensating, or mitigating the real and potential third party impacts of water transfers. Selecting the appropriate approach for managing the third party impacts of a particular proposed transfer will require time and thought on the part of all parties involved (including third parties whose involvement often might not be direct). Given the great economic advantage of many proposed transfers, there should be some resources available for addressing third party impacts. Negotiations over the proper philosophy for handling third party impacts are likely to be protracted, however, until the State develops policies on this matter. In the case of the current California drought, in 1991 and 1992, a short-term State policy was adopted which largely ignored many third-party impacts, given the drought emergency conditions and the resulting urgency of arranging transfers.

8. Government sponsorship is often required for significant water transfers to begin.

State and perhaps Federal governments have an important, and perhaps vital role in the adoption and acceptance of water transfers as part of water management activities. Several roles for government are apparent:

• *Rapid implementation of water transfers.* Perhaps the strongest conclusion from California's State Drought Water Bank Experience is that government sponsorship of a forum for water transfers can greatly accelerate the adoption of major water transfers over a wide area. The Drought Water Bank accomplished more water transfers during a few months of drought than had occurred in many years without such government sponsorship. The California case demonstrates that active and substantial government involvement is likely required to make water transfers and effective emergency drought management measure, particularly in regions without pre-existing water transfer mechanisms.

• *Reduction in uncertainty and risk.* Government involvement can reduce transaction uncertainties and risk to those interested in buying, selling or exchanging water. These risks are due largely to legal uncertainties as well as potential liabilities for third party impacts. Government can reduce these risks to individual parties by policy statements and directives supporting transfers, legislation or regulations establishing particular processes and criteria for regulatory approval of water transfers, establishing a legal basis for estimating third party impacts and quantification of water rights, or direct shouldering of risks through government operation of a water bank, as was done by the State of California and Solano County in 1991.

• *Reduction in transaction costs.* Transaction costs are the costs to the buyer of water not directly related to the water's purchase price, such as the costs of legal and technical work, costs of resolving third-party impacts, and the costs of conveying and utilizing transferred water. Governments can reduce these costs in ways similar to those used for reducing risks. In addition, by utilizing State and Federal facilities for conveying and storing transferred water, governments can reduce the costs of physically implementing water transfers.

• *Leadership.* Using transfers in water planning and management is still not widely accepted, particularly by smaller local water agencies. Leadership by State and Federal governments can help ease the legal, technical, and conceptual transitions required for local governments and individuals to make use of this sometimes economical water management technique. In California, the establishment of the State's Drought Water Bank illustrated this leadership role by "breaking the ice" on widespread water transfers, after many years of fitful progress in establishing water transfers. Following this experience, there are now many individuals, firms, and agencies that have become involved in water transfers, and for whom the process now holds less mystery and perceived risk.

After water transfers have become an accepted form of water management, and many of the current controversies have been resolved, the role of State and Federal government probably becomes less essential. However, these units of government will retain a high degree of responsibility for exercising leadership in resolving new issues in water transfers and in using the water facilities controlled by these governments to convey and store transferred water.

9. Drought motivates change.

Historically, major changes in water management philosophy have been motivated and incorporated as a result of experiences during droughts. This has been true for what are now traditional surface water storage and water conservation measures, spurred on by droughts in the late 19th and early 20th centuries and during the second half of the 20th century, respectively. It has also been true for the accelerated use of water transfers in California.

In all these cases, innovations in water management were preceded by a long period of legal and technical studies and sporadic small-scale experimentation. Acceptance by the profession and the public required "trial by fire" during relatively desperate drought circumstances.

As water demands continue to increase and diversify, existing facilities and techniques for water management will become adequate for an increasingly smaller proportion of hydrologic events. This implies that droughts, or water shortages perceived by the public and water users, will become more frequent and severe as water demands expand. This serves to motivate examination and experimentation with novel water management strategies, such as water transfers.

10. Transfers cannot be avoided, only delayed.

It has long been argued that water transfers are one of the least expensive sources of water for supplying new high-valued water demands, such as the growing demands of urban and industrial users (Milliman, 1959). These new high-valued water demands are vocal and vital to the economic welfare of millions of individuals. There is also limited ability to satisfy these demands through urban water conservation or traditional water supply measures alone.

As increasing demands for water make water shortages and droughts more frequent and severe, calls for water transfers are likely to become louder and more forceful. After the 1977 drought, California was able to delay significant water transfers for 14 years, until the next major drought. With the current drought, water transfers are now a significant and permanent feature of water resources planning and management in California.

Table 8-1
Conclusions

1. Water transfers can be useful for enhancing the performance and flexibility of existing water resource systems.

2. Water transfers must be integrated with traditional supply and demand management approaches.

3. Modification and expansion of water resources infrastructure is often required to take best advantage of transfers.

4. Water transfers can take many forms, each serving a different operational purpose in a water resources system.

5. Appropriate use of water transfers will likely vary between systems, reflecting local conditions.

6. Water transfers require a broader scope and scale of thinking about water resources management.

7. Environmental, legal, and third-party considerations will be important political, planning, and operational considerations in developing and implementing transfers.

8. Government sponsorship is often required for significant transfers to begin.

9. Drought motivates change.

10. Water transfers cannot be avoided, only delayed.

(Appendices A and B are unavailable electronically)
Appendix C
List of Interviewees

California State Department of Water Resources
Steve Macaulay, Manager, Drought Water Bank
Maureen Sergent, Staff, Drought Water Bank
Bob Aldridge, Staff, Drought Water Bank
Larry Gage, Operations
Dee Davis, Drought Information Center
Penny Howard, Water Conservation

Bureau of Reclamation
John Burke, Operations
Dell Tucker, Drought Bank Liaison
Merv De Haas, Contracts
Gale Heffler-Scott, Contracts

Yolo County
Jim Eagan, Yolo County Flood Control & Water Conservation District
Fran Borcalli, Consulting Engineer
Jim Yost, Consulting Engineer
Betsy Marchand, County Supervisor

Solano County
David Okita, General Manager Solano County Water Agency
Suzanne Butterfield, Special Assistant, Solano Irrigation District

San Francisco Water Department
Norm Lougee, Water Supply Engineer

Santa Clara Valley Water District
Barbara Bauer Judd, Engineer (telephone interview)
Frank Cotton, Engineer (telephone interview)

East Bay Municipal District
Leo O'Brien, Water Resources Project Manager (telephone interview)

Metropolitan Water District of Southern California
Ed Thornhill Wylie Horne

Others
Lyle Hoag, Director, California Urban Water Agencies
Jerome Gilbert, Consultant, (former-General Manager EBMUD)
B.J. Miller, Consultant (telephone interview)

Appendix D

References

Abbott, W.J. (1988), "California Colorado River Issues," *Pacific Law Journal*, Vol. 19, No. 4, July, pp. 1391-1434.

Agreement Between The United States Of America And The State Of California For Coordination Of The Central Valley Project And The State Water Project, November 24, 1986

Andrews, E.S. (1989), *Simulation Of Kern County, California's Conveyance System, Including Groundwater Recharge*, Masters Thesis, Department Of Civil Engineering, University Of California, Davis.

Attwater, William R. And James Markle, (1988), "Overview Of California Water Rights And Water Quality Law," *Pacific Law Journal*, Vol. 19, No.4, July, pp.959-1030.

Bain, J.S., R.E. Caves, And J. Margolis (1966), *Northern California's Water Industry: The Comparative Efficiency Of Public Enterprise In Developing A Scarce Natural Resource*, Resources For The Future, Washington, DC.

Brajer, V., A.L. Church, R. Cummings, And P. Farah (1989), "The Strengths And Weaknesses Of Water Markets As They Affect Water Scarcity And Sovereignty Interests In The West," *Natural Resources Journal*, Vol. 29, Spring, pp. 489-509.

Boronkay, Carl (1990), "Southern California Rx For Survival," *Aqueduct*, MWD, Vol. 56, No. 1, pp.31-33.

Brooks, D.C. (1983), "Managing Drought In Southern California," In V. Yevjevich, L. De Cuhna And E. Vlachos (Eds.), *Coping With Droughts*, Water Resources Publications, Fort Collins, CO, pp. 381-390.

Brown And Caldwell (1988), *Ebmud Exhibit No. 32: Environmental Assessment For Ebmud Bixler Emergency Pumping Project*, Exhibit For State Water Resources Control Board Hearing On Change In Water Use Location, 11 pp.

BUREC (1992), *Interim Central Valley Project Operations Criteria And Plan*, Bureau Of Reclamation, Sacramento, CA, February.

California Institute Of Public Affairs, (1991), *California Water Resources Directory: A Guide To Organizations And Information Resources, Second Edition*, Roberta Childers (Ed.)

"California's Ground Water After Five Years Of Drought," *Western Water*, November/December 1991, pp. 4-11.

CAN (1992), Open Letter From California Action Network Regarding Water Marketing And Public Policy, Dated August 11, Davis, CA.

Capen, C.H. (1975), "Real Or Rash Regionalization," *Journal Of The American Water Works Association*, Vol. 67, No. 10, pp. 588-590.

Colby, B.G. (1990), "Transactions Costs And Efficiency In Western Water Allocation," *American Journal Of Agricultural Economics*, December, PP. 1184-1192.

Committee On Western Water Management (1992), *Water Transfers In The West: Efficiency, Equity, And The Environment*, National Research Council, National Academy Press, Washington, D.C.

Contra Costa Times (1988), "Ebmud Offers To Buy Mokelumne Water Rights," *Contra Costa Times*, July 7, P. 13a.

Cox, William E., (1982), "Water Law Primer," *Journal Of Water Resources Planning And Management*, Asce, Vol. 108, WR1, March, Pp. 107-122.

Curie, M.M. (1985), "A Distinct Policy Which Forms A Market Within The California State Water Project," *Water Resources Research*, Vol. 21, No. 11, November, pp. 1717-1720.

CUWA (1992), *Survey Of 1992 Demand Management Measures*, California Urban Water Agencies, Sacramento, CA.

CUWA (1991a), *Survey Of 1991 Demand Management Measures*, California Urban Water Agencies, Sacramento, CA.

CUWA (1991b), *Industrial Water Conservation*, California Urban Water Agencies, Sacramento, CA.

Diringer, E. (1992), "State Plan For Water System," *San Francisco Chronicle*, 11 August, P. A1.

DWR (1992a), *The 1991 Drought Water Bank*, California Department Of Water Resources, Sacramento, CA, January.

DWR (1992b), *Contract For Water Service From A 1992 California Drought Emergency Water Bank*, California Department Of Water Resources, Sacramento, CA.

DWR (1991a), *California's Continuing Drought 1987-1991: A Summary Of Impacts And Conditions As Of December 1, 1991*, California Department Of Water Resources, Sacramento, CA, December.

DWR (1991b), *Urban Drought Guidebook*, California Department Of Water Resources, Sacramento, CA.

DWR (1991c), *Management Of The California State Water Project,* Bulletin 132-91, California Department Of Water Resources, Sacramento, CA.

DWR (1990), *Management Of The California State Water Project,* Bulletin 132-90, California Department Of Water Resources, Sacramento, CA.

DWR (1989), *Management Of The California State Water Project,* Bulletin 132-89, California Department Of Water Resources, Sacramento, CA.

DWR (1988a), *Landscape Water Conservation Guidebook No. 8*, California Department Of Water Resources, Sacramento, CA.

DWR (1988b), *Management Of The California State Water Project,* Bulletin 132-88, California Department Of Water Resources, Sacramento, CA.

DWR (1987), *California Water: Looking To The Future,* Bulletin 160-87, California Department Of Water Resources, Sacramento, CA.

DWR (1984), *Water Conservation In California*, Bulletin 194-84, California Department Of Water Resources, Sacramento, CA.

DWR (1983), *The California Water Plan: Projected Use And Available Water Supplies To 2010,* Bulletin 160-83, California Department Of Water Resources, Sacramento, CA.

DWR (1978), *The 1976-1977 California Drought: A Review*, California Department Of Water Resources, Sacramento, CA, May.

DWR (1975), *California's Ground Water*, Bulletin 118, California Department Of Water Resources, Sacramento, CA.

EBMUD (1991), *Urban Water Management Plan*, East Bay Municipal Utility District, Oakland, CA, February.

Ellis, W.H. And C.T. Dumars (1978), "The Two-Tiered Market In Western Water," *Nebraska Law Review*, Vol. 57, No. 2, pp. 333-367.

Enright, C.S. (1989), *Alternative Water District Organization And Efficient Water Allocation: Water Pricing And Water Transfers*, M.S. Thesis, Department Of Civil Engineering, University of California, Davis.

Getches, D.H. (1990), *Water Law*, West Publishing Co., St. Paul, MN.

Gilbert, J.B. (1986), "Preparing Short- And Long-Term Measures For Mitigation Of Droughts," Paper Presented At Symposium On Drought And Famine, International Water Supply Association, London, July.

Gleick, Peter H. And Linda Nash, (1991), *The Societal And Environmental Costs Of The Continuing California Drought*, Pacific Institute For Studies In Development, Environment, And Security, Berkeley, California, July.

Gray, Brian E. (1990), "Water Transfers In California: 1981-1989," In Macdonnell, Lawrence J.(Principal Investigator), *The Water Transfer Process As A Management Option For Meeting Changing Water Demands,* Volume II, USGS Grant Award No. 14-08-0001-G1538, Natural Resources Law Center, University Of Colorado, Boulder.

Gray, Brien E., (1989), "A Primer On California Water Transfer Law," *Arizona Law Review,* Vol. 31, pp. 745-781.

HEC (1988), *Lessons Learned From The 1986 Drought*, U.S. Army Corps Of Engineers, Prepared By The Hydrologic Engineering Center For The Institute For Water Resources, IWR Policy Study 88-Ps-1, June.

HEC (1990), *Modifying Reservoir Operations To Improve Capabilities For Meeting Water Supply Needs During Droughts*, U.S. Army Corps Of Engineers, Hydrologic Engineering Center, Research Document No. 34.

Hecht, P. And J. Mayer (1990), "Drought Dries Up Lifestyle," *Sacramento Bee*, April 3, p. A12.

Howe, C.W., J.K. Lazo, And K.R. Weber (1990), "The Economic Impacts Of Agriculture-To-Urban Water Transfers On The Area Of Origin: A Case Study Of The Arkansas River Valley In Colorado," *American Journal Of Agricultural Economics*, December, Pp. 1200-1204.

Howe, C.W., D.R. Schurmeier, And W.D. Shaw, Jr. (1986), "Innovative Approaches To Water Allocation: The Potential For Water Markets," *Water Resources Research*, Vol. 22, No. 4, April, Pp. 439-445.

Howitt, R., N. Moore, And R.T. Smith. "A Retrospective On California's 1991 Emergency Drought Water Bank". March, 1992.

Jenkins, Mimi (1992), *Yolo County California's Water Supply System: Conjunctive Use Without Management*, Masters Report, Department Of Civil And Environmental Engineering, University Of California, Davis, CA.

Johnson, W.K. (1988), *Opportunities For Reservoir Storage Reallocation*, U.S. Army Corps Of Engineers, Institute For Water Resources, Policy Study 88-Ps-2.

Johnson, W.K., R.A. Wurbs, And J.E. Beegle (1990), "Opportunities For Reservoir-Storage Reallocation," *Journal Of Water Resources Planning And Management*, Asce, Vol. 116, No. 4, July/August, Pp. 550-566.

Kelly, K.F. (1986), *Reservoir Operation During Drought: Case Studies*, Hydrologic Engineering Center, U.S. Army Corps Of Engineers, Research Document No. 25, Davis, CA.

Kahrl, W.L. (1982), *Water And Power*, University Of California Press, Berkeley, Ca.

Kahrl, W.L. (1978), *California Water Atlas*, Governor's Office Of Planning And Research, Sacramento, CA.

Kletzing, R. (1988), "Imported Groundwater Banking: The Kern County Water Bank - A Case Study," *Pacific Law Journal*, Vol. 19, No. 4, July, Pp. 1225-1266.

Laurent, M.L. (1992), "Overview New Development Process/ Water Allocations/ Conservation," City Of Morro Bay, CA.

Little, R.L. And T.R. Greider (1983), *Water Transfers From Agriculture To Industry: Two Utah Examples*, Research Monograph No. 10, Institute For Social Science Research On Natural Resources, Utah State University, Logan, UT.

Lougee, N.H., (1991), "Uncertainties In Planning Inter-Agency Water Supply Transfers," In J.L. Anderson (Ed.), *Water Resources Planning And Management And Urban Water Resources*, ASCE, New York, pp. 601-604.

Lund, J.R. (1991), "Totally Rad Urban Drought Management From California," In J.L. Anderson (Ed.), *Water Resources Planning And Management And Urban Water Resources*, ASCE, New York, pp. 532-536.

Lund, J.R. (1988), "Metropolitan Water Market Development: Seattle, Washington, 1887-1987," *Journal Of Water Resources Planning And Management*, ASCE, Vol. 114, No. 2, March, pp. 223-240.

Maass, A. And R. Anderson (1978), *... And The Desert Shall Rejoice: Conflict, Growth, And Justice In Arid Environments*, MIT Press, Cambridge, MA.

MacDonnell, L.J.(Principal Investigator) (1990), *The Water Transfer Process As A Management Option For Meeting Changing Water Demands,* Volume I, Usgs Grant Award No. 14-08-0001-G1538, Natural Resources Law Center, University of Colorado, Boulder.

Melton, P. (1989), "Ebmud Makes $2.7 Million Water Purchase," *Lodi News-Sentinel*, February 22, P. 1

Metcalf & Eddy (1985), *Sacramento Area Water Resources Management Plan,* Metcalf & Eddy, Inc., Palo Alto, CA.,

Milliman, J.W. (1959), "Water Law And Private Decision-Making: A Critique," Journal Of Law And Economics, Vol. 2, October, Pp. 41-63.

MOU (1991), Memorandum of Understanding Between Yolo County and the Conaway Conservancy Group, February, 1991.

MWD (1992), "A Rich Balance Among The Needs Of Nature And People," *Focus*, No. 1, Metropolitan Water District Of Southern California, Los Angeles, CA, P. 1.

Nunn, S.C. And H.M. Ingram (1988), "Information, the Decision Forum, and Third-Party Effects In Water Transfers," *Water Resources Research*, Vol. 24, No. 4, April, Pp. 473-480.

O'Brien, K.M. (1988), "Water Marketing In California," *Pacific Law Journal*, Vol. 19, No. 4, Pp. 1165-1200.

O'Neill, C.D. (1992), "The Corps' Role In The Water Management Of The Potomac And Susquehanna Rivers," Paper Presented At The 1992 ASCE Water Forum Conference, Baltimore, Md.

Palmer, R.N., *Et Al*. (1982), "Reservoir Management On The Potomac River Basin," *Journal Of The Water Resources Planning And Management Division*, ASCE, Vol. 108, No. WR 1.

Payton, P. (1989), "Yuba's Extra Water To Go To East Bay," *Sacramento Bee*, March 1, 1989, P. A17.

Phelps, C.E., N.Y. Moore, And M.H. Graubard (1978), *Efficient Water Use In California: Water Rights, Water Districts, And Water Transfers*, California State Assembly Rules Committee, Rand Corporation, R-2386-CSA/Rf.

Pisani, D.J. (1984), *From Family Farm To Agribusiness: The Irrigation Crusade In California And The West, 1850-1931*, University Of California Press, Berkeley, CA.

Reed, R.U. (1990), *Transferable Allocations In Urban Water Management: Short- And Long-Term*, Masters Thesis, Department Of Civil Engineering, University Of California, Davis.

Reisner, Marc And Sarah Bates, (1990), *Overtapped Oasis: Reform Or Revolution For Western Water,* Island Press, Washington, D.C.

Report Of The Governor's Drought Action Team, In Accordance With Executive Order No W-3-91, February 15, 1991.

Revesz, R.L. And D.H. Marks (1981), "Local Irrigation Agencies," *Journal Of The Water Resources Planning And Management Division*, Asce, Vol. 107, No. Wr2, October, Pp. 329-338.

Rigby, R.M. (1990), "Water Banking In Idaho," In J. Schaack, *Et Al*., (Eds.), *Planning For Water Shortages: Water Reallocations And Transfers Drought Management*, Proceedings Of The 1989 Regional Meetings Of The U.S. Committee On Irrigation And Drainage, Denver, Co, Pp. 113-118.

Rippl, W. (1883), "The Capacity of Storage-Reservoirs For Water-Supply," *Proceedings Of The Institution Of Civil Engineers*, London, Vol. 71, Pp. 270-278.

Saleth, R.M., J.B. Braden, And J.W. Eheart (1991), "Bargaining Rules For A Thin Spot Water Market," *Land Economics*, Vol. 67, No. 3, Pp. 326-339.

Sergent, M.E. (1990), Water Transfers: The Potential For Managing California's Limited Water Resources, Masters Thesis, Department Of Civil Engineering, University Of California, Davis.

Solano County Water Agency (1991a), "Local Agency Formation Commission Water Supply Report," Solano County Water Agency, November 4, Vacaville, CA.

Solano County Water Agency (1991b), *1991 Annual Report*, Vacaville, CA.

Solano County Water Agency (1992), *Drought Update*, April 9, Vacaville, CA.

Solano Irrigation District (1992), *Emergency Drought Water Pool Plan* March 5, 1992 (Inc/ Relinquishment Of Water Rights Agreements), Vacaville, CA.

Solano Irrigation District (1991), Resolution 91-04 "Drought Reduction Impact Program,' Vacaville, CA.

State Of California. “Report of The Governor’s Drought Action Team”. February, 1991.

SWRCB (1988), "Order Denying Petition For Temporary Urgency Change," Order: WR 88-15, State Water Resources Control Board, Sacramento, CA.

"Tehama County Enacts Strict Limitations On Groundwater Pumping" (1992), *California Water Law And Policy Reporter*, April, Pp 131-132.

Thorson, N.W. (1978), "Storing Water Underground: What's The Aqui-Fer?," *Nebraska Law Review*, Vol. 57, No. 3, Pp. 581-632.

"Tucson Extends Low-Flow Toilet Rebate Offer," *U.S. Water News*, August, 1992, P. 17.

United States Army Corps Of Engineers (1992), *Authorized And Operating Purposes Of Corps Of Engineers Reservoirs*, Department of The Army, Washington, D.C.

United States Bureau Of Reclamation, Mid-Pacific Region, (1992), *Interim Central Valley Project Operations Criteria And Plan*,

Vaux, H.J., Jr. (1988), "Growth And Water In The South Coast Basin Of California," In M.T. El-Ashry and D.C. Gibbons (Eds.), *Water And Arid Lands Of The Western United States*, Cambridge University Press, N.Y.

Vaux, H.J., Jr. (1986), "Water Scarcity And Gains From Trade In Kern County, California," In Frederick, K.D. (Ed.), *Scarce Water And Institutional Change*, Resources For The Future, Washington, D.C.

Wahl, Richard W., (1989), *Markets For Federal Water: Subsidies, Property Rights, And The Bureau Of Reclamation,* Resources For The Future, Washington, D.C.

Wall Street Journal, "Small Town Links Efficient Water Use In Existing Houses To New Construction," P. B4, October 28, 1988.

Warchol, Richard, "State Rejects County's Water Impact Claim," *Davis Enterprise,* P. A-5, March 18, 1992.

Yolo County Draft Water Plan Update, July 1992.

"Yuba County Water Agency Fails To Derail State Board Hearings" (1992), *California Water Law And Policy Reporter*, January, Pp. 71-72.