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Water Allocation During Drought in Arizona and Southern California: Legal and Institutional Responses

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WATER ALLOCATION DURING DROUGHT IN ARIZONA AND SOUTHERN CALIFORNIA: LEGAL AND INSTITUTIONAL RESPONSES

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--David H. Getches

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CHAPTER 1

OVERVIEW: AN ARID REGION DEPENDENT ON IMPORTED WATER

This report surveys the water sources available to a study area that includes Arizona and Southern California and the legal rights of water users in the two states. It assesses the security of those sources and how the various interests served by them will be affected during prolonged water shortages.

In the West, elaborate laws and government policies decide who gets water when supplies are in short supply. Nowhere else are water laws, policies and institutions more complex and firmly set than they are in the Southwest. Nowhere else in the country are so many people concentrated in such a naturally dry area. Millions of people have flocked to an area haunted by the specter of drought. Their security depends on accurate decisions being made about water to protect them from the destructive effects of a severe, sustained dry spell. The area has fortuitously been spared a truly severe drought during its period of greatest growth. It has the advantage of elaborate water conveyance facilities, and it is favored by laws that allocate water to it that originated in a much larger area.

The area includes some of the most arid territory in the world. Average rainfall ranges from 3 inches to 20 inches a year.[1] Usable water that reaches the Colorado River, a mainstay of the area's water supply, averages only about 1 inch a year spread over a vast watershed that drains parts of seven states. Snowpack in the surrounding mountains provides reliable but limited local sources of water. Most of the snowmelt flows into sandy-bottomed streams and alluvial valleys where it recharges shallow aquifers. The water can be recovered with relative ease but excessive pumping causes serious problems. Cyclical droughts are a fact of life in the area.

Considering only the water supplied by streams and aquifers in the area, one would expect a relatively small population, engaged in activities that demand little water. But the natural limits of aridity have not determined the area's course because vast quantities of water have been imported from outside the region and pumped from great groundwater reserves.

Rapid and unrelenting growth has continued through most of the twentieth century. Although the area is approaching the limits of its water supply, as demonstrated by its incipient vulnerability to drought, and significant new water sources are not on the horizon, growth conceivably can persist. This is possible through a combination of enforcing rights against water exporting regions, reallocation and tighter management of present supplies, and sacrifice of aesthetics, lifestyles and environmental values of water use. Securing water for future urban growth in these ways does require increasingly difficult tradeoffs and costs -- reduced agricultural production, environmental degradation, curtailment of lifestyle amenities like green lawns, and possible political conflicts with water exporting regions whose water use must be limited.

A Heavy Dependence on Water

Despite the scarcity of its indigenous natural water supplies, the study area is populated by over 19 million people, about five-sixths of them in Southern California; the area includes the fastest growing cities in the nation.[2] The expansion of human population in the area has accompanied intense economic activity. Much of the activity is water-dependent, including massive production of agricultural goods requiring heavy irrigation. In half a century of almost uninterrupted prosperity and growth there have been few concessions to the area's aridity.

The most obvious natural fact about the region, its dryness, has had little impact on the livelihoods or lifestyles of the people settling there. Indeed, the area abounds with outward manifestations of denial of its aridity. Green lawns and exotic plantings imported from humid climes are the hallmarks of suburban living. Golf courses have proliferated. Fountains and artificial lakes grace residential developments, places of business and government buildings. The area has not attempted to find alternate, less water-intensive ways to satisfy its economic goals, its aesthetic needs, recreational demands, environmental concerns and other objectives.

The government agencies and special districts charged with providing the area with adequate water historically succeeded in keeping supply ahead of demand. Until the last decade they insulated consumers from pressure to restrict usage. And there has always been sufficient water available to accommodate population growth in the region. Engineering ingenuity supported by public investment has created facilities to move water long distances and to store enough to smooth out annual fluctuations in precipitation. Political action and interstate accords have secured rights to use definite quantities of water in Southern California and Arizona vis a vis other states and Northern California.

The region has not yet confronted the limits of its ability to grow. It is, however, struggling to cope with the economic, social and environmental symptoms of rapidly expanding population. The area managed to keep water supplies ahead of growing demand by importing new water and exceeding safe groundwater pumping levels locally. Recently, however, governments and water suppliers in Arizona and Southern California have recognized that encouraging consumers to reduce water demand can relieve some of the pressure to develop new supplies which are increasingly difficult and costly to find.

Cyclical droughts have occasionally broken the illusion of security, reminding water consumers that some uses are more important than others. Legal principles for allocation of water are frequently invoked to determine which combination of streams, aquifers and reservoirs will provide water in a particular year. But ordinarily there is no apparent difference felt by consumers from one year to the next. Only in extraordinary episodes, such as the Southern California dry spell of 1988-1990, have supplies been so low that a few local curtailments in use have been necessary. Yet these droughts have been less severe, shorter and less widespread than the droughts revealed in tree ring studies that reveal historical precipitation patterns.

The moderately severe, multi-year dry spells the area has experienced in the post-war years, since demand has so dramatically increased, have caused localized minor intrusions on lifestyle -- brown lawns, reduction in car washing, attention to leaky plumbing. These episodes have aroused considerable citizen concern in recent years. In Southern California the effects have been confined to a few communities but, because of the publicity, for the first time in seventy years water is being perceived as a potential restraint on the quality of life and on ability to expand. In Arizona, precautionary legal reductions in per capita use in urban areas and controversy over retirement of agricultural uses to provide more water for urban growth have raised Arizonans' consciousness of the finite nature of water in the desert and its linkages to population growth and lifestyle.

The public is beginning to comprehend that every water use must be traded off against every other use and that, as a growing number of people must share a limited supply of water, the necessity for tradeoffs is ever greater. Droughts force those tradeoffs, simulating stresses that will be felt with increasing frequency as growth in demand outstrips supply. And ultimately it is drought that defines the limits of the present system, calling for reallocation among existing users, assertion and restructuring of rights to water from other areas and importation of more water from new sources.

Development of Imported Water

In both the Los Angeles area and in Arizona alluvial groundwater was a rich, vitally important resource that enabled oases to sprout in a desert environment. Early in their history, however, it became apparent in both areas that local water supplies would be inadequate to support extensive growth. The limits of groundwater pumping were realized as overdrafts caused saltwater intrusion along the coastal plain, and eventually land subsidence collapsed aquifers and caused property damage in Arizona. Both areas experienced escalating pumping costs.

Huge quantities of water are now imported from distant sources entirely outside the watersheds of the area served to augment locally available groundwater supplies. This enables millions of people, along with their water-intensive economies and culture, to survive in the deserts that comprise the study area.

The Colorado River, a river to which the area itself contributes only a small amount of runoff, is the mainstay of present and future supplies. The river originates in the Rocky Mountains a thousand miles from the study area. It drains the snowmelt of the Rockies in Colorado and Wyoming, and part of northern New Mexico, then flows generally through Utah and south to form the boundary between Arizona on the east and California and Nevada on the west.

The states along the river early perceived its importance as a source of water for future growth, and entered into legal negotiations to apportion rights to the water. Throughout the century they have pressed for federal expenditures to help harness and distribute the water to bolster the region's economic expansion. The Colorado River was first tapped for use in the study area around the turn of the century to irrigate rich desert soils deposited by the river millennia earlier. In 1901 irrigators in Imperial Valley dug a canal from the riverbanks some 50 miles through Mexico to their farms. From that time until recently, California has been the primary consumer of the river's water. The lucrative farming enterprises of the Imperial Valley and Coachella Valley would not exist today without elaborate canal systems to move water from the Colorado.

In addition, municipal demands created a heavy and growing dependence on the Colorado. Southern California cities from Ventura to San Diego, including Los Angeles, Orange County and their sprawling suburban communities, have relied heavily on imported Colorado River water. Indeed, they have been able to rely on a larger share of this water than is legally allocated to them because Arizona has lacked facilities to put its full share to use. The California cities now facing curtailment of their use of surplus water because Arizona is beginning to use it.

Farmers near the river used water from it from the early days of the Arizona Territory, but Arizona's major municipal uses of Colorado River water only started in the past few years. Yet the state has "depended" on fulfillment of its legal right of access to water for municipal expansion for decades. The state's growth exceeded the natural limits of its water and dangerously drew down its groundwater in the expectation that spent aquifers could be replaced and perhaps replenished with imported river water. The nearly completed Central Arizona Project will enable realization of Arizona's legal entitlements; river water is now delivered to Phoenix and soon will be available to the Tucson area.

Arizona and Southern California each have engineered systems to develop water from sources other than the Colorado mainstream. One of the first federal experiments in "reclaiming" arid lands was the Bureau of Reclamation's Salt River Project. It began as a way of taming and conserving erratic flood waters to serve farmers of Arizona's Salt River Valley. It still serves farmers but is also the main source of surface water for the Phoenix metropolitan area.

The City of Los Angeles began its own projects to import water from watersheds to its immediate north shortly after the turn of the century. The scheme to bring water from Owens Valley to slake the city's anticipated needs is now legendary. Streams feeding Mono Lake were also tapped. For years, the Los Angeles Aqueduct from Owens Valley and Mono Lake has been a vital source for Los Angeles. Southern California turned also to more distant sources of water from Northern California. The State Water Project was built with billions of federal and state dollars partially repayable over time by the users. The project now collects and distributes enormous quantities of water from water-rich northern rivers. Southern California municipal interests have greater contractual rights to these project waters than any of the agricultural contractors in the Central Valley.

For the present, further development of imported water for the region appears financially, politically or physically impractical. Extravagant schemes to develop water from river basins as far away as the Yukon and the Missouri Rivers were seriously discussed in the 1960s and conceivably could be revived. They are likely to encounter great opposition on the grounds that they would be too costly, would deprive the areas of origin of a vital resource and would cause considerable environmental disruption. Desalination of ocean water, cloud seeding and towing icebergs have been discussed. All face technological barriers and huge costs. Although several small structural projects that hold promise for improving the system's capacity and reliability have been proposed, only a few are feasible. This report therefore assumes that development of major new sources of water is not presently a realistic option. If new sources were pursued, they would not be able to produce substantial quantities of water for decades. Thus the question for present generations is how to plan for and survive major droughts with current supplies.

The Legal Matrix

The laws allocating and controlling the water sources used by the study area create a complex and interactive web that must be understood in order to determine who is entitled to water in a severe, sustained drought. All sources of water available to the study area are subject to legal restrictions on when, where and for what purposes they may be used. Present laws also influence the reallocation of existing water rights.

Because of heavy federal involvement and investment in development of water for the study area, federal law is important in determining who has rights to water in a drought. For instance, the Colorado River, which is the preeminent source of renewable water supply for users in the study area, is allocated by an essentially federal body of law. The "law of the river" is a unique aggregation of interstate compacts, Supreme Court decisions, federal laws and contracts that defining who is entitled to use specific quantities of water from the river and how federal facilities (controlling virtually all water in the river) will be operated.

The amounts and circumstances under which water can be delivered to parties who are beneficiaries of the Salt River Project, the California State Water Project and other water development projects are determined largely by contractual agreements. The contracts follow federal or state statutes and regulations depending on the project.

State water laws control how water may be allocated and used within each state. Locally developed sources, including groundwater, are subject to these laws. The same is true of water from interstate rivers once it is apportioned to a state. Arizona has a comprehensive law controlling groundwater pumping and future use which will increase the state's reliance for growth on imported water.

More than ever before, environmental laws affect the quantity of water available to the region. Concerns with destruction of fish habitat and other uses limit the quantities of California State Water Project water that can pass through the delta of the Sacramento and San Joaquin Rivers at San Francisco Bay. The public trust doctrine has been invoked to curb expansion of Los Angeles's use of water that causes harm to bird habitat. Owens Valley residents have sued to curtail exports of groundwater to Los Angeles because it affects ecological values. Increased salinity in the Colorado River may be the factor most likely to limit future use of water from that source. And groundwater pumping is causing salt water intrusion and contaminant plumes to threaten the quality of drinking water supplies.

Inevitable Drought

This report assumes that a severe, sustained drought in the region is inevitable. Cycles of droughts, including major events lasting several years, are shown by historical data and by information scientifically reconstructed from prehistory.

The field of dendroclimatology has produced estimates of flows for rivers on which the study area depends. Data from studies of tree rings furnish information about climate in the western United States going back hundreds of years. Scientists have calibrated and verified their reconstructions of precipitation data based on nearly a century of actually recorded flows. Reconstructions of data show that droughts -- dry years and series of dry years -- have been far more frequent and severe over the last 400 years than is indicated by the experience of the last few decades (Stockton, Meko & Boggess, 1989). It has been during the latter period that the region's population and economy have grown to rely on nearly all the water that is available to it in a "normal" year. It is reasonable to anticipate more serious drought events in the future than the area has experienced in the recent past. With present sources approaching full utilization, water supply systems will experience more stress than ever before.

In addition to evidence portending harsher and longer droughts for the region than have been experienced in the last thirty years, conditions of aridity may become worse than they were in the past. Most scientists now agree that the climate is changing and portions of the earth, including the study area and the areas where its waters originate, are becoming drier. This is almost entirely the consequence of human-induced polluting activities that have increased the layer of carbon dioxide and other gases confining the earth's atmosphere, trapping heat from the sun that would otherwise dissipate. It appears that this is both warming the land and air and changing patterns of precipitation. One study indicated that the annual flow of the Colorado River could be reduced by almost 40% with a 2°C temperature increase and 10% change in precipitation (Revelle & Waggoner, 1983). The exact effects of global climate change on performance of water supply systems of the study area are unknown. However, the prospect of global warming and all credible evidence about the phenomenon heighten the need to consider the consequences of a shortage on the system's performance.

The aim of this report is to identify, based on existing legal and institutional arrangements, the most drought-vulnerable aspects of the present system and the sequence in which stresses will be felt. This analysis should be useful in any attempt to model system performance with greater particularity based on drought experiences drawn from recorded events, from data reconstructed from tree ring studies, or from hypothetical droughts.[3]

Prospective weaknesses in the water supply system are revealed in water-short years. Therefore, it is instructive to model the system's performance against hypothetical severe, sustained drought events to determine where and to what degree problems will be felt under various scenarios of shortfall. Although the severest and longest droughts historically have been infrequent, they nevertheless are realistic bases for hypothetical events. Because demand in the study area is likely to continue to increase somewhat, even if immediate efforts are made to contain it, the types and magnitudes of effects caused by extreme droughts assuming present demand, may become more probable. That is, less severe droughts provoke more serious effects if demand increases and supply remains constant.

A Drought Resistant System?

This report concludes that, under the existing legal and institutional regime, most of the consumptive water uses in the study area (agricultural, municipal and industrial) can be maintained even during a severe, sustained drought. As groundwater supplies diminish, Southern California initially faces restrictions on some agricultural users and modest constraints on municipal deliveries, affecting principally outdoor uses. There will be more severe localized shortages (e.g., Ventura County, San Diego County) caused by limited storage facilities and groundwater in parts of the system. Some areas outside the MWD service area, notably Santa Barbara, lack the imported water to satisfy the demand of their population.

Reductions in State Water Project deliveries will occur after Central Valley users have been cut back for a period of perhaps several years, causing valley farmers to pump more groundwater. But Southern California's basic Colorado River supplies (not including the excess deliveries which have been made in recent years) would remain reliable even if the ten-year period yielding the lowest average flows shown in the data were repeated.[4] This is because the state secured firm legal entitlements to most of the water it diverts from the Colorado many years ago. Central Arizona would suffer some potential reductions in agricultural uses of Colorado River water after many years of drought, but the prospects of municipal cutbacks are remote. Limited foreseeable shortages in Colorado River supplies can be replaced by increased groundwater pumping in Arizona, although there may be problems allowing such increases under the existing groundwater law.

The area's remarkable "drought cushion" is the result of having secured the best legal rights to use a vast reservoir storage system and copious imported supplies drawing from the Colorado River and from Northern and Central California rivers. The plumbing system serving the study area spreads the risk of drought over a great expanse of time and space by collecting water from far beyond the area's bounds and storing many years' natural water production for future use. The legal arrangements that allocate rights to that system concentrate the remaining risk of shortages on some agricultural users in the area, but more heavily on the areas where most of the water originates -- Northern California and the upper basin of the Colorado River. In addition, the legal security of some sources, particularly the Colorado River, comes partly at the expense of environmental values.

Though the water supply for the study area is reasonably secure for present demands, that security may be short-lived. Ongoing expansion of the population and economy of the area will put new pressures on the system and eventually exceed its capacity. It is impossible to predict when that point will be reached. For a while growth can be sustained by using existing supplies more efficiently. Supply systems are being improved and extended, new water management techniques are being adopted and existing rights are being reallocated. Considerable savings of water may be possible with minimal impacts on lifestyle (leak reduction, curtailing over-irrigation of lawns and exotic plantings, agricultural efficiency improvements, retrofitting buildings with water-saving plumbing devices). But if growth continues, these savings will be consumed and further demand reduction will require alterations in lifestyle. The area must eventually turn to reallocation of existing rights, mostly rights now held by agricultural users. Choices among urban lifestyle, agricultural cutbacks and growth control are bound to be controversial. Unless those choices are consciously made, however, the system will become more sensitive to cyclical drought events, and droughts of longer duration or severity will cause greater dislocations.

It may not be immediately apparent that the system is becoming more vulnerable to drought and therefore hard political choices may be postponed. Built-in protections against long-term drought can be used up to meet periodic shortages. Although water managers know better, politicians, developers and consumers could go many years without facing the reality that a water shortage exists. The system may become more vulnerable to droughts, but minor and short-term fluctuations can be masked by drawing more heavily and more frequently on water in reservoir or aquifer storage. If basic demand is expanding there will be less water available to replenish these reserves when natural supplies are above normal and it will become increasingly necessary to tap into storage.

The cushion against severe, sustained drought thus gradually disappears and the potential effects to be suffered in a severe, sustained drought grow more serious and widespread. The risk of harm from drought can increase virtually unnoticed for several years. Eventually, however the greater exposure to risk will be perceived when water users are limited because water supplies are inadequate to meet unconstrained demands. The choice to run a greater risk of drought can be a rational one, but it requires preparation and planning. Restrictions on use are acceptable if they are planned to cause a minimum of surprise and dislocations.

Concern for interregional equity and environmental integrity create additional pressure for attention to the prospect of drought in the study area. The law allows the effects of water shortages to be deflected causing inequities outside the region and environmental harm both inside and outside the region. Though the upper Colorado River basin states are the source of most water in the river, in a severe drought they could be limited to using only the amount of water that was in use in the 1920s. Cities like Denver and Salt Lake City face termination of basic supplies, as do ski areas and agricultural users in the upper basin, long before agricultural, municipal and industrial users in the lower basin are legally required to make any significant cutbacks in water use. Rangeland and forests will suffer unavoidable damage as a consequence of reduced rainfall and runoff. These impacts will be compounded as users must rely on dwindling streams, lakes and groundwater in a desperate attempt to satisfy their historic consumptive uses.

There will surely be ecological damage and lifestyle changes for the residents of Southern California and Arizona who now benefit from and were drawn to the area partly by the area's fish, wildlife, boating, camping and skiing and other recreational opportunities. The damage imposed on such natural resources during any dry period will be exacerbated by heavier diversions depleting streamflows and diminishing wetland areas. These environmental effects will spread into the Rockies and, to a lesser extent (because of institutionalized environmental controls), to Central and Northern California.

Political pressure for nonenforcement or renegotiation of the rights of municipalities and agricultural interests in the study area will mount if their full enforcement results in serious environmental damage and inequities to other regions. It is beyond the scope of this report to analyze the extent of such damages. To the extent the beneficiaries of those rights can anticipate and ameliorate such concerns, however, they may avoid the prospect of political or judicial alteration of their present legal entitlements.

Water supply agencies and governments in the study area have performed well in moving water to the water-scarce region. They have obtained impressive legal protection for rights to import water from afar, even to the detriment of areas where water originates. Water users in Arizona and California consequently are beneficiaries of elegant engineering and legal schemes. But the system stands to lose its resilience as options for expanding supply are exhausted and demand is allowed to increase. The impacts of severe, sustained drought will be felt with increasing seriousness as growth burgeons in the study area unless demand is curbed or supplies are reallocated among existing users. The limits of supply systems, as revealed by their performance in drought will eventually intrude on the lifestyle and economy of the study area and will cause environmental, social and economic effects throughout the seven Colorado River basin states.

Action for Future Drought Protection

Governments and water suppliers in the study area have many options for addressing water supply and demand in order to forestall the effects of drought. Supply-oriented options include expanding sources of supply, managing supplies better, and reallocating supplies. Demand can be managed by limiting per capita use, using conservation measures, restricting population growth and finding less water-dependent means of achieving economic, environmental and other objectives. Drought vulnerability can be improved by incorporating all these options within the legal and institutional framework. Some measures may require alterations in the present framework.

Ultimately, solutions to the problems of water supply and drought require broad public discussion and high level policy decisions. It is inappropriate to expect water supply agencies alone to solve them. Issues like whether to phase out a portion of the region's agricultural industry, whether to place basic limits on water use that affect lifestyle, whether and how to control population growth and how much risk of unmet demand is tolerable are policy issues of fundamental importance. On the other hand, decisions not to improve supply or control demand are inherently decisions to increase the risk of drought effects.

Specific Recommendations

This report recommends the following measures that are discussed in Chapter 6:

Water Supply Management:

<u>Improved Drought Planning</u>

Governments in the area must design comprehensive new planning processes that identify alternatives for meeting society's many objectives that depend on water use.

> Comprehensive water planning includes setting levels of acceptable risks of shortage and commensurate limits on both per capita use and on the number of consumers who can be served.
>
> > Water suppliers and management experts should use comprehensive modeling exercises to determine the system's vulnerability to drought.
> >
> > Drought planning should consider the types and intensity of damage to natural systems that will occur at various levels of reduced supply.

<u>Groundwater Management</u>

The ability of the study area to cushion the impacts of drought depends on the amounts of water that are in aquifer storage.

Storage of groundwater should be a high priority use for any water in excess of essential water demands.

<u>Optimizing Colorado River Reservoir Management</u>

> Depletion of Colorado River reservoir storage in a drought triggers a chain reaction of negative impacts and should be minimized.
>
> Plans should be devised to shift uses to other sources of water as Colorado River reservoirs are drawn down.

<u>Coordination among Colorado River Basin States</u>

> A Colorado River basinwide organization should be formed to make plans and decisions concerning drought and other common interests of the basin states.

Reallocation of Supplies:

<u>Transfers and Marketing</u>

Firm water supplies that may be vital to surviving a drought can be assured through economically beneficial contractual arrangements.

Water salvage and reuse schemes can be pursued.

Exchange agreements can allow more flexible use of existing water resources.

Agreements for use of agricultural water can increase drought protection for urban areas without permanently impairing agricultural production.

Agreements with upper basin states could make present Colorado River supplies more reliable.

Urban water users can negotiate agreements with Indian tribes who have presently unused rights to ensure that water subject to Indian rights continues to be available to the cities.

Water Demand Management:

Demand Limitations

Reduced demand, like a source of supply, can furnish drought protection.

Land use controls can be employed to curb growth in Southern California and Arizona.

Water conservation is a high priority for water suppliers and governments at all levels.

State and federal governments can adopt agricultural water efficiency programs.

Major use restrictions, especially on outdoor urban water use, prolong supplies and delay the negative effects of drought.

Water pricing is the most effective means of reducing urban demand.

Flexible Use of Existing Institutions

Water suppliers in the project area must use the laws and institutions that secure their water supplies flexibly in order to cope with the inevitability of major droughts. Water laws and policies are now changing throughout the West to require better management of water, and water suppliers are responding by using innovative approaches. For instance, several water marketing programs are in the works to reallocate Colorado River water within California, including the widely-discussed Metropolitan Water District-Imperial Irrigation District deal. Creative ideas for storing excess supplies in distant groundwater basins are also being pursued. Those devices can give greater drought protection to urban uses where the growth in demand is the greatest. Millions of acre-feet of water are now allocated to agricultural irrigators in California's Central Valley and Imperial Valley and in western and central Arizona. A relatively small portion of this water could sustain substantial additional urban growth if that is the goal of the two states. Reallocation from several Indian tribes with rights to substantial quantities of water could also feed urban demand if appropriate arrangements were made to compensate them. Negotiations could also lead to a reallocation of water apportioned to the upper Colorado River basin states that is not now consumed by them or that is utilized for low-valued economic purposes, generally agriculture.

Major reallocations raise major questions of equity, environmental concern and social policy. Decisions to shift large amounts of water from agriculture into urban uses, even if they represent only a small percent of the total quantity of water committed to irrigation, may have impacts on the area where the water originates that go far beyond the farmers who sell it. Communities, local governments and economies can be affected. Indian tribes can decide whether or not to convey the right to use water away from their reservations, but must consider the lost opportunities for use of the same water and the effect on their culture and economy and on future generations. There are, of course, serious potential environmental consequences as water is transferred out of an area for use elsewhere.

Many of the same policy issues raised by reallocations must be considered in enforcing existing rights. Users in the study area now have rights to take water in times of shortage to the disadvantage agricultural users in California's Central Valley and, in an extended drought, users in the upper basin states. Environmental harm also becomes more likely throughout the system in years when consumptive demands exceed the quantities of water that are naturally available.

Water suppliers in the project area have often performed during droughts in ways that do not perpetuate inequities. Instead of insisting on their full legal rights regardless of the harshness of the consequences, they have allowed temporary reallocations to prevent socially unacceptable effects for parties disadvantaged under the law. For example, in the 1978-79 drought, the Metropolitan Water District of Southern California had sufficient Colorado River water available and so it agreed not to enforce strictly its rights to State Water Project water, thus allowing farmers in the San Joaquin Valley to sustain their uses of project water. Moreover, in 1990 MWD agreed to sell water outside its service area to relieve the distress of water-short Santa Barbara. It is not clear whether such charity would survive in a deeper or longer drought or if alternative sources were not available to MWD.

Planning to improve the system's drought performance is needed long before the onset of drought. Arrangements for coping with a serious drought are best considered outside a crisis milieu. The affected parties must make long range, creative decisions in advance, not in the heat of a drought. When the "haves" are insisting on their legal rights and the "have-nots" are insisting on their equities during a drought, the possibilities for creative responses are more limited. Furthermore, the emergency conditions can provoke externally imposed solutions.

Drought planning should be considered in a broader context than simply drought response. In a sense all water planning is drought planning. Planning is driven in large part by the amount of water that is available in dry years. Other government policies and powers affect demand for water and it is demand that determines how much water must be available before there is a "shortage." Therefore water supply and the risk of drought should be factors in land use planning and other decisions. If population is allowed to increase without check and per capita water demand is driven entirely by an oasis mentality, no amount of traditional drought response planning will suffice. The degree of future drought protection for the study area ultimately will be more a function of political will than of engineering genius, legal maneuvering or public finance.

This report is intended to contribute to the awareness of the issues and options that is necessary to equip decisionmakers -- not just water managers -- to protect the water security of the study area through a comprehensive approach to drought awareness and planning.

Chapter Organization

Chapter 2 deals with the Colorado River, a major resource that must be shared by Arizona, California and Nevada, as well as with four upper basin states and Mexico. Chapter 3 surveys several sources of water originating within California that are available to Southern California. Chapter 4 discusses sources of water developed within Arizona. In Chapter 5 the performance of the legal institutions allocating available water sources is analyzed. Drought-vulnerable aspects of present supply sources are identified based on the existing legal arrangements. The final chapter recommends options for policy makers and water managers to relieve vulnerabilities to drought in the study area.

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CHAPTER 2

THE COLORADO RIVER -- A SHARED SOURCE OF SUPPLY

The Colorado River is the lifeline of the study area, sustaining its meteoric growth. Local surface water supplies in Southern California and Arizona could meet only a tiny fraction of demands. Copious groundwater were overdrawn to stanch shortages while the two states grew rapidly. Meanwhile they searched for and developed imported water. The first imports came from the Owens Valley in 1913, then from the Colorado. The California State Water Project started delivering water to Southern California from the north 17 years ago but until recently portions of the project were under construction and its waters could satisfy only a small part of the area's demands. Southern California could not have grown as large and as fast as it has, nor could it sustain present levels of consumption, without Colorado River water. Arizona has grown on the strength of the future promise of Colorado River water, while overdrafting groundwater.

Demands on the Colorado River are now so great that none of the average flow of about 13.5 million acre-feet a year reaches the sea.[5] The population within the watershed of the river is sparse and has a history of very slow growth. But the river has been tapped to the limits of its capacity in order to fuel development and population expansion, much of it outside the watershed. Demands are heavily concentrated in the lower basin states of Arizona, California and Nevada. Present demands of the upper basin states, Colorado, New Mexico, Utah and Wyoming, are relatively small. Colorado and Utah, however, depend on the river for significant diversions for municipal uses outside of the watershed, principally in the Denver, Colorado Springs and Salt Lake City areas.

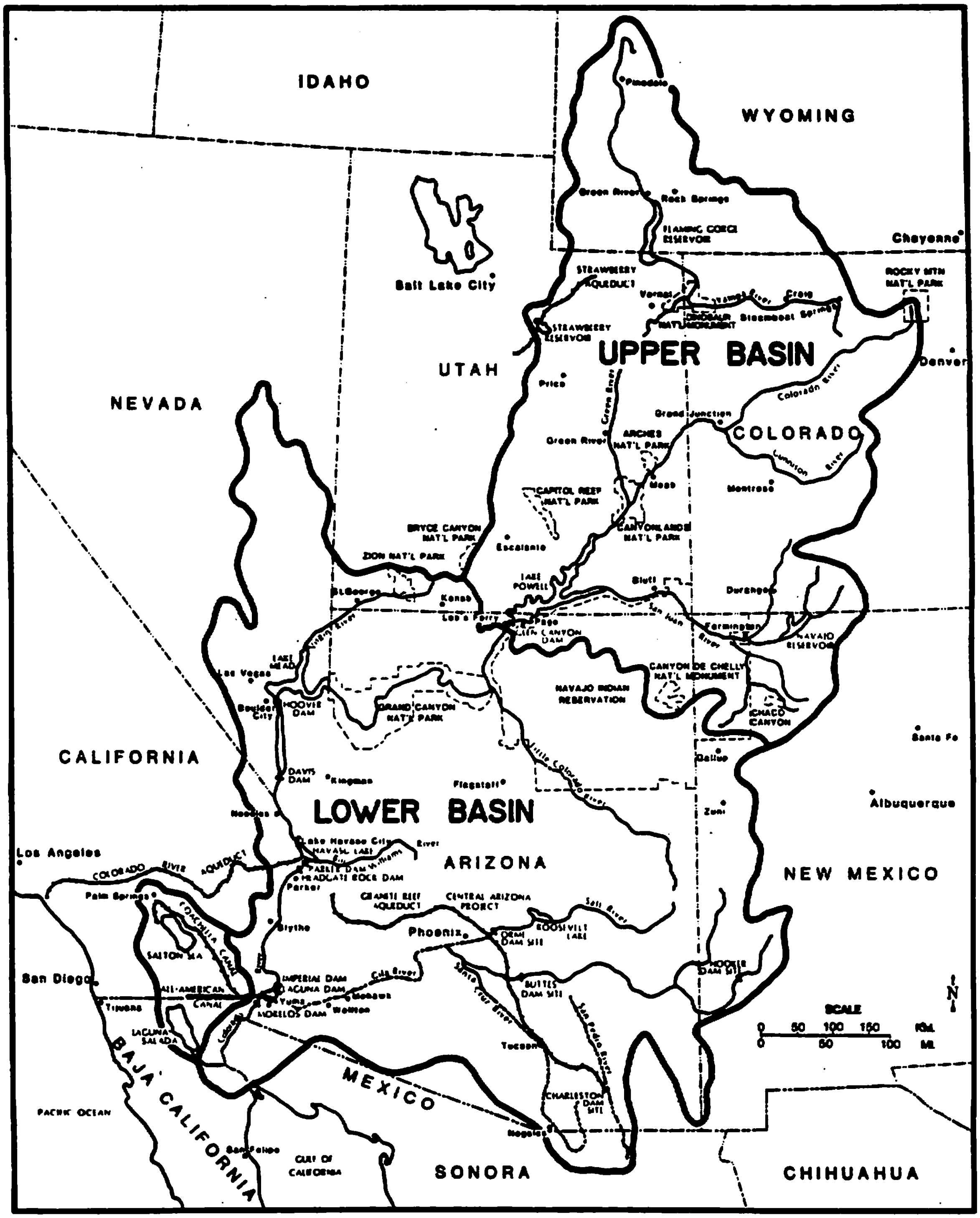
Legal Division of Colorado River Water

The Colorado River Basin, shown in Figure 2-1, comprises parts of seven states. By dint of hard-fought lawsuits, negotiations and political battles, the river's water has been parceled among the neighboring states. The apportionment has been more complete than that of the waters of any other river. The process was contentious and painful at times, and some ambiguities remain. But it is striking how solidly the apportionment is embedded in the relations of the seven states. They disagree on many issues but they seem unanimous in their commitment to keep the basic allocations of the Colorado River immutable.

The lower basin states' resistance to altering legal institutions for sharing the river can be explained by the fact that the present arrangement generally favors them. They have priority to most of the water produced in the basin, with a storage and delivery system that helps to ensure satisfaction of their rights. Still, the upper basin states do not urge alterations in the scheme. If they were left to the mercies of the political process or to the Supreme Court's "equitable apportionment" doctrine, they almost certainly would fare no better. With their smaller populations, slow growth, modest economic importance and relatively meager representation in Congress they are no match for powerful interests in Southern California and Arizona.

Early in the twentieth century, interests in California laid plans to develop the water of the Colorado River. The rich agricultural potential of the Imperial Valley and burgeoning growth in Los Angeles created demands for water and hydroelectric

FIGURE 2-1
Colorado River Basin



power. Thus, Southern California civic leaders, politicians and newspapermen pressured the federal government to build major facilities to store and transport river water.

Upper basin interests were concerned that heavy investments in water project development and lower basin reliance on uninterrupted water flow would make it difficult for upriver states to claim a share of water in the future. Legal precedent suggested that the Supreme Court would, if called upon to apportion an interstate stream, favor the state that gains the most benefit from use of the water (Kansas v. Colorado, 1907) and that, as between two states that follow the law of prior appropriation, the first state to put water to use has a better right (Wyoming v. Colorado 1922). The relatively undeveloped upper basin therefore sought the security of a negotiated interstate compact allocating rights in the river. The Constitution authorizes states to enter compacts, subject to congressional approval, to deal with interstate issues. Before 1922, the device had been used to settle boundary disputes and other controversies, but never to apportion an interstate stream.

The seven states along the 1400-mile river entered into the Colorado River Compact of 1922 dividing use of the river's water between the upper basin and the lower basin. The lower basin states of Arizona, California and Nevada were guaranteed that the upper basin states of Colorado, Wyoming, Utah and New Mexico would deliver an annual average of 7.5 million acre-feet of water to Lee Ferry, a point on the river approximately on the Arizona-Utah border.[6] The upper basin states received a right to use an equivalent amount of water (if it was available). The lower basin also secured the right to increase its beneficial consumptive uses by another one million acre-feet.[7] The Compact recited that "present, perfected rights" are "unimpaired."[8]

The parties contemplated each basin eventually using equal quantities of water (7.5 million acre-feet), plus up to another one million acre-feet for the lower basin. They also expected that the United States would have a future obligation to deliver water to Mexico and agreed to share that obligation equally.

The practical difficulty with the Compact is that it attempted to allocate more water than is likely to be available in an average year. A 1944 treaty with Mexico set the obligation for U.S. water deliveries from the Colorado at 1.5 million acre-feet a year (Treaty with Mexico, 1944). Thus, it would take a total flow of 16.5 million acre-feet a year for this obligation to be met if each basin used its full 7.5 million acre-feet of water. It may not have seemed unreasonable to expect flows of at least 16.5 million acre-feet at the time the Compact was negotiated. In 1922, the average annual flow since 1896 was 16.8 million acre-feet. And the twenty years ending in 1922 were particularly wet ones in the basin, averaging almost 18 million acre-feet a year. These averages are all high, however, based on long-term data. Tree ring studies covering hundreds of years, however, justify a far lower average figure, only about 13.5 million acre-feet (Stockton and Jacoby, 1976).

Demands in the lower basin states are now large enough to consume their full 7.5 million acre-feet per year share of river water. Annual deliveries of this quantity at Lee Ferry plus the upper basin's one-half share of the Mexican Treaty obligation (750,000 acre-feet) would leave an average of only 5.25 million acre-feet available for upper basin consumption in average years.[9] The burden of meeting lower basin delivery requirements generally is on the upper basin because the upper basin apportionment is expressed in terms of limitations on its use, so as to guarantee deliveries in the specified amounts at Lee Ferry. This burden has worked no hardship so far because the upper basin has actually developed and used less than 4 million acre-feet annually and reservoir storage has generally been high since the upper basin facilities were built.

The upper basin has the right to use 7.5 million acre-feet only if that quantity is available after it has satisfied its delivery requirements which average 8.25 million acre-feet a year (the assumed lower basin demand 7.5 million acre-feet plus an upper basin contribution of .75 million acre-feet toward the Mexican Treaty obligation). Another million acre-feet also potentially goes to lower basin beneficial uses. Beyond these amounts, the allocation of any additional waters is not specified by the Compact, but is left to future apportionment in Article III(f). However, the point is largely academic given the mistaken estimates concerning average flows. Above average flows in most years will most likely be needed to replenish and build up supplies of water in storage.

Under the Compact, the upper basin is not actually required to deliver a fixed quantity of water at Lee Ferry for the lower basin in any particular year, though current operating criteria adopted by the Bureau of Reclamation provide for releases of 8.23 million acre-feet annually. The only annual delivery obligation in the Compact is one-half the Mexican Treaty guarantee of 1.5 million acre-feet. This presumably could allow the upper basin the flexibility to consume up to the full virgin flow in low water years and store water in excess of its needs in high water years. This is subject to the condition that deliveries to the lower basin at Lee Ferry for the current year plus the immediately preceding nine years (the ten-year moving average) total no less than 75 million acre-feet (Colorado River Compact, Article III(d)).

The waters apportioned between the basins have also been rather precisely divided among the states within each basin. The Upper Colorado River Basin Compact approved in 1949 gave each upper basin state a percentage of the quantities of water left over after meeting obligations to the lower basin and Mexico.[10]

The lower basin states were unable to agree on an apportionment among themselves for many years. Arizona refused to ratify the Colorado River Compact, fearing that it would enable California to monopolize the river. California was indeed pressing for major development of the river with annual proposals in Congress for what was to become Hoover Dam. Arizona was able to stall enactment of a law approving the project for six years. But in 1928 the Boulder Canyon Project Act authorized the dam and further provided that the Colorado River Compact could become effective upon the ratification of only six states, i.e., without Arizona's consent.

The Boulder Canyon Project Act conditioned authorization of Hoover Dam on California's agreeing that its consumption of water would not exceed 4.4 million acre-feet a year. The Act further provided that the three lower basin states could enter a compact that would apportion to Arizona 2.8 million acre-feet and Nevada 300,000 acre-feet for their annual consumptive use. Excess deliveries were to be apportioned under the authorized compact 50% to California, 46% to Arizona, and 4% to Nevada.

No such lower basin compact was ever negotiated but in 1963 the Supreme Court held that the Boulder Canyon Project Act effected an allocation of the lower basin share of water among the three states

(Arizona v. California, 1963). The Act's particularity in specifying each state's proposed share convinced the Court that Congress had made an apportionment of the river's water whether or not the states actually entered into an agreement to that effect.

Arizona eventually approved the 1922 Compact as a means of securing some of the benefits of Hoover Dam, but not until 1944. The state's resistance had been worn down after twenty-two years, three unsuccessful Supreme Court cases (Arizona v. California, 1931, 1934, 1936), internal strife, drought and even a short-lived military action against crews building a dam partly on Arizona land to serve Southern California. Facing dwindling water supplies, inadequate electric power, dry wells and a lack of facilities to bring water from the Colorado, Arizonans rethought their refusal to cooperate in the allocation of river water. The United States' 1944 agreement that Mexico was entitled to a 1.5 million acre-feet share of the river was the last straw. Three weeks after the Mexican Treaty was signed, the Arizona Legislature, perceiving that the state was effectively disenfranchised in Colorado River affairs, ratified the Compact.

Arizona's belated acquiescence in the Compact may have removed one perceived obstacle to its sharing the fruits of federal investments in river development, but its agreement did not move the state noticeably closer to the water and power it needed. Years of fighting to procure the massive Central Arizona Project (CAP) followed. Arizona embraced the Bureau of Reclamation's plan for an aqueduct system that would pump 1.5 million acre-feet of water per year 1800 feet uphill, then transport it more than 240 miles to Phoenix and Tucson. California bitterly opposed the project. At first, the two states sharply disagreed over the quantities of water to which each was entitled. Congress refused to approve any project until the two states worked out their differences. This led to the 1963 Supreme Court decision in Arizona v. California that recognized the shares set out in the Boulder Canyon Project Act as effecting a congressional apportionment of the river.

The Supreme Court's decision validated Arizona's claim to 2.8 million acre-feet and thus enhanced the state's standing to seek congressional largess for Colorado River development. But the Court also reckoned with the claims of five Indian tribes whose reservations lie along the river. The Court held that the tribes had a right to use up to 900,000 acre-feet of water a year. The amount of water was based on the implied intent of Congress: it would take this amount of water to irrigate the arable lands on the reservations. Because Congress apparently intended the Indians to be farmers the Court said that they should have enough water to carry out this purpose. It is significant, however, that although the rights of the tribes were quantified based on potential irrigation demands, their future use was not legally limited to agriculture (Arizona v. California, 1979).

Arizona's quest for the CAP continued for several more years. California persisted in using its dominant political force to oppose the project, realizing that its demands already exceeded its legal share of water. The political price of California's support was Arizona's concession that any annual shortages would be met from the CAP's share before any reductions were made in California's 4.4 million acre-feet share of water. The upper basin states also argued successfully for authorization of several water projects in exchange for their support of the bill. Finally, in 1968, Congress passed the Colorado River Basin Project Act allowing the project to proceed under these and other conditions.

It took almost eighteen years after the authorization to complete the basic works of the Central Arizona Project (CAP). Appropriations for the costly project -- about $2 billion -- were difficult to obtain, and building the behemoth aqueduct was a major undertaking. Most of Arizona's great population growth had been supported by groundwater pumping, resulting in huge annual overdrafts that caused water tables to drop sharply and much overlying land to subside.[11] The Carter Administration invoked a restriction in the 1968 authorizing act against use of CAP water in areas that did not effectively control the expansion of groundwater use for irrigation and threatened to withhold financial support for the CAP. This put pressure on Arizona to proceed with efforts to control groundwater withdrawals. The state then passed a significant new groundwater management law in 1980, designed to phase out agricultural use of groundwater and to impose conservation planning requirements on areas of concentrated municipal growth.

California's rather firm entitlement to 4.4 million acre-feet a year, plus any surpluses to which the state is entitled, has been divided by a 1931 "Seven Party Agreement." The Agreement gives the highest priority to several agricultural irrigation districts for up to 3.85 million acre-feet, then to the Metropolitan Water District of Southern California (MWD) and the City of Los Angeles for up to 550,000 acre-feet, then (to the extent water remains unused) to MWD and to the City of San Diego and County of San Diego for 550,000 and 112,000 acre-feet respectively, with equal priority.[12] There are additional allocations and priorities, but these major provisions actually leave little water for any users other than the agricultural districts and MWD together because they are virtually certain to use their full allocations. The additional allocations (beyond the total California entitlement of 4.4 million acre-feet) have been extremely important to MWD for many recent years as Arizona has not taken its full share of the lower basin entitlement: MWD has actually taken about 1.2 million acre-feet under the Seven Party Agreement. California thus has diverted several hundred thousand acre-feet a year more than the state's Compact share. These additional diversions to California are being reduced as the Central Arizona Project becomes operational and Arizona is able to call for its share of Colorado River water.

The prospect of losing the use of waters apportioned to Arizona has caused MWD to seek replacement sources. One of the most promising approaches is to reallocate rights to Colorado River water under the Seven Party Agreement through a variety of innovative transfers. MWD has begun negotiating agreements with the agricultural districts, attempting to expand its right to use river water. These agreements are possible without a reduction in agricultural production because water that has been lost by inefficient conveyance facilities and practices can be salvaged.

The largest of the agricultural water districts entitled to Colorado River water is Imperial Irrigation District (IID). For many years it has been apparent that IID was diverting far more water than necessary for its crop lands, resulting in the waste of huge quantities of water through seepage and return flow into Salton Sea, a saline water body in a sink that collects runoff from the entire valley. The State Water Resources Control Board found IID's excessive use of water to be unreasonable and ordered it stopped. Meanwhile, MWD was searching for new water supplies to substitute for the surplus Arizona water it was temporarily using while Arizona completed the Central Arizona

Project, which will enable delivery of that water to the Phoenix and Tucson areas.

After five years of study and negotiations, IID and MWD reached an agreement in 1989 for MWD to take IID water conserved by projects financed by MWD. The Conservation Agreement commits the parties to a five-year program commencing in 1990 which involves lining canals, constructing new regulating reservoirs and automating the IID delivery system. These projects will cost MWD an estimated $97.8 million and it has agreed to pay an additional $23 million for certain indirect costs, including mitigation of adverse impacts on agriculture and the environment and for lost hydroelectric revenues. These improvements are to conserve some 106,100 acre-feet a year, which will be available to MWD. This results in a capital cost of about $1,139 per acre-foot to MWD. MWD has the right to the water for 35 years and will take it from on the Colorado at its Parker Dam diversion, resulting in a nominal cost of about $33 per acre-foot if all the conserved water is delivered over that period.

Other transfers hold considerable promise for augmenting MWD's share of waters from the Colorado River. Congress has authorized California contractors to line the All American Canal and to contract to receive the benefit of the water conserved, estimated to be about 70,000 acre-feet per year (102 Stat. 4005). In 1987 MWD concluded a contract under which it is lining 31 miles of the Coachella Canal for which it will receive the right to use about 26,000 acre-feet of the Coachella Valley Water District's allocation (Kaman, 1991). Approximately 300,000 acre-feet more water may be available from other conservation improvements within the IID. MWD and perhaps other municipal users in Southern California will negotiate for the right to use this water in return for paying the costs of salvage.

Present Demands

For the last 10 years California alone has taken about 5 million acre-feet a year from the Colorado River (including its share plus much of the unused portion of Arizona's share). The upper basin states collectively have consumed about 3.5 million acre-feet of water in recent years, less than half their apparent legal entitlements. Though Arizona's lack of delivery facilities has impeded its ability to consume water legally available to it, the completion of the Central Arizona Project, by far the most elaborate and expensive project ever sponsored by the United States Bureau of Reclamation, will make it possible for Arizona to divert its full share. California and Arizona each already has consumptive uses capable of exceeding its full legal apportionment of Colorado River water. And Nevada, the other lower basin state, now has demands for more than its 300,000 acre-feet entitlement. The extent to which Arizona decides to use river water or to use other sources to meet its growing demand is heavily influenced by economics. At an estimated $55 per acre-foot, the cost of pumping CAP water could make the lower cost option of pumping groundwater more attractive to Arizona users. While this would continue overdrafts in Arizona, it would allow Southern California to continue to use more than its apportionment of river water.

The five Indian tribes with reservations along the mainstem of the river have been consuming only about 395,000 acre-feet, or about 44% of their maximum entitlement of 900,000 acre-feet (or sufficient water to irrigate about 140,000 acres, whichever is less). The amount they consume is to be charged to the shares of the states where the water is used. This theoretically reduces the amounts of water now available to non-Indian users in Arizona and California under the Compact by 340,000 acre-feet and 55,000 acre-feet respectively, but it has not led the Interior Department to restrict diversions by the two states. The tribes have recently begun to increase their use of water, which will further diminish the water legally available to the two states. The tribal allocations appear to be fixed and not subject to later expansion even if the Indians make a substantial showing that they ought to have been awarded rights to a greater volume of water in the original adjudication (Arizona v. California, 1983).[13] However, the demands of dozens of other tribes in the basin have not yet been quantified. Their claims based on practicably irrigable acreage could be enormous: most estimates are in the millions of acre-feet.[14]

In times of shortage, priorities of Indian reserved water rights throughout the basin entitle them to be satisfied first, in order of priority date, along with non-Indian "present perfected rights." Unlike the absolute priority of such rights in the upper basin, "present perfected rights" in the lower basin are to be satisfied according to Arizona v. California, 1963, which recognizes broad discretion for the Secretary of Interior to allocate Colorado River water by contracting for water deliveries from the river's storage facilities.

Storage and Delivery Facilities

Federal subsidies have supported the development of Colorado River water, enabling Southern California and Arizona to prosper and grow. Well over half of the federal Bureau of Reclamation's total construction budgets from inception of the national program has been invested in the region (U.S. Bureau of Reclamation, 1981). Much of the investment has been recovered from power sales and municipal water contracts.

Virtually all of the water in the river now can be regulated by Reclamation dams which have a storage capacity equal to about four years' average annual flows. Total storage is about 63 million acre-feet. Of this amount, 34 million acre-feet are in the upper basin, most of it (27 million acre-feet) in Lake Powell, behind Glen Canyon Dam; and 28.6 million acre-feet are in the lower basin. Most of the lower basin storage (26.2 million acre-feet) is in Lake Mead, which was created by Hoover Dam. Though the facilities are constructed in both the upper basin and lower basin states, they store water that is primarily available for use in California and Arizona.

The extensive reservoir storage system on the Colorado provides protection against periods of uneven or below average annual flows. While most of the reservoir storage is located too far down the river to hold water for use in the upper basin, storage complements the Compact to serve both basins' needs. Indeed, the compact allocation scheme would not work without some storage facilities. The potential benefits to the lower basin states from the reservoirs are great. Flood waters are captured when they would otherwise flow to the sea, so that stored water is available in dry years. This is especially important because runoff, and consequently the quantity of unused upper basin water flowing to the lower basin, fluctuates tremendously.[15] Furthermore, storage facilities allow the Secretary of Interior to make deliveries of water to users at the times when the water is needed, not just when the upper basin states decide to deliver it.

The upper basin also realizes benefits from the reservoirs. It need not deliver a set amount of water for lower basin uses in any particular year because the compact obligation is expressed as an aggregate release requirement for the most recent 10-year period. So if excess water has flowed to the lower basin in wet years, it results in a credit that allows the upper basin to use most or all of the virgin flow if necessary in dry years. Meanwhile, water in storage from years in which there was a surplus can be released to satisfy compact guarantees to the lower basin and Mexico.

The Colorado River reservoirs, like other surface storage systems, lose stored water to evaporation. Evaporative losses are especially high in the Colorado River basin because the region is so arid. The Bureau of Reclamation estimates that the average annual evaporative loss between 1976 and 1980 was over 1.7 million acre-feet.[16] Evaporative loss has two consequences for drought planning: 1) there is an optimum level of storage in the basin beyond which there will be no net increase in the long-term usable supply, a level that was long ago reached on the Colorado (Langbein, 1959; Hardison, 1972); and 2) evaporative loss is a consumptive use that is debited to the basin in which the water was stored.

The elaborate system of dams on the Colorado River also produces hydroelectricity selling for about $500 million per year. The power is priced at below market rates and used mostly in California and Arizona. The largest single power customer is the Metropolitan Water District of Southern California which uses it to pump Colorado River water into its south coast service area. Hydroelectric power production was not a primary purpose under federal statutes authorizing most of the facilities on the Colorado River. The 1922 Colorado River Compact expresses a preference for the "dominant purposes" of domestic and agricultural uses over the "subservient" use of water for power generation (Article IV(b)). The preference is reflected in the Boulder Canyon Project Act which implements the Compact and declares that the project (Hoover Dam and related facilities) is to be used "first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and satisfaction of present perfected rights [pursuant to the Compact]; and third, for power." The purposes of the federal facilities and the comprehensive water development have been expanded in successive enactments, for instance the 1968 Colorado Basin Project Act, authorizing the CAP and other projects and providing for the methods for long-range operation of all system reservoirs, added specific mention of "improving water quality; providing for basic public outdoor recreation facilities, improving conditions of wildlife ... ." (43 U.S.C. § 1501 (a)). But Congress insisted that "generation and sale of electrical power [is] an incident of the foregoing purposes."

Although power generation was only an incidental motive for Congress's decision to construct facilities on the Colorado River, it has become a highly influential factor in how the Secretary operates the reservoir system. Sales of hydropower have replenished government coffers, satisfying project repayment obligations even as agricultural users have sought relief from those obligations. Although the seven basin states tend to resist operations designed primarily to produce more power while depleting the storage available for future water delivery needs, they recognize the benefits of achieving repayment of project costs. The tension between releasing water for power production and the need to hold it in storage to conserve it for consumptive needs has not yet been fully felt because the reservoir system has been filling or nearly full in most years since it was constructed.

Reservoir Operations: Authority of the Secretary of the Interior

The operation of storage and delivery facilities is determined largely by the Secretary of Interior. Several acts of Congress vest the Secretary with broad powers to decide how much water to store, how much to release, for what purposes and when.[17] The United States Supreme Court resoundingly endorsed extensive exercises of Secretarial discretion in Arizona v. California, 1963. The Court found that Congress effectively gave the Secretary authority to carry out interstate allocation of lower basin water through contracts with water users.

Conflict over the manner in which the Secretary exercises his discretion arose when the new Glen Canyon Dam was completed. The Secretary decided to release water from Lake Powell for power generation while the reservoir was still filling. Water users challenged the decision but the court ruled that the Secretary acted within his discretion (Yuma Mesa Irrigation & Drainage District v. Udall, 1966; Yuma County Water Users Ass'n v. Udall, 1964). The controversy over whether the Secretary should release water for power generation, allow consumptive uses and store water for future needs led to the enactment of a provision in the 1968 Colorado River Basin Project Act requiring the Secretary to promulgate operating criteria (43 U.S.C. §1552). The resulting criteria adopted by the Secretary, which are subject to review every five years, govern operation of Lakes Powell and Mead. The Secretary has broad discretion to fashion these operating criteria. Thus, a court would have to find that the Secretary's decisions on how to operate the reservoirs amounted to an abuse of discretion in order to overturn them. The need for conservation storage has not yet been great enough for water users to make such a showing.

An important feature of the operating criteria affecting drought management is that the Secretary will release a minimum of 8.23 million acre-feet of water from Lake Powell in each year that he finds that it is "reasonably necessary to assure compact deliveries without impairing upper basin uses". The lower basin must rely on inflow of the Paria River just Glen Canyon Dam to supply the other 20,000 acre-feet needed to make up the 8.25 million acre-feet upper basin delivery obligation. Thus the lower basin cannot ordinarily call for additional releases for present beneficial uses under article III(b). Greater amounts than 8.23 million acre-feet can be released, however, if the lower basin has beneficial consumptive uses for it and the upper basin does not, provided two conditions exist: 1) active storage in the lower basin in Lake Mead is less than the amount of active storage in Lake Powell; and 2) the Secretary finds that Lake Powell storage is not "reasonably necessary" to meet the upper basin's delivery requirements under the Mexican Treaty and the Compact "without impairment of annual consumptive uses in the upper basin."

The first condition can benefit the upper basin. It ensures that Lake Mead must be drawn down for lower basin uses rather than allowing storage in Lake Mead to be built up while depleting Lake Powell with upper basin releases for the annual needs of the lower basin. Balancing the use of the two reservoirs provides some assurance to the upper basin that it will not be forced someday to forego use of annual runoff in order to make annual compact deliveries even as the lower basin has copious water in storage.

Other aspects of the criteria could potentially operate to the detriment of the upper basin. For instance, they allow the lower basin to draw on Lake Mead for more than 7.5 million acre-feet of annual consumptive uses in years when the Secretary finds that a "surplus" exists. Depending on how liberally the Secretary interprets the criteria for determining a surplus, the provision could accelerate drawdowns of Lake Mead, creating an imbalance between the two reservoirs thereby helping to justify further releases from Lake Powell. Furthermore, the basic requirement of a constant delivery of 8.23 million acre-feet could be applied to deny the upper basin's ability to make excess deliveries in high-flow years and then deliver less in dry years. This was an important element of flexibility built into the Compact. The provision requiring basically constant annual deliveries has not operated to the harm of the upper basin because Lake Powell has been full or nearly full in recent years. Nevertheless, the criteria could prove troublesome, for instance, if in a series of dry years the upper basin needed to use nearly all the natural inflow for its own purposes and Lake Powell had inadequate water in storage for releases of 8.23 million acre-feet. It might be in the upper basin's interests to curtail deliveries for a few years, relying on past years surplus deliveries or counting on years of surplus occurring in the future to even out the averages. This would allow it to use limited inflows to meet its own demands. Presumably, the compact negotiators intended to allow such flexibility when they provided a ten-year moving average as the measure of the upper basin's delivery requirements rather than a constant annual requirement.

The operating criteria can be read to require very conservative secretarial policies with respect to releases from reservoir storage. They specify that the Secretary must prepare an annual operating plan for the Colorado River reservoirs. The plan must consider several factors including:

(a) Historic streamflows;
(b) The most critical period of record;
(c) Probabilities of water supply;
(d) Estimated future depletions in the upper basin, including the effects of recurrence of critical periods of water supply;
(e) [various studies];
(f) The necessity to assure that upper basin consumptive uses not be impaired because of failure to store sufficient water to assure deliveries [of the Mexican Treaty obligation and of the 75 million acre-feet of water every ten years as required by article III(d) of the Compact]. (U.S. Dep't of Interior, 1978)[18]

If the criteria are read to prefer storage of water for drought protection, releases beyond the basic compact requirements and Mexican Treaty deliveries would be rare, largely confined to years when the reservoirs were full or nearly full. The ten-year treaty quota for the lower basin of 75 million acre-feet probably will be a maximum except when there are spills from a full reservoir or to the extent storage space must be vacated for flood control.

The operating criteria, especially as applied in the Secretary's plan of operations, now favor power generation. The attempt to balance storage in Lake Mead and Lake Powell is more than an attempt to achieve some degree of interbasin equity. It is a means of optimizing the power generating potential of the two reservoirs. The minimum delivery quota of 8.23 million acre-feet provides the reliable annual supply of water needed to produce power. Furthermore, when additional releases are made to equalize Lake Mead and Lake Powell storage (i.e., when the Secretary determines there is sufficient water in upper basin storage), the criteria ensure that "the annual release will be made to the extent that [water] can be passed through Glen Canyon Powerplant when operated at the available capacity of the powerplant." In this way, the

Secretary through the Bureau of Reclamation has operated the facilities, especially the timing of releases, to maximize power generation. The availability of a large supply of low cost power benefits some users like CAP and MWD who have to pump river water over mountains lessening the likelihood of lower basin objections.

The hydropower-inspired regime of reservoir operations is potentially at odds with drought protection goals and water use and conservation. Sometimes it can mean less water is released than the upper basin might choose to release in a high water year. At other times it could lead to premature depletion of stored water in dry years that could be detrimental to water users in both basins. Surely it denies the upper basin some of the flexibility it bargained for in the Compact.

Major conflict over the Secretary's operating criteria has been avoided only because of the extraordinarily high runoff conditions in recent years. Operation of the Colorado River reservoirs could be legally challenged as contrary to the Law of the River if it results in preference to hydropower over the project's primary purposes. As a drought approaches, the likelihood of such a challenge increases because the Secretary presumably is charged with reconciling competing uses consistent with the Law of the River. Overall, the law favors conservation storage and service of multiple purposes which the Secretary must consider and reflect in the criteria and plans of operation.

Conflicts between power generation and environmental and recreational concerns have become more apparent than conflicts with water storage needs in the operation of Colorado River reservoirs. Impairment of recreation and environmental harm occur not only during the periods of low flow. Radical fluctuations in water releases from Glen Canyon Dam that respond to peak power demands disrupt recreational uses by creating hazards and limiting overall opportunities for white-water boating and they cause environmental damage in Grand Canyon by eroding banks and beaches, stranding fish, exposing spawning beds and artificially altering wildlife habitats.

Recreational and conservation interests have challenged the operating regime (<u>Grand Canyon Dorries v. Walker</u>, 1974; <u>National Wildlife Federation v. Western Area Power Administration</u>, 1989). These challenges and the Department of the Interior's own recognition that there were existing and potential problems with the way the reservoirs were being operated led to the commissioning of the Glen Canyon Environmental Studies. The resulting studies furnished considerable new information but, according to a National Research Council review requested by the Department, were lacking in a number of respects (National Research Council, 1987). A new round of studies is now in progress and the Department has decided to prepare an Environmental Impact Statement (EIS) on Glen Canyon Dam operations. In addition, the Western Area Power Administration (WAPA) which is in charge of marketing power from dams on the river will prepare an EIS on the post-1989 General Power Marketing and Allocation criteria which guide its contracting activities. The WAPA EIS is the result of a lawsuit initiated by conservation groups.

The environmental impact statements, Glen Canyon Environmental Studies, and the National Research Council review should aid in determining how the reservoir system can be operated for optimal benefits. According to the National Research Council, "Changes in operations at the [Glen Canyon] dam . . . could reduce the resource losses occurring under current operations and, in some cases, even improve the status of the resources ... ." The Council's report, however, pointed out that the United States has assumed major contractual obligations to provide power which could be a constraint on any operational changes that attempt to balance competing demands. The Council urged a close look at these constraints, noting succinctly that, at this point in the management of Colorado River resources, "power not water delivery is the key to the operation of Glen Canyon Dam." Presumably water supply, including drought management, and other goals will take a higher place in the considerations of the Department as it revises dam operations to correct the "tail-wags-dog" preference for hydropower that has evolved into the present regime.

The Salinity Problem

Colorado River water is heavily polluted with salts by the time it reaches diversion points for California and Arizona users. The problem is caused by natural salt seeps, by irrigation return flows carrying salts leached from soils and by concentration of salts due to depletions from consumptive uses and from reservoir evaporation. In the past, salinity has occasionally reached levels that are considered unsuitable for irrigation. A salinity control program now helps to keep water quality at acceptable quality. Nevertheless, maintaining the quality needed by users depends precariously on having sufficient flows to dilute salts in the river. Higher salt concentrations in a drought could render waters in the river useless for many purposes.

The salinity problem became an international incident in 1961 when salt concentrations in the water flowing into Mexico to satisfy the Mexican Treaty obligation reached 2700 mg/l, too salty for irrigation. The sudden increase in salinity was caused by a federal "rescue" project that removed salty water from the Wellton-Mohawk Division of the Gila Project in southern Arizona and put it in the Colorado River just above the Mexican intake. The rescue was necessary because of an earlier Reclamation project by which the Wellton-Mohawk Division had imported Colorado River water into an area where farming with groundwater had become difficult because of salt buildup. The imported water raised the level of salty groundwater to the point that it began killing plants. Then the second rescue project was built by the Bureau of Reclamation to pump down the groundwater. Pouring the salty pumped water into the river was made worse because the Bureau was then filling Lake Powell behind the newly completed Glen Canyon Dam, leaving very little water in the river below the dam to dilute salts.

Mexico complained loudly about the degraded quality of the river. The Mexican Treaty is silent on the quality of the water to be delivered to Mexico but the United States eventually agreed to deliver water of a minimum quality. Treaty deliveries are to have salinity concentrations no greater than 115 parts per million higher than the concentrations in water used in the United States as measured at Imperial Dam (Minute 242).

The United States' commitment to reduce salinity has been supplemented and implemented by federal statutes. The Clean Water Act requires states to set water quality standards based on uses designated for waterways by each state. Measures to protect those waters are then adopted either by the U.S. Environmental Protection Agency (EPA) or the state (if the state has been delegated authority to administer the Act as nearly all the basin states have).

In 1974, two years after major amendments framed the basic program of the

Clean Water Act, Congress enacted the Colorado River Basin Salinity Control Act authorizing an elaborate and expensive program of structural measures to prevent and remove salinity from the river. Authorized projects under the Bureau of Reclamation include wells to intercept saline groundwater and surface waters destined for the river, improving irrigation systems, disposing of salt wastes and building a huge desalination plant. The Department of Agriculture also sponsors projects targeting on-farm irrigation system improvements.

For several years, EPA has allowed the basin states collectively to set numerical criteria for water quality in the Colorado River in the plan developed under the Salinity Control Act. The criteria are to be satisfied at three checkpoints along the river rather than requiring each of the states to set its individual stateline standards. EPA's approval of this practice has been upheld as a proper exercise of its discretion (Environmental Defense Fund v. Costle, 1981). Federal estimates show, however, that water quality can be kept within the limits set by law only for a few more years unless additional controls are imposed (U.S. Bureau of Reclamation, p. 2, 1989). The most obvious further measures to control salinity require reducing the amount of irrigation water applied to the most saline soils -- mostly in the upper basin states where farm production is the least valuable. This could be accomplished by payments to irrigators, by outright purchase and retirement of farm lands or by more complex contractual arrangements that involve farmers, communities, states and the lower basin consumers.

Extraordinarily high flows in the river in the early 1980s filled reservoirs, diluting salinity. A sustained drought would cause the opposite effects, though salinity would not increase in direct proportion to reductions in flow (Vaux, 1990). The limits set for salinity would soon be exceeded. Water could eventually become too salty for farming, especially at diversion points on the river. Presumably municipal users could bear the substantial costs of treating the water satisfactorily but irrigators in the United States and Mexico would have greater difficulties bearing the costs and might have to curtail their uses. Planning for a severe, sustained drought therefore must consider the effects on water quality because much of the water available in a drought could be too salty to use. Legal limits on salt concentrations will be violated in low flow periods without control measures beyond those in place and authorized by existing salinity control legislation, even without a severe, sustained drought. Thus the issue of additional salinity control is ripe for immediate further action and discussion, a process that could trigger a broader examination of water use and growth issues. The process should be informed by a comprehensive consideration of how to manage both supply and demand of water in light of major drought cycles.

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CHAPTER 3

SOUTHERN CALIFORNIA'S WATER SUPPLY

History and Overview

California's multi-year drought beginning in 1987 was not a unique event. The state experienced critically dry periods in 1976-77, in 1928-34 and in a drought at the turn of the century that sparked the development of Southern California's major water supply systems.

In 1904, William Mulholland, long-time superintendent of the Los Angeles Water Department, declared that the City would have to supplement its Los Angeles River water supply. The catalyst for Mulholland's announcement was a multi-year drought during the previous decade. The City of Los Angeles concluded that its water supply would be insufficient to meet the needs of its population during future droughts. In the years following, the City's rapid growth rate corroborated the urgency for a new water source; the population of Los Angeles swelled from 200,000 in 1905 to well over 1 million by 1925 (Kahrl, p. 228, 1982).

The City of Los Angeles first turned to the Owens River, some 250 miles to the northeast, for its supplemental water supply. City voters passed bond issues in 1905 and 1907 to purchase private lands and water rights in the Owens Valley and to finance construction of the Los Angeles Aqueduct to carry the water to the City by gravity flow. The aqueduct supported Los Angeles's expansion within and beyond its boundaries, even into the then-rural San Fernando Valley where farmers depended on the erratic flood flows of the Los Angeles River.

The 200-mile Los Angeles Aqueduct was begun in 1908 and completed in 1913 at a cost of over $23,000,000. The original aqueduct supplied five times the water previously obtained from the Los Angeles River (Boronkay and Hutchinson, p. 142, 1977).

Los Angeles next moved to augment its aqueduct supply by developing the groundwater potential of the Owens Valley, purchasing an additional 200,000 acres of valley lands toward that goal. The City's exploitation of surface and subsurface water from the Owens Valley led to recurrent conflict with valley residents.[19] Recent battles have been over the environmental effects of the City's pumping operations on the valley's water table.[20] Over the years, resentment of the City's de-watering of the area by valley residents has sometimes been expressed in violent acts, including the repeated dynamiting of the aqueduct and intake facilities.

In the early 1920s, the City of Los Angeles began planning to extend its Owens River aqueduct system into the Mono Basin to develop additional water. It took five presidential orders and two acts of Congress to withdraw federal lands in the basin from entry by private developers and allow Los Angeles to purchase all federal land in Mono County necessary for the City to develop its planned water supply (Kahrl, p. 433, 1982).

Los Angeles voters in 1930 approved a $38 million bond issue to complete the purchase of Owens Valley lands and build an extension to the Mono Basin, with a reservoir at Long Valley. A second aqueduct was completed in 1970 to carry increased Owens Valley and Mono Basin waters developed mostly by groundwater pumping. This added

139 miles of pipe to feed into the 338 mile aqueduct.

Even as the Los Angeles Aqueduct was being planned and built, Southern California turned its eyes to the Colorado River. Since the turn of the century, vast quantities of water had been diverted to the hostile but fertile desert lands of Imperial Valley. The canal system that delivered water to the valley was highly unreliable, however, being vulnerable to disruption by floods and needing constant repair. Large landowners in the valley sought the aid of the federal government for a dam and canal system. They were soon joined by investors and boosters from Los Angeles who saw the potential for bringing even more water to support population growth in Southern California.

With the new Owens Valley supplies, most Los Angeles leaders could hardly imagine a water shortage, and some considered the cost and difficulty of moving water from the Colorado River to the city over the intervening mountains to be excessive. Ultimately they were persuaded to support the project and an alliance of Imperial Valley landowners and Los Angeles investors was forged. Concern that California would monopolize the river provoked other basin states to agree to the 1922 Colorado River Compact that divided the river's water between the upper and lower basins of the Colorado River. The Compact led directly to congressional enactment of the Boulder Canyon Project Act authorizing spending an unprecedented amount of public money principally for Hoover Dam and the All American Canal, both largely for the benefit of California.

Municipal interests, primarily the newly-formed Metropolitan Water District of Southern California (MWD), were assured of over a half-million acre-feet of water annually from the river by agreements negotiated with farm interests in the Imperial and Cochella Valleys who would take most of the state's share of water. MWD constructed a canal system capable of taking much more than its portion of water, evidencing a prescience about both its future demand and about its ability to use greater quantities than the basic allotment. The upper basin states demanded little of the river and Arizona used less than half of its entitlement, leaving much of its water unused and available for Southern California municipal consumers. Later, the greater capacity of the system was to prove a vital element in providing MWD flexibility to bargain for use of additional water based on rights of the irrigation districts.

The almost continuous water development that began in 1908 -- Los Angeles Aqueduct, Hoover Dam, All American Canal, Colorado River Aqueduct, Mono extension of the Los Angeles Aqueduct -- paused during the war years of the 1940's. After the war MWD began planning a second aqueduct from the Colorado River which it did not build. Although the full California apportionment was in use, Arizona's still remained unused. But by then Arizona had commenced a new round of litigation in the U.S. Supreme Court against California.

Eventually, although no real water shortage was foreseeable, Southern California threw its support to the State Water Project. At first the project had no possibility of political success because it lacked the support of Southern California, the State's great tax base; the only immediate beneficiaries were Central Valley irrigators. Those irrigators had begun receiving water from the Central Valley Project, a federal project that proved inadequate for California's participation in a revised statewide design to develop and distribute water. It was an elaborate plan to move vast amounts of water south from the state's water-rich northern region, to agricultural lands of the Central Valley, and on to the burgeoning urban populations of the south.

In 1920 Robert Marshall of the U.S. Geological Survey had proposed a comprehensive plan to utilize the waters of California's Central Valley. The Marshall Plan called for water from the Sacramento River to be transferred by successive southward exchanges through the Central Valley. Southern California was to receive a transfer from the Kern River (Boronkay and Hutchinson, p. 144, 1977). The essential elements of the Marshall Plan became embodied in the water and power bills and initiatives of the 1920s, all of which were defeated by interest groups opposed to the state's involvement in water development.

The spirit of the Marshall Plan was revived in 1930 with the original State Water Plan, which called for the transfer of surplus Northern California waters to areas of predicted shortage in the Central Valley where large farms were quickly and dangerously drawing down groundwater supplies. The plan, a state agency report to the legislature, was approved by legislation and by a referendum authorizing the sale of $170 million in revenue bonds to finance the Central Valley Project (CVP).
California was unable to sell the bonds in the depths of the Depression, however, and turned to national spending programs to save the project.

By 1937 the federal Bureau of Reclamation had fully assumed the financial burdens and administration of the CVP. The project facilitated the transfer of water from the Sacramento and Trinity River Basins to undersupplied areas of the Sacramento and San Joaquin Valleys and helped to develop local supplies from the Kern and San Joaquin Rivers. But the Central Valley Project ended up exciting more agricultural growth then it could support. Farming was so lucrative it continued to expand and almost immediately the CVP needed supplemental water for irrigation. Continued heavy pumping was depleting the groundwater supplies the CVP was to help conserve.

In the mid-1940's, the legislature authorized a series of studies on statewide water use and future needs which culminated in the 1957 State Water Plan. The plan was intended to set forth California's ultimate water requirements with all areas of the state at projected levels of full development. It was designed to be adaptable to the demands of advancing technology and changing future conditions (Meyers and Tarlock, p. 347, 1980). The plan called for the development of local sources of supply and urged the construction of a State Water Project to transport Northern California waters to areas of the state where future supply was deemed insufficient.

The California Legislature in 1959 passed the Burns-Porter Act, a water development plan financed by $1.75 billion in general obligation bonds to finance the first phase of the State Water Project (SWP). The state's voters supported the bond issue in a referendum. Some influential Southern California interests opposed its proposal but changed their views at the last minute. The measure barely passed thanks largely to support of the populous southern counties.

The first phase of the SWP now transports water as far as 700 miles through the California Aqueduct from its Feather River source in Northern California to satisfy demands in the San Francisco Bay area, the San Joaquin Valley and Southern California. The SWP delivers about 2.4 million acre-feet of water a year to 30 public agencies serving some 17 million people throughout the state. The largest single customer is MWD, which takes almost half the water. The terms and conditions for delivery of SWP water are governed by state water contracts, under which each agency has contracted with the DWR on a long-term basis for the delivery of annual entitlements.

The 444-mile-long California Aqueduct is the main transportation facility of the SWP. The Aqueduct system includes dozens of dams, reservoirs and pumping and generating plants as well as several branch aqueducts. The aqueduct divides in Southern California, with the West Branch carrying the largest share of SWP water to the Castaic Lake Reservoir northwest of Los Angeles. The East Branch delivers water to contracting agencies in the Antelope Valley, San Bernadino County and Riverside County. The East Branch is currently being enlarged to increase pumping and power generation capabilities.

The main SWP storage facility is Lake Oroville in Northern California's Butte County, which has a capacity of 3.5 million acre-feet. From there water flows down the Feather River into the Sacramento River and then into the delta where the Sacramento and the San Joaquin Rivers converge and then flow into San Francisco Bay. The Sacramento-San Joaquin-San Francisco Bay Delta (Bay-Delta) serves as an intake pool for both the SWP and Central Valley Project (CVP) systems, with pumps diverting the water into the California Aqueduct and various canals for delivery to the San Francisco Bay area, the Central Valley and Southern California. These, along with other California water-supply facilities, are shown in Figure 3-1.

Using the Bay-Delta as a conduit for major water project diversions causes water quality problems. As freshwater is removed from the Delta, salt water from San Francisco Bay backs up into the estuary and into the rivers, harming valuable anadromous fish (salmon and striped bass) populations and other beneficial uses of water. A 1986 state court decision instructed the State Water Resources Control Board (SWRCB) to revise its plan for checking saltwater intrusions into the Delta from the Bay (U.S. v. SWRCB, 1986). To implement the water quality control plan the board has the authority to modify the extractions of water from the Delta by all users including the State Water Project and the Central Valley Project. The SWRCB is charged with setting water quality standards to protect the diverse uses of water that depend on the Bay-Delta. It then must determine how to achieve the standards by imposing various control measures including limitations on diversions.

The SWRCB initiated hearings in response to the court's ruling to determine the optimum balance between Bay-Delta water quality and reasonable beneficial uses of the water. One of the SWRCB's options is to require that SWP and CVP water be released from upstream storage to flow through the Delta to the Bay to combat saltwater intrusions. The Board, however, seeks to share responsibility for maintaining adequate flows among all water users and to concentrate on controlling sources of pollution rather than relying on freshwater releases to dilute pollutants. Still, it will be difficult to meet any reasonable water quality goals for the Bay-Delta without some required releases.

Several years ago, federal and state officials proposed a joint project, the Peripheral Canal, as a major phase of the SWP to increase deliveries to water contractors in Southern California and other areas served by the project and thereby avoid Bay-Delta transportation problems. The plan was to divert both SWP and CVP water into a new canal to the east, bypassing the Bay-Delta. Canal proponents claimed it would

FIGURE 3-1: Major California Storage Reservoirs and Conveyance Facilities

produce the added benefit of solving the contamination problem (Meyers and Tarlock, p. 352, 1980). Environmentalists opposed the canal on the ground that it would deprive the Delta of vital freshwater flows. Proponents insisted that failure to build the canal would come at the expense of Project contractors, especially Southern California water users, since freshwater releases would then be required from the State Water Project to halt the salinity and silt intrusions.

Despite winning the endorsement of key state agencies, the Peripheral Canal proposal was defeated soundly by referendum in 1982. Northern California overwhelmingly opposed the canal but the project's defeat was ensured when it received only a weak approval from voters in Southern California, the area that was the major intended beneficiary, and heavy negative votes throughout most of the rest of the state. A more recent proposal by California Governor George Deukmejian for a different project to get water past the Bay-Delta also was stopped by wide political opposition.

The feelings of Californians about the distribution of water between the northern and southern regions of the state remain strong today. Unresolved conflicts over water quality, conservation, water marketing and groundwater rights are certain to be exacerbated in the event of severe drought.

There are several proposals to expand and complete the SWP. Indeed, construction is underway on the East Branch Enlargement and additional pumps are being installed at the Delta pumping plant. They could add considerably to the delivery capacity of the SWP. The efficacy of these projects, however, may be limited by the State Water Resources Control Board's resolution of the Bay-Delta issue. Thus, improvement in the system's physical capacity to meet Southern California's water supply needs may not be fully realized because of the necessity to restrict the quantity of water pumped from the Bay-Delta to protect public values.

Water Allocation Law and Agencies in California

Legal Regime

<u>The Dual System</u>

California is often described as having a "dual system" of water law. The two primary legal doctrines that form California's law of water rights are: (1) the riparian doctrine; and (2) the prior appropriation doctrine. These doctrines quickly came into conflict as the state began to develop its water resources.

The riparian doctrine is the legacy of the common law, which had developed in the eastern United States by the time of California's statehood in 1850. The first California legislature adopted the common law as the rule of decision for state courts. The common law, it was assumed, embraced riparianism (Attwater and Markle, 1988).

The riparian doctrine gives the owner of land abutting a watercourse full use of the water on the adjoining -- or "riparian" -- land. The doctrine provides that all landowners abutting a stream share equally in any loss in streamflow during times of shortage; that the water must be used only on stream-front parcels within the watershed; and that no one may unreasonably interfere with the use of another riparian owner on the stream.

The miners who swarmed to California in the Gold Rush of 1848 found the riparian doctrine inadequate to meet their needs. Since riparian rights could belong only to landowners and all the land was owned by the United States, there was no way for the miners, who were essentially trespassers, to obtain water rights. They required water to work their placer deposits in California's mountain country, which were not always conveniently located along flowing streams. Traditionally (though not consistently) riparian jurisdictions had held that only the owners of land on streams were entitled to water that could be used only on the streamside land.

Since riparian law did not fit the miners' situation they formulated their own water rights rules by custom. They simply went ahead and diverted the water they required through ditches and flumes to their diggings. The mining camps had developed a rule of "first in time, first in right" to resolve disputes among mineral claimants. The same rule was applied to water. The first miner to "appropriate" water -- the prior appropriator -- established a priority of right to use it. The miners believed the United States intended minerals on the public lands to be developed free of charge, using any water that was necessary to do the job.

The new doctrine vested the prior appropriator with a right to divert water from the stream so long as it was used beneficially. Rights did not depend on land ownership. In contrast to riparian law, prior appropriation also enabled a user to diminish the flow of a stream and even change its course to fit the "beneficial" purpose (Bowden, Edmunds, and Hundley, p. 167, 1982).

In 1855 the California Supreme Court applied the prior appropriation doctrine to resolve the rights of two miners "trespassing" on the public domain (Irwin v. Phillips, 1855). These rights, established by usage, remained valid so long as the beneficial use continued, even after title to the public land was patented to private individuals. But in later cases where water use commenced after land was patented to private parties, rights were considered to pass with the land and to be held under the riparian doctrine. Thus, the state recognized two very different water rights systems. The court was forced to resolve the inevitable clash between the doctrines in 1886, which it did by announcing what would be known as the California Doctrine (Lux v. Haggin, 1886). It declared that an appropriator who began using water before a private landowner acquired the property from the United States (by homestead, mining claim patent, etc.) held a superior right to use the contested water. If the appropriator began using the water after riparian land was patented by the United States, the landowner's riparian right would be superior.

The California Supreme Court elevated the rights of riparians in a 1926 decision by holding that riparian rights were not limited to "reasonable uses" in contests with appropriators.[21] The decision departed from the reasonable use principle that had been widely accepted in eastern states. It appeared to sanction wasteful uses by riparians who were competing with appropriators for water. As a result, the California Constitution was amended in 1928 to impose upon riparians and appropriators a uniform standard prohibiting the waste of water and limiting water rights to reasonable beneficial use (Calif. Const., 1928). The principle of reasonable beneficial use is now considered "the central theme of modern California water rights law" (Governor's Comm'n, p. 9, 1978; United States v. State Water Resources Control Board, 1986).

The 1928 Amendment to the California Constitution does not provide any exact definition of what constitutes "wasteful" or "reasonable" use of water. State judicial decisions interpreting the terms indicate that a use considered reasonable under one set of facts and circumstances may be considered wasteful under different conditions (Attwater and Markle, p. 979, 1988). Consequently, a significant change in conditions affecting many users, such as a severe drought, could potentially trigger constitutionally sanctioned prohibitions against widespread current uses on the ground that they are not reasonable under drought conditions.

Even before the 1928 Amendment, the state had placed some controls on the use of water and created a system to recognize and administer water rights without resort to the courts. In 1914 California voters passed a referendum approving the Water Commission Act, which established a permit system and recording requirements. The Act provided that, while all water within the state belongs to the people, the right to use water can be conditioned "as provided by law." The Water Code is the modern statutory expression of California water law and it declares a policy that domestic purposes, followed by irrigation, are the "highest use[s]" of water. (Cal. Water Code § 106, 1971).

Applications for permits based on new appropriative rights are now approved, denied or conditioned according to several standards including public interest considerations at the discretion of the State Water Resources Control Board. The Board then requires that permittees exercise "due diligence" in making their appropriations. Riparian rights are not subject to state permitting requirements unless they have never been exercised.[22] The state supreme court has ruled that the priority of a "dormant" riparian right may be subordinated to other rights in a statutory adjudication of a stream system. (In re waters of Long Valley Creek Stream System, 1979).

Appropriators who, through a lack of due diligence, fail for five continuous years to apply water to a reasonable beneficial use are subject to forfeiture of their appropriative rights. Critics have charged that this law discourages conservation because any waters conserved could be considered unused and the right to use them forfeited. The Water Code was amended in 1979 to protect appropriators' future rights to use water that is salvaged by conservation efforts. In addition, water rights holders who meet the conditions of the statute are allowed to transfer their rights without the amount transferred being subject to forfeiture (Cal. Water Code § 1011). An apparent effect of this latter change is to facilitate the lease or sale of "surplus" water from agricultural users, who account for about 80% of California's water consumption, to municipal users (Bliss and Imperati, 1978).

Groundwater Law

Groundwater rights exist as a distinct subset of California water law. Groundwater basins are vitally important, especially in Southern California and the San Joaquin Valley, as sources of supply and as natural alternatives to above-ground storage facilities. They are especially valuable during a drought when surface supplies are limited. Eventually, however, aquifers are subject to depletion as a drought deprives them of recharge from surface runoff and as water users increase pumping to offset shortages in surface water supplies.

Groundwater extractions which take water for public service or for non-overlying uses are considered appropriations. Appropriators are limited to the extraction of "surplus" water, that which is not needed for overlying uses.[23] Owners of land overlying a groundwater basin generally have rights to extract a share of the water in the aquifer for reasonable overlying uses. There is no priority among overlying users, but each has a "correlative right" to pump a portion of the water. But overlying users have priority over appropriators regardless of when the various uses began.

California law also has allowed groundwater rights by "prescription" in overdrafted basins. That is, overlying users taking more than their shares under the correlative rights doctrine, and appropriators taking non-surplus water, were allowed to acquire the rights to those additional amounts and thereby defeat the correlative rights of other overlying owners. This encouraged excessive pumping. Basins were being "overdrafted" -- pumped beyond replenishment levels.

The courts consequently began adjudicating contested groundwater claims (Bowden, Edmunds, and Hundley, p. 168, 1982). The California Supreme Court attempted a solution by developing a doctrine of "mutual prescription," whereby all users in an overdrafted basin were given prescriptive rights against one another (City of Pasadena v. City of Alhambra, 1949). Though designed to restore equality in the sharing of basin supplies, the doctrine generally increased overdrafting, as users raced to establish their extra pumping rights.

The court modified mutual prescription in 1975 by holding that private users could not obtain a prescriptive right against a public agency or utility (City of Los Angeles v. City of San Fernando, 1975). The court also suggested that case-by-case adjudications and the use of negotiated water supply arrangements among groundwater users should be employed in the future to conserve basin supplies.

Critics have pointed out that California lacks comprehensive state groundwater management (Governor's Comm'n, pp. 142-143, 1978). Only limited state agency oversight extends to groundwater; most control is exerted by special districts. The legislature has approved establishment of several districts in Southern and Central California to manage the groundwater resources of entire basins. Once rights are adjudicated among claimants within a basin, their pumping is limited to a "safe yield" that recognizes established rights but prevents overdrafts. "Safe yield" is a relative figure that may temporarily exceed the average rate of natural replenishment if it does not result in damage such as land subsidence or pollution (e.g., from salt water intrusion).

Pueblo Rights

During the period of Spanish and Mexican rule in the American Southwest, the Catholic Church established missions throughout the area. Under Spanish and Mexican law the communities, or pueblos, that grew up around these missions received the right to use waters running through them from their source to the sea. This right applied to both surface water and groundwater basins supplying these watercourses (Attwater and Markle, p. 969, 1988). When the region became part of the United States the cities which succeeded the pueblos retained these water rights.

A city which is a successor to a pueblo right has the right to take from the normal river flow as much water as may from time to time be reasonably necessary for municipal purposes and for the use of its inhabitants, both those within and those without the boundaries of the original pueblo. This right is prior to and paramount over the right of any other person whether claiming as a riparian owner or appropriator (City of Los Angeles v. City of Glendale, 1942).

Los Angeles' pueblo rights attach to the Los Angeles River (Vernon Irrigation Co. v. City of Los Angeles, 1895) and to the San Fernando Groundwater Basin, which is a source of the Los Angeles River (City of Los Angeles v. City of San Fernando, 1975). San Diego has a pueblo right to the San Diego

River (City of San Diego v. Cuyamaca Water Co., 1930). The cities have the right to the entire water sources because both require much more water than the rivers supply.

In practical terms, however, pueblo rights have very little significance today. Local water supplies fill only a small portion of the area's total water demand. By giving a preference in use of these local sources to the cities, pueblo rights can reduce costs to the cities holding them. Thus, Los Angeles and San Diego can rely on a larger share of local water, purchasing less imported water. Others, lacking pueblo rights, rely more heavily on imported water, typically from Metropolitan Water District deliveries. Of course if there were a shortage of imported water the two cities with pueblo rights would enjoy priority in use of waters from the Los Angeles and San Diego Rivers.

Area of Origin Protection

California enacted two of the earliest area of origin protection laws in the country. In the 1930s, the state began major initiatives to develop projects in water-rich areas of the north to serve agricultural needs in the Central Valley and municipal growth in Southern California and the San Francisco Bay. People in areas where the water originated were understandably concerned about exporters monopolizing rights to water resources that would be needed locally in the future.

In 1931 California passed its county of origin law (Cal. Water Code § 10505). The statute is narrowly applicable to appropriations of water held by the state of California and assigned or released by the state to others. And it protects only counties where exported water originates. The statute in its entirety states that: "No priority under this part shall be released nor assignment made of any application that will, in the judgment of the board, deprive the county in which the water covered by the application originates of any such water necessary for the development of the county." Several limitations are apparent in the statute: (1) It protects only the ability of the county to "develop," not necessarily against the effects the county would suffer as a result of exports during a drought; (2) It applies only to appropriations of water made by the Department of Water Resources ("assignment" refers to the Department assigning these rights for use by others), to enable fulfillment of a water plan or future water needs; (3) It depends on judgments of the State Water Resources Control Board made at the time an assignment of rights from the Department is approved. As a practical matter, this last qualification makes the statute extremely difficult to apply unless there is an identifiable future development on the horizon in the county of origin. The Board otherwise must speculate about long-range county development and the water that would be necessary for it. In practice the Board avoids this speculation in approving assignment contracts by requiring that a proviso be included in each contract reciting that they are subject to "any and all rights of any county" of origin.

California enacted a broader area of origin statute in 1933. The Watershed Protection Act was designed to deal with the equities of the much larger areas that would be deprived of water by development of the massive Central Valley Project (CVP). Thus, the law extends rights to entire watersheds and to areas adjacent to them that can conveniently be supplied with water from the watershed. The Act creates a "prior right to all of the water reasonably required to adequately supply the beneficial needs of the watershed, area, or any of the inhabitants or property owners therein" (Cal. Water Code § 11460). Importantly, it protects a right to water required for watershed needs on an ongoing basis. Presumably this statute can be applied as shortages occur, giving it importance in drought.

The Watershed Protection Act is by its terms enforceable only against the Department of Water Resources. It does not apply generally to the State Water Resources Control Board's exercise of its water allocation responsibilities (except when water is allocated by the Board to the Department for the CVP).

Although the Act was designed specifically to deal with the CVP, its applicability to the project as it finally developed has never been tested. After the law was passed, the state decided that it did not have the financial means to build the CVP as it had planned. Instead, the federal government took over the Project in 1935. As such, the project is subject to Section 8 of the Reclamation Law which declares that the federal government will proceed in conformity with state water laws when acquiring rights for Reclamation projects (43 U.S.C. § 383). The Supreme Court has interpreted Section 8 as requiring the government to follow mandates of state law "which are not inconsistent with congressional provisions authorizing the project in question" (California v. United States, 1978). If a preference for the watershed of origin resulted in inadequate water for the CVP or otherwise offended the fundamental purposes of the project, operation of the Watershed Protection Act would be precluded (Fresno v. California, 1963).

The watershed of origin for the CVP, while covering a vast area of Northern California, is sparsely populated, has relatively low agricultural demands and is already well-supplied with water. However, if watershed needs were read as including all environmental resources of the area the statute could be a further tool in limiting the extent and manner of diverting CVP water. This could bear on decisions concerning the Bay-Delta discussed elsewhere in this report. Limits on CVP supplies would not directly affect use or availability of water in the study area, even in a drought. This is because CVP water is not allocated to Southern California. There could be indirect effects on the region, though. Exchanges and other arrangements that have been pursued recently between MWD and CVP contractors assume continued CVP supplies being available to the contractors.

State Agencies

The two key state agencies charged with administration of water rights under California law are the State Water Resources Control Board (SWRCB) and the Department of Water Resources (DWR).

The SWRCB is made up of five members appointed by the Governor. It has quasi-judicial and quasi-legislative functions. The Board is authorized by statute to permit appropriations "under such terms and conditions as in its judgment will best develop, conserve, and utilize in the public interest the water sought to be appropriated." In evaluating applications, the SWRCB considers the likely effect of the proposed use on existing beneficial uses. It also evaluates the reasonableness of the purpose and amount of the proposed use and the relative benefits to be derived considering all beneficial uses of water (Attwater and Markle, pp. 984-85, 1988; Cal. Water Code § 1257). Beneficial uses include fish and wildlife protection as well as domestic and agricultural uses (Cal. Water Code § 1243).

The DWR is a unit of the California Resources Agency, a cabinet-level entity. The Department's directive is to protect, conserve, develop and manage California's water. Its primary duties are to plan the statewide water supply, provide for public safety and build and operate the State Water Project (SWP). In its planning capacity the DWR cooperates with SWRCB in developing the California Water Plan, a periodically updated framework for water management. DWR's safety functions are flood control and supervision of dam operation, maintenance and construction. Its management of the SWP is discussed elsewhere in this report.

The SWRCB and the DWR agencies are both directed by state law to prevent the waste or other misuse of water by enforcing the constitutional rule of reasonable beneficial use. They have fashioned joint rules to investigate and act upon waste or other misuse of water, whether in the context of a permit application or otherwise. The SWRCB is empowered to conduct adjudicatory hearings to determine reasonableness of use and to enforce its findings in three ways. The Board may go to state court for an order enjoining the misuse of water; it may assess civil penalties against unauthorized appropriators; and it may issue its own "cease and desist" order to stop violation of a water rights permit (Cal. Water Code § 1831).

Concerns over shortages from drought prompted the legislature in 1982 to expand the roles of the SWRCB and the DWR in facilitating conservation. The agencies are directed by section 109 of the Water Code to encourage voluntary transfers of water and water rights and to help users implement technical conservation measures to increase the availability of water. The DWR is charged with collecting and making available information on the physical facilities which can be used for transfers and listing possible water lease and exchange partners (O'Brien, p. 1195, 1988).

An appropriator who wishes to transfer water or make any other change in the point of diversion, place of use or purpose of the use allowed under the water right must secure the permission of the SWRCB. The Board's approval depends on a showing that "no injury" (i.e., reduction in reasonable use) will result to any legal user of the water involved (O'Brien, p. 1170, 1988). It has been suggested that conservation would be further enhanced by giving the SWRCB statutory authority to compel users "injured" by water transfers to accept substituted sources of supply or to modify their uses at the transferring party's expense (Dunning, p. 448, 1986).

The SWRCB is also entrusted by law with oversight of water quality within the state. The problem of salt water coming into the Sacramento-San Joaquin Delta from San Francisco Bay, discussed in this chapter in connection with the State Water Project, exemplifies a situation in which the board must consider modifying existing water rights in order to preserve the water quality of a given area.

Water Sources

Colorado River

As discussed in more detail in Chapter 2, California's total apportionment from the Colorado River is 4.4 million acre-feet per year. Of this amount, generally speaking, 550,000 acre-feet are for municipal users. The rest of the state's share, 3.85 million acre-feet, belongs to three large irrigation districts. The consumptive use of Indian tribes with reservation land in California, now 55,000 acre-feet a year, should be deducted from the total water available to other users.

MWD has secured the right to use 100,000 acre-feet a year of Imperial Irrigation District's entitlement and 26,000 acre-feet a year of Coachella Valley Water District's entitlement, resulting in a rather certain MWD supply of 676,000 acre-feet, even in very dry years. Negotiations are proceeding for MWD and perhaps other municipal users to obtain rights to salvage and use 70,000 acre-feet from the All American Canal and additional high priority Colorado River water allocated to agricultural irrigators.

As noted earlier, MWD has used several hundred thousand acre-feet a year of "surplus" lower basin entitlements while the Central Arizona Project has been under construction. Continued use of some of that water will probably be possible until the growing urban areas of Arizona, especially Phoenix and Tucson, have exhausted less expensive groundwater supplies or local or state decisions are made to import the full share of the state's CAP water and use it to recharge aquifers.

Although the salinity of water imported from the Colorado River is high, it can be blended with locally pumped groundwater and treated so that it is of acceptable drinking water quality.

Local Surface Water

In a normal year, only five percent of Southern California's water comes from local streams (State of Cal., DWR, Drought..., p. 23, 1989). Figures for surface water supplies in Southern California are difficult to distinguish from groundwater, however. Little surface water is used directly; most is collected as floodwater runoff and used to recharge groundwater basins. In Los Angeles County and Orange County, reservoirs capture runoff from the surrounding mountains and allow it to percolate into groundwater. Only one of these, the San Gabriel Dam and Reservoir, has facilities for direct use of runoff flow; the rest are used solely to supply spreading grounds which recharge groundwater, averaging about 300,000 acre-feet a year. Only about 28,570 acre-feet a year of water are directly delivered downstream to the "Committee of Nine," a consortium of water users in the San Gabriel Valley (David, 1989).

San Diego County uses about 100,000 acre-feet of local runoff in an average year. All of this water is captured by dams and then allowed to flow down to users' diversion points (Maitski, 1989). In addition, Camp Pendleton, located north of San Diego in the county, takes all the water from the Santa Margarita River to supply the Marine base's needs (Duncan, 1989).

Inland areas of Southern California receive almost no rain, and what does fall soaks into the ground almost immediately. Because of these factors, use of water by surface diversions is minimal. The entire Colorado River Desert area produces only 4,000 acre-feet annually while total water use is about four million acre-feet (State of Cal., DWR, Drought, p. 35, 1989). Complete loss of local surface supplies would have almost no effect on this area.

Groundwater

Groundwater basins underlying Southern California contain a vast amount of water -- an estimated four million acre-feet. Their average annual safe yield -- the estimated amount that will be replaced -- is over one million acre-feet, more in a wet year. Annual pumping can exceed safe yield without "overdrafting" a basin because large amounts of imported water are put into groundwater basins for storage, providing artificial recharge. Temporary overdrafts also may be motivated by exigencies. In the drought year of 1977, the City of Los Angeles overdrafted the San Fernando Basin, one of its primary local water sources, by 40,000 acre-feet (Boronkay and Hutchinson, p. 146, 1977).

Local groundwater pumping provides about one-third of all water used in Southern California (Metropolitan Water District, p. 7, 1987). The area relies heavily on supplemental water supplies imported and delivered by the Metropolitan Water District. There is a growing problem of aquifer contamination from organic compounds and toxics that seep in from dumpsites, old industrial plants and leaking underground storage tanks. Groundwater is usually mixed with imported water to dilute such pollutants before it is delivered to customers. Water for Southern California comes from about thirty different groundwater basins, which provide a stable supply of about 1.3 million acre-feet each year to users in the area (see Table 3-1).

The groundwater basins serving Southern California vary greatly in quality. For instance, the basins underlying the City of Beverly Hills contain significant water deposits that are unusable because of inferior quality. San Diego County has sizable groundwater basins but most of the water is affected by saline intrusions from the Pacific Ocean and so the basins provide almost no usable water.

State Water Project

Entitlements to delivery of Northern California water are based on of each long-term contractor's future water needs as estimated when the contracts were signed between 1960 and 1965; some entitlements have been revised from original estimates. The Metropolitan Water District of Southern California, by far the largest of the SWP's public agency contractors, is entitled to 2,011,500 acre-feet annually. This comprises nearly half of all SWP entitlements which are 4,217,786 acre-feet for all areas served. MWD's contract was the first one for SWP water. It is the prototype for the contracts used by the state to allocate project water to some 30 other agencies (State of Cal., DWR, Bulletin 132-88, 1988).

Although entitlements exceed 4.2 million acre-feet annually, the current annual "firm yield," or dependable annual water supply, of the SWP is limited to approximately 2.4 million acre-feet. Thus, the amount of water actually delivered to MWD is about 1.15 million acre-feet per year (Kendall, 1990). This is because transfer and conservation facilities planned for the Sacramento-San Joaquin Delta and other unbuilt facilities would be necessaryfor the SWP to operate at full capacity (Littleworth, p. 1203, 1988).

SWP contractors may be allowed deliveries in excess of their annual entitlements under conditions that protect the entitlements of other contractors. In 1987, for example, the DWR allowed two contractors, the Oak Flat Water District and the Antelope Valley-East Kern Water Agency, to take increased deliveries as advance deliveries of their 1988 entitlement water. "Future entitlement delivery credits" for "make-up water" are available to all contractors when the SWP is unable to deliver the requested entitlement in any year. These credits entitle them to deliveries of "wet-weather" water at times when above-normal local supplies reduce the demand for SWP water.

Contracts for State Water Project water provide for reducing deliveries to agricultural users during shortages by up to 50% before any reductions are made for municipal and industrial purposes. Agricultural reductions may amount cumulatively to 100% of the annual entitlement over any given period of seven consecutive years. After either a 50% reduction in a single year or reductions over seven years amounting to 100% of a contractor's annual entitlement, municipal and

TABLE 3-1

SOUTHERN CALIFORNIA GROUNDWATER SUPPLIES

Groundwater Basins	Groundwater production (safe yield) (acre-feet)
Southern Ventura County Basins	75,000
ULARA	100,000
Raymond Basin	32,000
Main San Gabriel	200,000
Central, West Coast, Santa Monica Basins	269,000
Other Los Angeles County Basins	18,400
Orange County	270,000
Western Riverside County	33,000
Eastern Riverside County	94,000
Chino Basin	140,000
Bunker Hill Basin	30,000
San Diego County	0
Colorado River Desert	68,000
Total	1,329,400

Sources: Metropolitan Water District, 1987; State of California, DWR, Bulletin No. 160-83, p. 133, 1983.

agricultural users must share reductions in their contractual entitlements equally.

Under Article 15 of the State Water Contract, contractors can sell entitlement water outside their own districts. If the water is to be used within another SWP contractor district the transfer requires the permission of the DWR and the district. Transfers that would impair the ability of contracting agencies to make payments on their entitlements are not allowed.

The greatest constraint on the State Water Project's capacity to deliver water is the Bay-Delta problem. Pumping operations can seriously reduce flows into the Bay-Delta, increasing salinity and siltation. In times of low flows, which generally coincide with the greatest demand for pumping, serious water quality problems occur as salt water from the San Francisco Bay intrudes, threatening the ecology of a large expanse of low-lying lands and associated wetlands. Degradation of fish and wildlife habitat and of other beneficial uses of water have led to a full consideration of how to meet water demands consistent with protection of public values. There is also general correlation of low outflow and the incidence of trihalomethane precursors. Carcinogenic organic chemicals known as trihalomethanes are formed when water containing precursors are subjected to chlorination (Vaux, 1990). Measures to control these contaminants are also being considered.

The State Water Resources Control Board is developing a revised water quality control plan for the Bay-Delta. Although the Board intends for all users of Bay-Delta water to share to some extent the burdens of maintaining its quality, the plan almost certainly will result in some required releases of water. Such releases will reduce the overall amounts of water available for SWP and CVP water users and restrict new uses of water from these projects. The consequences of reducing Southern California's SWP supply to satisfy the Bay-Delta water quality plan would obviously be magnified if a severe drought reduced supplies from other sources.

The SWP and CVP have some joint-use facilities for pumping, generating and storage under a 1961 agreement between the DWR and the U.S. Bureau of Reclamation (USBR). In 1986, these two agencies signed the Coordinated Operation Agreement (COA), which provides for the sharing of responsibility to meet Delta water quality standards. Also under the COA, the DWR and the USBR have recently concluded a contract that allows CVP water to be conveyed through SWP facilities in exchange for interim SWP use of excess CVP water. This arrangement is expected to enhance the DWR's ability to meet SWP contractor entitlements. The agreement allows the DWR to convey CVP water as long as such deliveries do not reduce SWP supplies, increase costs to SWP contractors or adversely affect the quality of water delivered to the contractors (State of Cal., DWR, Bulletin 132-88, pp. 5-6, 1988).

Los Angeles Projects

<u>Owens Valley</u>

By purchasing lands in distant Inyo County riparian to the Owens River, as well as lands overlying groundwater supplies, Los Angeles effectively gained a monopoly on water rights in the Owens Valley less than a decade into the twentieth century. The City currently receives about 370,000 acre-feet per year from the Owens Valley, by far the largest portion of the City's water supply. Plans to expand this source have been thwarted so far by legal opposition.

In the 1970s, the City planned to augment water delivered by the Los Angeles aqueduct from increased surface diversions out of the Mono Basin, reduced irrigation of Los Angeles' Owens Valley lands and increased pumping of the underlying groundwater reservoirs. Inyo County sued to enjoin Los Angeles' expanded groundwater pumping until the City filed an Environmental Impact Report (EIR) in compliance with the California Environmental Quality Act (CEQA). In 1973 the state court of appeal ordered the City to prepare the EIR and later imposed a limit on the amount of groundwater to be pumped until the document was approved (County of Inyo v. City of Los Angeles, 1973). The court retained jurisdiction and made several additional decisions (County of Inyo v. City of Los Angeles, 1976, 1977, 1981, 1984).

In 1980 Inyo County voters approved the Owens Valley Groundwater Ordinance, giving the County regulatory authority over groundwater pumping in the valley. After the Inyo Superior Court declared the ordinance unconstitutional, Los Angeles and the County entered into a five-year interim agreement in 1984. The agreement suspended all litigation and called for a long-term groundwater management plan for the Owens Valley. It also established an enhancement and mitigation program to develop wildlife habitat, recreational areas and greenbelts as a condition to the County's acquiescence in the City's continued groundwater pumping (Los Angeles Dep't of Water and Power, 1988). In July, 1989, Los Angeles and Inyo County entered a long-term agreement. The agreement is subject to court approval, which would allow Los Angeles to pump groundwater from the Owens Valley so long as it does not cause mining of groundwater or create surface vegetation problems. Los Angeles will be required to mitigate any problems that arise (Los Angeles Dep't of Water and Power, Agreement, 1989). Approval of the agreement awaits the preparation of an adequate EIR. The City will submit an EIR, its third attempt, in mid 1991.

In 1940 the Los Angeles Department of Water and Power (DWP) was granted appropriation permits by the State of California to divert water from streams tributary to Mono Lake for municipal uses and power generation. Shortly thereafter, DWP completed an extension of the Los Angeles Aqueduct from the Owens Valley to the Mono Basin to a total length of 338 miles. It then began diverting about half the flow of these streams into the aqueduct. Between 1941 and 1970 the City imported a yearly average of approximately 57,000 acre-feet from the Mono Basin. In 1970 DWP completed the second Los Angeles Aqueduct and has since imported an annual average of 100,000 acre-feet from the Mono Basin, about 17% of the City's total water supply (Attwater and Markle, p. 1028, 1988).

The future of the City's Mono Basin water supply became uncertain as a result of a 1983 California Supreme Court ruling (National Audubon Society v. Superior Court of Alpine County, 1983). The court held that appropriative water rights in the state are subject to review and potential reallocation under the public trust doctrine. Under this judicial doctrine the state holds all navigable waters and underlying lands in California in trust for the benefit of the people. Environmentalists charged that Los Angeles' diversions from Mono Lake lowered its level by more than 40 feet and made it more saline. This reduced the brine shrimp population and seriously diminished the value of the lake as migratory bird habitat. The state supreme court found that the state had granted Los Angeles its rights without considering all the competing interests, particularly environmental consequences. Because water is held in trust for the public, the City's rights must be reconsidered. The court held that the SWRCB and the courts have authority to reexamine previously authorized diversions of the state's waters, such as DWP's Mono Basin rights, to determine whether they were permitted consistent with the public trust.

Subsequent lawsuits by public interest environmental groups have challenged specific diversion licenses held by Los Angeles in the Mono Basin. In January, 1989, the state court of appeal ordered the SWRCB to revoke two of Los Angeles' Mono Basin licenses and reissue them with conditions requiring releases to create water flows for fishery maintenance (California Trout, Inc. v. SWRCB, 1989). The City appealed, but the California Supreme Court refused to hear the case. The Sacramento County Superior Court is currently implementing the appeal court's order.

According to the Los Angeles DWP, Mono Basin releases would require replacement supplies at a cost of $230 per acre-foot, a maximum of $23 million per year, if the full 100,000 acre-feet claimed by the city must be left in the streams flowing into the Mono Lake to protect the environment. Los Angeles would purchase any necessary replacement water from the Metropolitan Water District of Southern California (MWD) (Los Angeles City Attorney's Office, 1989). All the above sources are summarized in Table 3-2.

Institutional Water Management in Southern California

Metropolitan Water District

There are over 1,000 separate water districts in California which deliver water to various urban and rural users. The largest of these districts is the Metropolitan Water District of Southern California (MWD). MWD was organized as a public agency in 1928 by the City of Los Angeles and ten other cities to develop a municipal water supply from the Colorado River to augment local supplies. It now delivers full or partial supplies as a wholesaler to 27 member public agencies in six Southern California counties, providing for about 50% of the water demand for the 14.5 million people in its service area. Although MWD's primary mission is to supply municipal water, it serves a small number of irrigators in its service area; deliveries to irrigators may be curtailed in shortages.

The water delivered by MWD comes from two sources: dams and reservoirs that are mostly federal on the Colorado River, with delivery through the Colorado River Aqueduct which MWD owns and operates; and State Water Project reservoirs whose waters are conveyed through the California Aqueduct under a contract between the state and MWD.

MWD, the first contractor for SWP water in 1960, is entitled to over 2 million acre-feet of water per year of which it receives a firm annual yield of 1.15 million acre-feet. As explained in the preceding section, MWD has the right to demand curtailment of agricultural uses to allow it to use its share of firm yield in a time of short supply. Only after severe reductions in agricultural uses is MWD exposed to reductions of SWP deliveries. In the drought year of 1977, for example, after an initial 50% reduction in all agricultural supplies MWD's contractual entitlement of SWP water was reduced by some 75,000 acre-feet concurrent with a 10% additional agricultural reduction (MWD Contract with DWR, 1988; State of Cal., DWR, 1976-1977 California Drought, 1978). In the same year, MWD initiated a conservation program aimed at reducing the demand of its 27 member agencies. The program included a surcharge on water sales to member agencies, offset by rate reductions for agencies that developed

TABLE 3-2

Summary of
Southern California Water Supplies

	Million acre-feet per Year	Percentage of total
Groundwater	1.33	17
Surface	.4	5
Total	1.73	22
Imported		
Colorado River	4.4	57
Los Angeles Projects	.47	6
State Water Project	1.15	15
Total	6.02	78
Totals	7.75	100

Sources: Attwater and Markle, p. 1028, 1988; David, 1989; Kendall, 1990; Metropolitan Water District, 1987; State of Cal., DWR, Bulletin 160-83, p. 193, 1983; State of Cal., DWR, Drought, 1989.

conservation practices (State of Cal., DWR, Drought, 1989).

MWD's current objective is to maximize deliveries of Colorado River water to meet its requirements. Its goal is to reduce the higher energy costs involved in pumping SWP water and generally to lessen its demands on the State Water Project. It is endeavoring to do this in a number of ways, including several agreements with agricultural users of Colorado River water that give MWD firmer rights to large quantities of that water. MWD's claim on Colorado River water is being greatly enhanced by virtue of its agreement with the Imperial Irrigation District (IID). Over 125,000 acre-feet a year of additional water will be available as a result of the MWD investment in conservation measures to improve agricultural water delivery system in the Imperial and Coachella Valleys. MWD has entered into exchange agreements that allow it to take direct delivery of SWP water belonging to the Desert Water Agency and the Coachella Water District. MWD continues to take delivery of its full share of Colorado River water which is then stored in the Coachella groundwater basin where it is available for users there.

MWD is also using conservation to stretch present supplies. In 1987, MWD began offering financial incentives to member agencies that implemented conservation measures. Reclamation and reuse of water within the MWD service area has also begun. These measures now produce less than 200,000 acre-feet a year, but opportunities for greater salvage of usable water are tremendous. Notwithstanding all these programs, increased demand from rapid growth in the service area is quickly outstripping the savings.

Pressures on MWD will increase as locally developed groundwater supplies of MWD's member agencies are limited by groundwater contamination and the DWP's Los Angeles Aqueduct supply (Mono Lake and Owens Valley), are restricted by legal requirements and agreements. As noted previously, MWD's supply of SWP water is itself subject to potential limitation since the SWRCB's Bay-Delta water quality plan may require releases of SWP water. These pressures coincide with Arizona's incipient capacity to use its share of Colorado River water. Consequently, MWD's dependence on SWP water may increase despite MWD's goal of maximizing Colorado River water deliveries.

Los Angeles Department of Water and Power

The Los Angeles Department of Water and Power ("DWP") provides municipal and industrial water for the City of Los Angeles. The Department serves about 3.4 million people through more than 650,000 connections and makes minimal agricultural deliveries (State of Cal., DWR, Drought..., p. 61, 1989).

DWP's primary source is surface water delivered through the Los Angeles Aqueduct from the Owens Valley and the Mono Lake Basin. As noted above, these sources supply an average of 470,000 acre-feet per year to the City. They are subject to considerable uncertainty due to legal problems that may limit their future yield. Local supplies also provide DWP with some water. Groundwater pumping provides DWP with about 100,000 acre-feet per year. Surface water is also used, primarily for groundwater recharge.

During 1988, DWP's Los Angeles Aqueduct supply was reduced to about 75% of normal, due to the summer's extended dry conditions. This shortage was partly offset by increased groundwater pumping from the Owens Valley and water from reservoirs in the Los Angeles Aqueduct system. DWP has greatly increased its reliance on purchases from MWD to meet growing demands as it has been faced with the uncertainties and limitations on its own supplies. Purchases have escalated from the range of 50-100,000 acre-feet a year historically to 150,000 acre-feet in 1988 and 200,000 in 1989. DWP expects to buy over 260,000 acre-feet in 1990 (MWD, 1989). The role of MWD water is evolving from a secondary, supplemental source into a basic, very substantial source for DWP.

The City of Los Angeles has adopted water conservation ordinances in recent years and spent $5 million in 1988 to enforce them. The City implemented Phase I of its Emergency Water Conservation Ordinance in April 1988, restricting some residential water uses such as hosing of sidewalks and driveways. Under the ordinance, residents were required to repair all water leaks on their property and were asked to reduce their water consumption voluntarily by 10%. The City also passed an ordinance requiring the retrofitting of water conservation devices on all commercial, industrial and residential properties. DWP will assess surcharges of 10% to 100% against certain users who fail to install retrofit devices, but the charges do not apply to the largest numbers of customers (single-family dwellings and duplexes). In addition, a 10% to 100% surcharge will apply to all owners of large turf areas who do not reduce their water use by 10% (State of Cal., DWR, Drought..., 1989).

DWP has the option, in the event of reduced Los Angeles Aqueduct supplies in the future, to implement Phases II through V of the Emergency Ordinance, which require mandatory reductions of 10%, 15%, 20% and 25%, respectively. DWP also considers increased conservation efforts as a way of obviating the potential environmental effects of continued extensive groundwater pumping in the Owens Valley.

Special Water Districts

The DWR and the U.S. Bureau of Reclamation are the largest water suppliers in California, wholesaling water through the SWP and the CVP, respectively. These agencies deliver water to nearly 1,000 local districts, cities and water companies which then sell it to water users (Phelps, Moore, and Graubard, 1978). These entities were created under state law with duties and powers over water distribution. Special districts include irrigation districts and municipal districts.

Special water districts are autonomous governmental organizations formed for the purpose of managing water supplies to the citizens of an area. California has over a hundred general and special acts authorizing different kinds of water districts (Leshy, p. 357, 1982). Most districts primarily provide water to farmers for irrigation but as California and the West as a whole become more urbanized this is changing; many of these districts now provide considerable municipal and industrial service. Economies of scale help special water districts give water users access to water sources and facilities they could not otherwise afford. They also provide a framework for operation of these facilities.

All seventeen western states have some act authorizing water districts, also known as irrigation districts. They are all based to some extent on California's 1887 Wright Act.[24] The Act defines five typical aspects of irrigation districts: (1) They are under local control. Under the California act (though not in all western states) local voters elect the directors of the district, who must own land within the district boundaries. In some instances, voters and directors need not be residents if they own land in the district. (2) Irrigation district boards have generalized powers to perform any acts necessary to carry out the purposes of the Act. (3) Directors of water districts have the power to issue bonds enabling development of more expensive projects than would otherwise be possible. (4) Districts are authorized to levy assessments on real property. In California, assessment rates are based on property values; in other states they can be based on a rate per acre or on the benefit received from water. (5) As governmental entities, water districts have tax-exempt status. All property owned by the district, as well as its income, is exempt from taxation by the state, county or municipality.

In California, the district holds legal title to water rights within its boundaries. Landowners have a right to use the water under a beneficial title. The system is much like a trustee-beneficiary relationship.

Special agricultural water districts have rights to significant quantities of water. Municipal interests like MWD have begun to explore the possibility of water transfers to areas of high use during droughts. Such sales are legally and physically feasible. The California Supreme Court has ruled that sale is a beneficial use for water. The district must have incentives to sell, however. It must either have extra water or be able to induce reductions in use within the district to obtain extra water. Although the parties to a transaction must arrange transportation for the water, Southern California's water supply system is so extensive that most areas of the state are on or near some part of the network. Local prohibitions against transfers out of the district can be a problem. The directors of a district not only must be persuaded to sell their water, but also to change the rules prohibiting sale.

Southern California must pay enough to persuade districts and their constituent agricultural users to market their water and give up their entitlements. As water becomes scarcer during a drought, the value of water to Southern California municipal users is sure to be greater than its value to farmers in other parts of the state. Theoretically, the amount of water subject to transfer is limited only by the total amount of water use in the state. However, there are political and economic arguments against a serious intrusion on the state's rich agricultural industry. Ultimately, though, most of the water needed for municipal uses could be acquired through agricultural transfers.

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CHAPTER 4

ARIZONA'S WATER SUPPLY

History and Overview

Arizona was originally part of the New Mexico Territory that was won by the United States in its 1846 Mexican War victory. The separate Arizona Territory was created in 1863. Settlers began to concentrate in the south central region of Arizona by the end of the nineteenth century. Until after World War II when Arizona's population growth exploded, water was supplied mainly by surface diversions from the Colorado, Verde, Salt and Gila Rivers and their tributaries. Agriculture was then the primary user, accounting for approximately 95 percent of consumption.

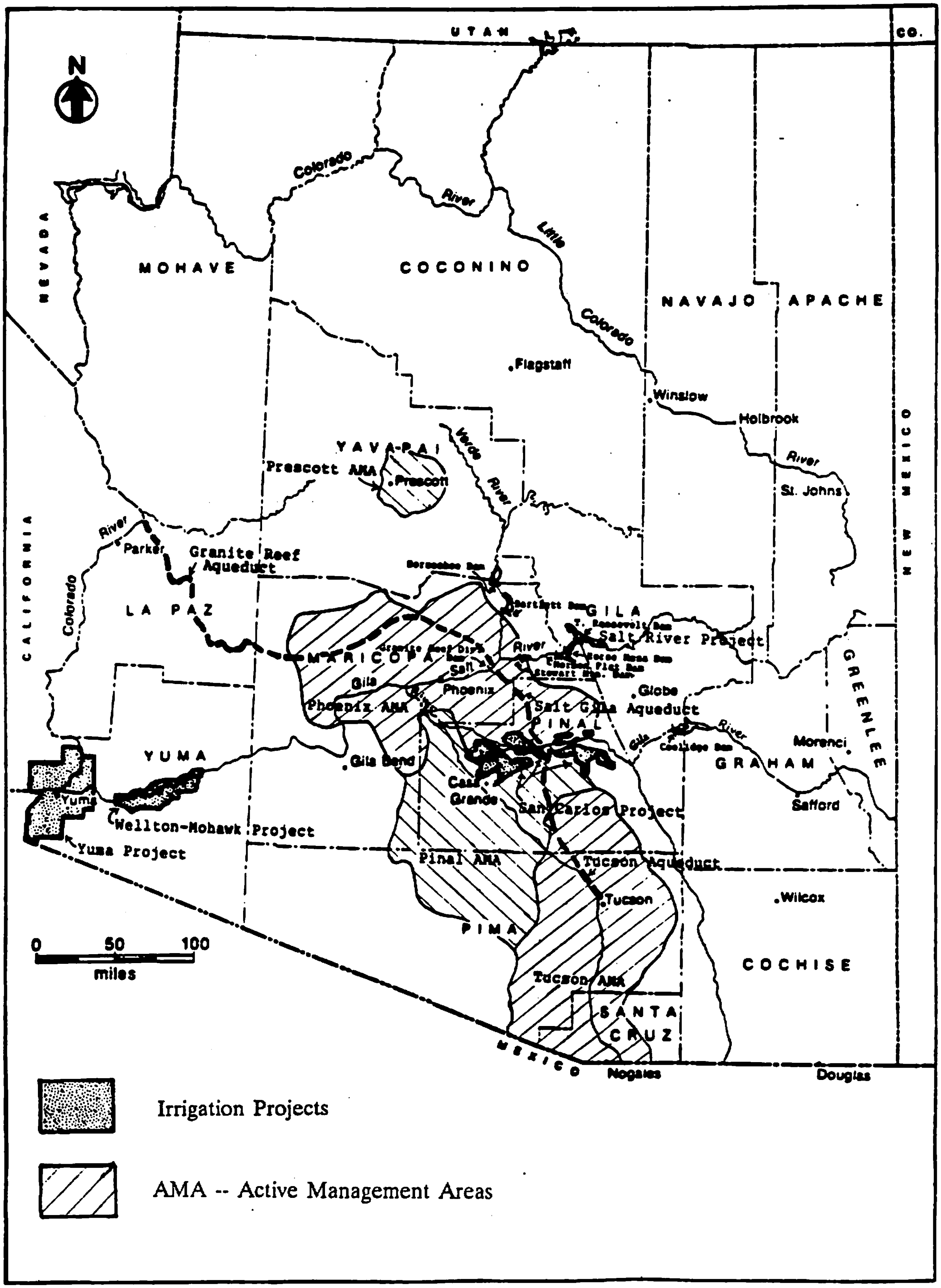
Demand for diversion and storage facilities in the Salt River Valley (which includes Phoenix) led to the creation of Arizona's first major water project, the Salt River Project (SRP). See Figure 4-1. During the late nineteenth century, the future development of the area was limited by a lack of water storage, inadequate diversion dams and inequitable water distribution. Landowners in the valley resolved to overcome these problems by building a reservoir at the confluence of Tonto Creek and the Salt River some 80 miles northeast of Phoenix. The cost of such a reservoir was projected at $2-$5 million. As a territory of the United States, Arizona was prohibited from incurring debt, and private financing was unattainable. Consequently, private landowners in the valley turned to the newly created federal Bureau of Reclamation to help fund the proposed Salt River Project (SRP). The project was included in the first project authorization bill under the Reclamation Act of 1902.

Valley landowners created the Salt River Valley Water Users' Association on February 9, 1903 to ensure repayment of project costs. They pledged members' lands as collateral. A 1904 agreement between the Bureau and the Association provided that the obligation for construction costs and assessments would be distributed among Association members on a per-acre basis regardless of the use or non-use of water. The agreement was sanctioned by a federal court decree apportioning stored Salt River Valley waters in proportion to the landowners' acreage. The rights to the natural flow of the valley's streams remained subject to determination under the prior appropriation doctrine. The Association was also formed to assume responsibility for operation of the project.

The initial feature of the SRP was the Roosevelt Dam at the Salt River-Tonto Creek confluence. It was begun in 1905 and completed in 1911 at a cost of more than $10 million. The reservoir, known as Roosevelt Lake, had an original capacity of 1.2 million acre-feet. Spillway modifications completed in 1936 increased the reservoir's capacity to 1.38 million acre-feet.

The SRP was expanded to include five smaller reservoirs on the Salt and Verde Rivers, with nearly continuous construction spanning the four decades from 1908 to 1949. The Horse Mesa, Mormon Flat and Stewart Mountain Dams create a chain of reservoirs called the Salt River Lakes. The Horseshoe and Bartlett Dams are on the Verde River. With Roosevelt Dam these facilities have a combined storage capacity of over two million acre-feet. Irrigation flow is regulated by Bartlett Dam and Stewart Mountain Dam on

FIGURE 4-1
Major Arizona Water Facilities and Districts



the Salt River. Four miles downstream from the confluence of the Salt and Verde Rivers (about 22 miles east of Phoenix) water is diverted into two main canals at the Granite Reef Diversion Dam for delivery to water users within the SRP area (U.S. Dep't of Interior, 1981).

The SRP now serves an area of about 250,000 acres and includes 248 well-pumping units to supplement surface water supplies, as well as 1,259 miles of canals and ditches of which 842 miles are lined or piped. In 1937, the Association persuaded the Arizona legislature to form the Salt River Project Agricultural Improvement and Power District to help meet the SRP's financing obligations. The Power District's boundaries and constituencies are practically identical to those of the Association. The Power District, a political subdivision of the state, was empowered to refinance the Association's outstanding bonds at a lower rate with tax-exempt bonds. The Association transferred all of its properties to the Power District under contract, but the Association continued to operate the entire SRP until 1949 as an agent of the Power District. The Salt River Valley Water Users' Association completed the repayment of the federal loans in 1955.

The administration of the SRP is now effectively divided into two systems: water supply and power supply. The Association still operates the water system for agricultural, municipal and industrial uses. The Power District maintains the power generation and delivery system. The two legally distinct entities are commonly considered to comprise the Salt River Project.

Agriculture was the dominant land use when the SRP was formed. It still accounted for 80% of the use of SRP member lands in 1956. By 1982, however, agricultural use had fallen to 41%, due to the steady expansion of the greater Phoenix metropolitan area and the consequent increase in demand for municipal and industrial water. Agricultural uses of water within the SRP area are projected to cease entirely by 2034. As completed, the SRP now includes a total of seven dams on the Salt and Verde Rivers. It provides a total storage capacity of over 2,000,000 acre-feet for surface water supplies.

The other major source of surface water in Arizona, the Gila River, flows through southern Arizona, and is joined by the Salt below Phoenix. It is hydrologically part of the Colorado River basin, but its water rarely reaches the Colorado River. It has historically been administered separately. Most of the Gila's waters are used for agricultural purposes.[25] The largest consumers are the Gila River Indian Reservation and the Wellton-Mohawk Irrigation District. Several dams have been built on the river, most notably Coolidge Dam, which creates San Carlos Reservoir.

The San Carlos Irrigation Project was authorized by Congress in 1924. Coolidge Dam, located on the Gila River about 100 miles east of Phoenix, is the project's main facility. The project diverts water from the Gila River at the Ashurst-Hayden Diversion Dam just above Florence, Arizona. The San Carlos Reservoir created by the dam has a capacity of about one million acre-feet. Although the reservoir floods part of the San Carlos Indian Reservation, uses water subject to Indian water rights, and is administered by the Bureau of Indian Affairs, the project Act recognizes no prior rights in the tribe to use water or storage relative to other project beneficiaries. The project was designed to provide water to 50,546 acres of the Gila River Indian Reservation owned by Pima Indians, and 50,000 acres off the reservation owned by non-Indians (U.S. v. Gila Valley Irrig. Dist., 1935). Because of chronic water shortages, however -- the reservoir has only reached its capacity once, in 1983 (Walsh,

1989) -- it usually irrigates a total of only 55,000 to 65,000 acres (Dodge, 1989). The most common use of project water is irrigation of cotton and alfalfa fields (U.S. Department of the Interior, 1988). Each year, the project manager sets an allotment of water for that year based on the estimated available amount. This allotment has historically ranged from one half to four acre-feet per acre (Neumann, 1989). Once the allotment has been determined, each farmer decides how much land to irrigate. Any water captured by a water user which has not been stored in the San Carlos Reservoir is not counted against the allotment (Neumann, 1989).

The San Carlos Irrigation Project has several water rights in the Gila River. The earliest is an immemorial (earliest priority) right to 437.5 cubic feet per second (cfs) based on Indian reserved rights. The project also has water rights totalling 819 cfs with priority dates ranging from 1868 to 1924, the latter being among the most junior in the system. In all, the project has rights to 1256.5 cfs out of total rights on the river of 1805.22 cfs (Gila Commissioner's Report, plate 29, 1977). Rights on the Gila River were adjudicated in 1935 in a decision known as the "Gila Decree" (U.S. v. Gila Valley Irrig. Dist., 1935).

From 1930 to 1975 inclusive, the project's water rights yielded an average of 177,132 acre-feet annually. This figure is the amount that actually reaches the land to be irrigated, and takes into account a 43.7 percent transit loss from Coolidge Dam to the land (W.S. Gookin, 1977). About one third of this loss occurs in the river between Coolidge Dam and Ashurst-Hayden Dam. Most of the ditches in the system are unlined so that some of this transit loss is recaptured as groundwater, but much of it is lost to evaporation (Dodge, 1989).

The land served by the San Carlos Project also gets water from groundwater basins. The project has about 100 wells on its lands. The wells provide 60,000 to 100,000 acre-feet annually (Dodge, 1989). The groundwater basins' primary source of recharge is seepage from the river and irrigated lands.

Dam safety concerns limit the amount of water that the San Carlos Project can store and deliver (Walsh, 1989). In late 1988, the Bureau of Reclamation, which had been requested by the Bureau of Indian Affairs (BIA) in 1980 to inspect Coolidge Dam, found safety deficiencies. Instability of the foundation could lead to dam failure during normal operating conditions. As a result, restrictions on use of the dam have been imposed. The reservoir cannot be filled above eighty percent of capacity for extended periods of time. Also, whenever the reservoir reaches sixty percent of its capacity, BIA must institute an around-the-clock watch on the left abutment where the greatest problem was found.

While surface water diversions in Arizona have generally been governed by the prior appropriation doctrine, groundwater withdrawals have not been subject to a system of priorities. The development of groundwater supplies began in Arizona about the turn of the century and increased steadily over the next several decades. Following World War II groundwater use grew rapidly with the innovations in pump technology which then were available. Groundwater became the chief source of water and in many areas of the state it is now the only source. It soon became clear that Arizona was depleting its groundwater more rapidly than aquifers were being recharged in large part because the Arizona courts and legislature steadfastly declined to impose legal limitations on the extraction of groundwater (Mann, p. 17, 1963).

Virtually all dependable supplies of surface water in Arizona were appropriated by the 1960s. Total reliance on groundwater supplies for all new growth exacerbated the overdraft crisis. The state anticipated delivery of surface supplies from the Colorado River to abate the problem. Huge farms in the three western counties along the Colorado River, Mohave, LaPaz and Yuma, began irrigating with river water early in the century. As explained in Chapter 2, however, Arizona always assumed that it was entitled to a significant additional quantity of water from the Colorado but the exact amount was not determined until 1963. Then it took many more years to finance and construct the massive facilities needed to bring the water from the river to the areas of the water demand in the state.

As early as the 1940s the importation of Colorado River water to central Arizona was advanced as a solution to the state's groundwater overdraft problem. The U.S. Bureau of Reclamation completed a feasibility study of the Central Arizona Project (CAP) in 1947 and for the next several years Arizona sought congressional authorization and funding for the project.

Arizona maintained a prolonged feud with California over the proper apportionment of the river and while the stalemate continued the CAP could not achieve congressional approval. California used its congressional clout to block the project because of an ongoing dispute over the two states' respective entitlements to Colorado River water under the 1922 Colorado River Compact. The issue was not resolved until 1963 when the U.S. Supreme Court ruled that Arizona had a right to 2.8 million acre-feet per year of Colorado River water (Arizona v. California, 1963). In 1968, the CAP was approved by Congress with California's support, after Arizona agreed to guarantee California's 4.4 million acre-feet annual entitlement as a priority over use of Arizona's apportionment in the CAP.

The CAP consists of three main transportation facilities. The Granite Reef Aqueduct running from Parker Dam on the Colorado River to the greater Phoenix area began deliveries in 1985. Deliveries via the Salt-Gila Aqueduct, which extends the system to Pinal County, began in 1986. The Tucson Aqueduct, the project's final stage, is expected to be completed in 1992 at which time Arizona will be capable of diverting its full share of Colorado River water.

The federal government erected a hurdle to construction of the CAP when it required that Arizona have a program to conserve groundwater as a prerequisite to federal funding of the project. The state passed the 1980 Groundwater Management Act (GWMA) in response. This complex groundwater management scheme is described below.

As the twentieth century draws to a close, Arizona is experiencing continued dynamic population growth, primarily in the Phoenix and Tucson metropolitan areas. The state's population rose by 51 percent to 2.8 million people between 1971 and 1981. Phoenix is now the 9th largest metropolitan area in the United States. This growth has led, in turn, to a steady increase in the use of water for municipal and industrial purposes, with a commensurate reduction in agricultural use. Nevertheless, most of the state's water is still used for irrigation. Irrigated agriculture consumed 6.3 million acre-feet of water in 1980, while municipal and industrial users consumed about 971,000 acre-feet. The Arizona Department of Water Resources (ADWR) projects that municipal and industrial water use will continue to increase and agricultural consumption will decrease.

Water Allocation Law and Agencies in Arizona

Legal Regime

Surface Water

The Spanish tradition of civil law was firmly rooted in Arizona when the territory passed from Mexican to American control in 1846; the riparian common law, which governed water rights in the eastern United States, had made no inroads in the region. By the time Arizona became the 48th state in 1912, the prior appropriation doctrine was established as the guiding principle of water law there as in the other western states. The doctrine was seen as preferable to the common law doctrine of riparian rights which some believed would create monopolies for the few landowners strategically located along streams with dependable flows.

The 1864 Howell Code which served as the territorial constitution declared that all surface water capable of being used for purposes of navigation or irrigation was public property. It also guaranteed the rights of settlers to build *acequias*, or irrigation canals, and to "obtain the necessary water for the same from any convenient river, creek, or stream of running water" (Mann, p. 32, 1963), In 1887 the legislature amended the code to declare that, "[t]he common law doctrine of riparian rights shall not obtain or be of any force or effect in this territory." This language was later adopted in the Arizona Constitution.

The Howell Code did not define requirements for valid appropriations of surface water. Thus the territorial (and later state) courts supplied guidance, asserting that diversions under the prior appropriation system required an intention to divert followed by an actual appropriation pursued with diligence toward some beneficial purpose. In 1893 the Howell Code was amended to require the publication of notice of any intended diversion, as a means of gauging the appropriator's diligence in putting the appropriation to a beneficial use. Failure to pursue the appropriation diligently would result in forfeiture of the right. The statute was amended again in 1921 and 1928. Only a few reported cases dealing mostly with the extent to which certain types of underground water were covered by the code, applied the law.

A 1945 law removed all underground water from the Howell Code's coverage; nearly all subsequent developments in water law have dealt with groundwater. (Leshy and Belanger, 1988). Historically, Arizona water law focused on distinguishing between surface water which was covered by appropriation law and groundwater in which rights were linked to land ownership. There was essentially a dual system. Pumpers attempted to avoid the obligations to prior users under the appropriation doctrine by seeking to classify as much water as possible as groundwater. The courts often cooperated even where pumped water was hydrologically connected with a stream.

The 1980 Act centralized the administration of water law in the state. Surface water matters were formerly handled in the office of the State Water Commissioner. Extensive administrative authority over surface waters has been maintained in the 1980 Groundwater Management Act, but the Director of the Arizona Department of Water Resources (ADWR) is now vested with the authority to approve or reject applications for permits to appropriate all water. The Director must reject applications which conflict with vested rights, menace public safety or threaten public interests (Ariz. Rev. Stat. Ann. §§ 45-152, 45-153). An application may not be approved for a greater quantity than can actually be put to a beneficial use and thus may be approved for less water than is requested in the application. Applications for municipal uses may be approved to the exclusion of all subsequent appropriations from the same source if the Direcfor determines that the estimated needs of the municipality so require (Ariz. Rev. Stat. Ann. § 45-153).

The state has assigned relative values to uses of water to help in resolving conflicts between applications for use from a given supply. The order of preference for uses is: (1) domestic and municipal; (2) irrigation and stock watering; (3) power and mining; (4) recreation and wildlife, including fish; (5) artificial groundwater recharge (Ariz. Rev. Stat. Ann. § 45-157). Historically, Arizona water law focused on distinguishing between surface water which was covered by appropriation law and groundwater in which rights were linked to land ownership. There was essentially a dual system. Pumpers attempted to avoid the obligations to prior users of a source of water under the appropriation doctrine by seeking to classify water as groundwater even though it might be hydrologically connected with a stream.

While the 1980 Act discussed below is nominally a groundwater law, it also makes important changes in the law affecting surface water. It generally moves Arizona toward cooperative use of surface and groundwater (See Leshy and Belanger, 1988). Many of its provisions apply to both kinds of water. How successful the concept of conjunctive management will be in practice depends on the discretion of the Director of Water Resources.

Groundwater

Arizona's territorial legislature did not specifically address groundwater in its 1893 amendment to the Howell Code. Very little groundwater was being used at that time, in marked contrast to the prevailing pattern of use in the state now. The water that was being used collected in shallow wells and was subject to surface water law. Other pumped water, if considered groundwater, could be exploited by overlying landowners without state control. The 1919 amendment to the State Water Code made the first legislative reference to underground water in declaring that water flowing in definite underground channels was subject to appropriation. Meanwhile, the Territorial Supreme Court in 1904 applied common law principles in drawing a distinction between waters flowing in underground channels and those which "percolated" through the soil. Percolating waters were held to belong to the owner of the land overlying them (Howard v. Perrin, 1904).

After World War II, Arizona became more dependent upon groundwater supplies than any other western state. In 1945 the legislature passed the state's first Ground Water Act requiring minimal filing requirements of well owners and drillers. Because of concern that an increasing dependence on groundwater was rapidly depleting the state's supplies, additional controls were enacted in 1948. The law provided for the designation of critical groundwater areas in which pumping for agricultural purposes could be restricted unless the land to be irrigated had been in cultivation for five years prior to passage of the act. The 1948 Ground Water Code was largely ineffective because of a lack of enforcement and the fact that it did nothing to reduce existing overdrafts (Mann, pp. 53-54, 1963). Groundwater pumping actually increased dramatically in the first five years following passage of the act. Attempts to strengthen the 1948 Code failed, and the legislature did not come to terms with Arizona's groundwater supply problem for another three decades.

Judicial activity created considerable uncertainty. At one point, the Arizona Supreme Court declared all groundwater subject to the prior appropriation doctrine (Bristor v. Cheatham, 1952). Then it reversed the decision on rehearing and adopted a common law rule allowing landowners to pump groundwater subject only to a reasonable use limitation (Bristor v. Cheatham, 1953). The reasonable use rule allowed virtually all agricultural withdrawals. The court declined to embrace the correlative rights rule which California employs to apportion limited groundwater basin supplies. Several years later, the court held that municipalities purchasing and retiring farmland could pump and transport only as much groundwater as the prior agricultural owner had consumed (Jarvis v. State Land Dep't, 1976). This case retreated from an earlier ruling involving the same parties that was more favorable to municipalities. The court next ruled that use on municipal and industrial (mining) lands was unreasonable where such lands were not actually overlying a statutorily designated critical area from which the water was pumped (Farmers Investment Co. v. Bettwy (FICO), 1976).

Until the 1976 FICO decision, the cases imposed little restraint in groundwater pumping. By then Arizona was pumping an average of 4.8 million acre-feet of groundwater per year, while diverting 2.5 million acre-feet of surface water per year. The annual rate of groundwater recharge, made up of natural recharge was 2.6 million acre-feet, of 300,000 acre-feet plus return flows from previous uses which found their way back into the groundwater basins, leaving a yearly statewide overdraft of 2.2 million acre-feet, about 45% of the total amount pumped. Overdrafting has caused substantial subsidence and ground fissures in areas where heavy pumping has been employed to meet agricultural demand.

For many years, the state's ultimate strategy for dealing with the overdraft problem was to rely on future Colorado River supplies from the planned Central Arizona Project (CAP). However, when the CAP received congressional authorization in 1968, it carried the stipulation that no water from the project would be delivered in absence of measures to control expansion of groundwater use. The Carter Administration, in furtherance of its water conservation goals and to assist Arizona Governor Bruce Babbitt's efforts to develop a new groundwater law, later threatened to withhold funding for the CAP until Arizona complied with the groundwater management stipulation. The state responded by enacting the 1980 Groundwater Management Act, creating a system to restrict new groundwater uses in overdrafted areas of the state with concentrated municipal growth (Meyers, Tarlock, Corbridge and Getches, 1987).

The Groundwater Management Act (GWMA) was designed to manage the supply and use of Arizona's water in such a way as to achieve a condition of "safe annual yield" within certain geographic areas where there is groundwater overdraft. This translates to a management goal of maintaining a long-term balance between groundwater withdrawn and groundwater replenished each year. The other goal apparent throughout the Act is to facilitate and regulate the conversion of agricultural rights to municipal uses.

The GWMA created two classes of areas in which new uses are severely restricted. First, the Act established four Active Management Areas (AMAs) for the groundwater basins containing Phoenix, Prescott, Tucson and Pinal County. These areas cover 80% of the state's population and 69% of the overdraft occurs there. New AMAs may be designated by the Arizona Department of Water Resources or by voter initiative in the proposed area. Second, the

GWMA designated three Irrigation Non-Expansion Areas (INAs) in which only the land cultivated in the five years prior to the year of designation may continue to be irrigated with groundwater. The goal for the Phoenix, Tucson and Prescott AMAs is to achieve safe annual yield by January 1, 2025. For the Pinal AMA, the goal is the preservation of the area's agricultural economy "for as long as feasible, consistent with the necessity to preserve future water supplies for non-irrigation uses" (Ariz. Rev. Stat. Ann. § 45-562).

The GWMA's program for groundwater conservation is implemented through a series of five management plans over a 45-year period. Each successive planning cycle will tighten restrictions on withdrawals, gradually imposing conservation requirements on all types of users. Almost all groundwater use in an AMA depends on a statutory category. Groundwater rights may be grandfathered for agricultural or non-agricultural purposes or for conversion from agricultural to municipal uses. They may also be obtained through a groundwater withdrawal permit for non-agricultural purposes. Both grandfathered and newly permitted rights must comply with the management plan's conservation requirements.

Plans for the AMAs call for achievement of safe annual yield by focusing on improved efficiency of use by all three major classes of water users, agricultural, pumped and industrial. But because agriculture is the largest user, the greatest reductions will result from major reductions in irrigation use. In the AMAs there is a flat prohibitio against irrigating new agricultural land. Three of the four AMAs account for over 30 percent of the state's total agricultural water consumption. Agricultural use in the Phoenix AMA is projected to decline from 1980 levels of 1,300,000 acre-feet to 530,000 acre-feet by 2025, a 59 percent reduction. Agricultural reductions in the Tucson and Prescott AMAs are projected at 36 and 35 percent, respectively, over the same period (Arizona Academy, p. 66, 1985). Tucson will remain entirely dependent upon groundwater for its water supply and overdrafts will continue until completion of the Tucson Aqueduct phase of CAP in 1992 (Ariz. Water Comm'n, pp. 24-25, 1975).

State Agencies

Water use in Arizona is controlled by the Department of Water Resources. The Department is headed by a Director, who is appointed by, and serves at the pleasure of, the Governor. The Department promulgates and enforces all rules for water use in the state. A seven-member board, the Arizona Water Commission, reviews and makes recommendations as to water policy, but the Director is not legally obligated to follow these recommendations.

The Director must approve all applications to appropriate or change the use of appropriated water. Any applicant whose rights are affected by the Director's decision may appeal to the state superior court. In addition, anyone appropriating from a given source may directly petition the court for a general adjudication of the nature, extent and relative priority of the water rights of all users of that source as an alternative to an administrative determination (Ariz. Rev. Stat. Ann. § 45-252). The Director also provides technical assistance to the superior courts in general stream adjudications.

Water Sources

The sources of water used in Arizona will change in importance after the Central Arizona Project (CAP) is fully operational. Table 4-1 depicts the state's major sources of water before and after the CAP.

Local Surface Water

Surface water available to Arizona, other than from the Colorado River mainstem, flows primarily in the Gila, Salt and Verde Rivers. These rivers in the south-central part of the state, are connected: The Verde is a tributary of the Salt, which is in turn a tributary of the Gila. Water supplied by the rivers is used heavily by agricultural interests and the City of Phoenix. The quantities available are discussed below under the major projects that make possible their delivery.

Major Water Projects

The Salt River Project currently contracts to deliver surface and groundwater supplies to ten municipalities within the SRP area, including the cities of Phoenix, Tempe, Glendale, Mesa and Scottsdale. These municipalities pay the SRP an annual assessment for formerly irrigated urban acreage and receive the water to which this acreage is entitled (Salt River Project, 1984). Other cities partially within SRP district boundaries cannot contract for SRP water, though there is water available, because of prohibitions in present law against serving such customers. Actual diversions by the project from 1930-1985 averaged 892,000 acre-feet per year (Linkswiler, 1990).

Because many of its water rights are relatively junior, deliveries from the San Carlos Project on the Gila River are not entirely reliable in a drought. The Indians' immemorial right will always provide some water but other water rights could be ineffective in a shortage. Those shortages are shared by Indians and non-Indians alike. From 1930 to 1975, the Indian portion of the project never received more than 78% of its decreed water right; in most years, the percentage was below forty (W.S. Gookin, 1977). With the recently imposed restrictions on dam usage, it seems unlikely that even in wet years the project will be able to deliver more than it has in the past. The project is currently capable of delivering less than 177,000 acre-feet per year. That amount, on the average, most likely will be deliverable once repairs on the unsafe dam structure have been completed. About 77,000 acre-feet of groundwater are pumped from the project area which represents seepage from system facilities and return flow from irrigation with project water.

Colorado River

The largest single source of water to Arizona is the Colorado River from which the State is entitled to take 2.8 million acre-feet per year. About 1.3 million acre-feet are used on the lands closest to the river. The remainder depends on major transportation facilities to pump and convey it to central Arizona. Those facilities are partially completed allowing delivery as far as the Phoenix area and soon, on full completion, will allow the rest of Arizona's apportionment to be diverted and delivered throughout Central Arizona as far south as Tucson.

When fully operational, the CAP will deliver an initial average of 1.5 million acre-feet of water annually. (Another 50,000 acre-feet of annual CAP supply could conceivably come from development on the Gila and San Pedro Rivers.) Of total available CAP supplies, 640,000 acre-feet per year have been allocated to municipal, industrial and recreational uses; 310,000 acre-feet have been allocated for use by Indian tribes; and the remaining 600,000 acre-feet have been allocated to non-Indian agricultural uses (Arizona Academy, 1985).[26]

All non-Indian users of CAP water will pay a charge of $53 per acre-foot for project operation and maintenance, plus a water service charge per acre-foot. The

TABLE 4-1

Summary of Arizona Dependable* Water Supplies
(million acre-feet/year)

	Pre-CAP	Percent of total***	Post-CAP	Percent of total***
Surface Water				
Salt-Gila River System	1.2	43	1.2	28
Colorado River				
Non-CAP (Mohave, La Paz & Yuma Counties)	1.3	46	1.3	30
CAP			1.5	35
Groundwater				
Natural Recharge	.3	11	.3	7
Return Flows to Aquifers**	2.3		0-2.3	
Totals	5.1	100	4.3-6.6	100

* The Pre-CAP figure for "dependable" water supplies excludes historical overdrafts of groundwater that amounted to about 2.2 million acre-feet per year. See Table 4-2. Presumably some overdrafts will be required to meet demand even after the CAP is fully operational.

** Return flows from previously applied water from all sources historically have provided 2.3 million acre-feet of water available for reuse. As uses change from agriculture to municipal, it is difficult to predict the amount of water that will return to aquifers and be available for reuse, although the amount is certain to be considerably lower.

*** Exclusive of return flows and overdrafts.

Source: Arizona Water Commission, 1975.

Bureau of Reclamation has set the service charge at $2 per acre-foot for non-Indian agricultural users. The Central Arizona Water Conservation District, the contracting agency for the CAP, has set an initial charge of $5 per acre-foot for municipal and industrial users. The "M & I" charge will eventually rise to $40 per acre-foot. The acre-foot charges will be an important factor in determining the amount of CAP water that is used. Given the cheaper option of pumping groundwater, users will generally choose that source.

Groundwater

Much of Arizona's water supply, nearly all the water historically used in the state, comes from its aquifers. The most active source is the basin underlying the Salt River Valley, which has provided well over one million acre-feet a year. In addition, almost one million acre-feet has been pumped annually from the Lower Santa Cruz Basin near Tucson. In total, the groundwater basins of Arizona have historically provided over four million acre-feet per year to water users throughout the state (Arizona Water Commission, p. 10, 1975).

Table 4-2 shows that the historical use of water in Arizona exceeded the dependable water supply (from Table 4-1) by about 2.2 million acre-feet per year and, if total water usage remains constant (7.3 million acre-feet), will exceed the dependable water supply by between 700,000 and 3 million acre-feet per year. Deficits historically have been met by overdrafting groundwater -- pumping in excess of the natural recharge plus return flows (waste water which soaks back into the groundwater basins). Since the Groundwater Management Act of 1980, overdrafting of aquifers has decreased and is expected to decrease more in the future, though it will be difficult to meet the act's objective of no overdrafts by 2025. Arizona is still using far more water than it can dependably supply, and overdrafting aquifers will continue unless agricultural rights are retired, not simply converted to municipal uses. In the first place, present demand requires overdrafts even with CAP fully on line. Furthermore, reusable return flows tend to decline with conversion to municipal use. Substantial agricultural return flows are now pumped from aquifers and reused, but municipalities typically consume more of the water delivered to them and are capable of reusing nearly all of it. Thus, it is theoretically possible to reduce return flows to much smaller amounts. In fact, an Arizona court has ruled that cities have the right to the sewage effluent they generate and may reuse it or sell it for reuse even in other areas (Arizona Public Service Co. v. Long, 1989). The ruling that effluent is not subject to regulation under state water law may mean that little of the water used by cities -- much of it converted to municipal use from former agricultural uses -- will be returned to groundwater. Of course this results in highly efficient use of valuaable water, but will result also in fuller consumption, and therefore greater depletion of groundwater supplies.

TABLE 4-2

Arizona Historical Water Use
Pre-Central Arizona Project

	million acre-feet year	percent of total
Surface Water		
Salt-Gila River System	1.2	16
Colorado River	1.3	18
Groundwater		
Natural recharge	.3	4
Return flows to aquifers	2.3	32
Overdrafts	2.2	30
Total	7.3	100

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CHAPTER 5

PERFORMANCE OF LEGAL AND INSTITUTIONAL SYSTEMS IN DROUGHT

The impacts of a drought within the study area are distributed partly according to phenomena of weather and geography and partly according to legal and institutional arrangements allocating scarce water. The sources of water available to Southern California and Arizona and the legal arrangements for utilizing them are described in Chapters 2, 3 and 4. Water rights priorities, interstate apportionments and contractual rights are critically important in allocating water as storage is depleted and as annual runoff is diminished. The purpose of this chapter is to determine generally how those arrangements operate in a drought situation and to identify the aspects of the water supply system that are the most vulnerable to drought.

Decisionmakers can use information about drought effects to determine with greater accuracy the trade-offs involved in political decisions to allow further growth in demand, to preserve or phase out agriculture, to tolerate a greater risk of drought effects and to deflect greater consequences on the areas where imported water originates. Limitations on water supply inevitably will force decisions about major redistribution of water from agricultural to municipal uses and from other regions to the study area. Consciously or unconsciously, these decisions will involve choices about the limits and kinds of growth and the quality of life in the study area. It is essential to have such a modeling tool to inform these decisions.

The water sources and the legal and institutional arrangements allocating them should be tested with greater precision than is possible here to determine their adequacy to serve the study area assuming various drought scenarios. In the absence of a model to test legal and institutional variables in the context of particular drought scenarios, it is possible to describe in a general way how the system would perform in a drought. The discussion that follows is necessarily theoretical and only broadly indicative of what would happen during a severe, sustained drought.

The following assessment is based on certain status quo assumptions about facts and conditions that are virtually certain to be different in fact. Pending negotiations and legal proceedings could have dramatic effects on actual performance. The Metropolitan Water District is negotiating several market transactions that could improve its position. It is pursuing deals with irrigators who have high priority rights to Colorado River water that would result in firming up MWD's rights and with other State Water Project contractors that would secure MWD more project water. Other developments could diminish the water available to the study area. For instance, the full extent of limitations imposed on water passed through the Sacramento-San Joaquin Delta will not be known until 1992, and Los Angeles' rights to Mono Lake water are still subject to judicial review. Further adjudication or negotiated settlement of Indian water rights and greater use of adjudicated rights will reduce the quantities available for non-Indian users.

For purposes of this report in discussions of likely drought consequences, a severe, sustained drought is defined as several years of significantly below-average runoff, beginning in a year with quantities of water stored in reservoirs at average levels. It is also assumed that drought conditions coincide throughout the areas where water for the study area originates -- the watershed of the Colorado River and in Northern California. This is an unusual coincidence, though it has happened historically. The goal here is not to define exactly where or in what degree of severity the effects of drought will be felt, but rather to describe what interests will be affected, and in what order, if water sources should seriously decline.

The following descriptions of how existing water supply systems could be expected to perform in a drought are built on the discussions in earlier chapters. The consequences of applying the Law of the Colorado River, which is the backbone of water supply in both Southern California and Arizona, are described first. The following two sections discuss the availability of other water sources to Southern California and Arizona in a drought. In the final chapter several possible options for improving drought performance are suggested for consideration by water supply officials.

Colorado River

There is tremendous reliability built into the system for distributing Colorado River water. Huge storage facilities make the river a dependable source of water even in years when flows are below normal. Releases necessary to fulfill basic lower basin and Mexican deliveries can continue undiminished for many below-normal years. The only immediate effect felt by the lower basin states would be a cessation of deliveries of water to Southern California in excess of the basic compact apportionment. This should not be understated in its importance, however, in light of the many years that Southern California has been able to rely on those deliveries. But only when storage is depleted will the lower basin states be threatened with limitations on their compact apportionments. Thus, much of the discussion of the impacts of drought focuses on the upper basin states.

The storage system on the Colorado mainstem can forestall many of the impacts of drought on the upper. So long as there is adequate water stored in the mainstem reservoirs the system can satisfy compact delivery requirements to the lower basin with reservoir releases. This then allows the upper basin to use all of the direct flow as well as all of the water in upper basin storage (not including water in Lake Powell which is too low on the river for delivery to upper basin states) to meet its current demand which now amounts to about 3.5 million acre-feet a year. Some immediate effects of a drought may nevertheless be felt locally in the upper basin. Particular streams may not produce enough water for some users to capture the water to which they are entitled at the points where they are entitled to take it under state water law. This may result in some upper basin demands going unsatisfied even when there is enough upper basin water available in the aggregate throughout the basin.

Besides the rather abrupt impacts of a severe drought on upper basin consumptive users who lack storage or whose storage becomes depleted, there will also be immediate impacts on instream flows. Some instream flows are protected under upper basin state laws benefitting fish, wildlife and recreation uses. Rights held by the states for these purposes will mean little in drought, though, because virtually all are junior to consumptive use rights and therefore seniors can generally consume all the water in stretches of most streams. To the extent that the federal government may hold reserved rights for instream flows with sufficient seniority, however, those rights may be enforced to maintain some basic flows. Such rights are likely to be concentrated in small, high mountain streams where the earliest National Parks and Forests were established.

Generally the only water that will flow in the river and in lower reaches of its tributaries in the upper basin is that which is not consumed by upstream water rights holders and which is required to meet a downstream state's call under the Law of the River. This could result in immediate and irreversible consequences for riparian areas and for fish and wildlife. Sectors of the upper basin economy that depend on these resources, including the increasingly important recreation industry, will be harmed. Only limited "protection" is furnished for such values by having a compact call that demands leaving water flowing in the stream so that it reaches the lower basin. Calls will be satisfied under present institutional arrangements within the upper basin states simply according to where and when water is available, not necessarily with any sensitivity to other values.

Other immediate effects of drought in both lower and upper basin states are not necessarily linked to reductions in river diversions. Crops that rely on rainfall or sub-irrigation supported by runoff for parts of the year may fail. Rangeland and forests may suffer immediate and economically measurable consequences. Recreational uses of water such as fishing, hunting, boating and skiing may decline, and with them economic returns will drop and the quality of life will suffer.

The operation of each state's water rights system in low flow years will generally track actual operations in recent drought events. These operations should be studied. Generally, in droughts water is more strictly administered by state water officials. The most junior users may face cutbacks; seniors will receive water according to the priorities and quantities of their rights. Thus, the effects on particular users in each state can be modeled to some extent based on knowledge of existing uses and water rights and assumptions about streamflows, an exercise that is beyond the scope of this study. Of course the reliability of projections depends on there being no interstate demands resulting in compact calls that alter the overall amounts of water that can be used by a particular state.

Compact Calls

There has never been a compact call on the Colorado River. A call could occur in one of two circumstances:

1) Interbasin call: Lower basin versus upper basin. When mainstem storage has been depleted to the point that it is inadequate to make required deliveries to the lower basin at Lee Ferry the lower basin can call for the upper basin to leave enough water in the river at Lee Ferry to satisfy the Compact and to fulfill the upper basin's portion of the Mexican Treaty requirement. The upper basin, however, would be guaranteed use of a quantity of water equal to its "present perfected rights" (at the time of the Compact) -- about 2 million acre-feet a year.

2) Interstate call: Upper basin state versus upper basin state. If an upper basin state is consuming more than its percentage share of the available flow in a particular year and another upper basin state downstream of the first is not getting all of its percentage share for which it has beneficial uses, the downstream state can call on the upstream state to let

water flow to it. A call can be made also if it is necessary to reduce overall upper basin use to meet a lower basin call. Upper basin interstate calls can be made, as a practical matter, by Utah against Colorado, Wyoming and New Mexico and by New Mexico against Colorado.

An interbasin call will occur when it is necessary to curtail upper basin uses to deliver current flows sufficient to meet the 75 million acre-feet guaranteed compact delivery requirement for the current ten years plus half the annual delivery requirement to Mexico of 1.5 million acre-feet. Only what is left over is then available to be used in the upper basin. Present perfected rights are not subject to the call.

The upper basin versus upper basin interstate call can be made any time one state's use exceeds its percentage share under the Upper Colorado River Compact and injures another. The injury may be caused by cutting into the amount of water another state needs to use or by failing to reduce usage enough to respond to an interbasin call. Since the percentages are not based on established uses, the effects of a call would be the harshest on the most developed states. Of the upper basin states only New Mexico is currently using its full apportionment. The prospect of cutbacks and economic dislocations raises concerns for upper basin states as they consider building up a greater dependence on consuming Colorado River water.

Upper basin states theoretically must be concerned with the possibility of an interstate compact call in any very dry year. But a lower basin call can occur only in extreme situations when reservoirs are virtually empty and flows available for current use are meager, historically rare circumstances. It would take many years for the mainstem storage system to become so depleted that it was unable to satisfy lower basin delivery requirements, promoting a lower basin call. In these instances, the upper basin states' only protection against shortages is existing tributary storage and the ability to curtail demand. Once there was a lower basin call, however, the probability of successive calls would tremendously increase because it would be difficult to build up storage without some extraordinarily high runoff years -- producing enough water to satisfy all current uses plus a surplus. Whenever lower basin calls are in effect, it is more likely that there would also be upper basin interstate calls. Furthermore, the upper basin versus upper basin interstate call can occur in a single low flow year, even when there is plenty of water in downstream storage to meet downstream compact obligations. Neither kind of call is likely at present levels of development and use in the upper basin but the likelihood of a call increases as upper basin states increase their consumptive uses. All calls bear most heavily on the most developed states.[27] During episodes when calls are made lower basin states can avoid any significant cutbacks so long as their full compact entitlements are timely delivered at Lee Ferry. Still, they face insecurity of future supplies when the enormous mainstem reservoirs are drawn down.

The Reservoir System

The drought protection capability of the Colorado River plumbing system has never been tested. Evidence indicates that the period during which the study area has become so dependent on Colorado River water is a statistical anomaly; the long-term averages are lower, and the extreme low flow years are worse than the area has experienced in the post-development period. Assuming an annual average flow of 13.5 million acre-feet,[28] only nine of the twenty-five years since completion of the Glen Canyon Dam have produced "below average" virgin flows (Upper Colorado River Commission, 1988). Only once since 1896 has there been a series of more than three consecutive below-average flow years, and that happened in 1953-1956, before Glen Canyon was completed. The reservoir system was filled to capacity in recent years by several successive high precipitation years. Nevertheless, storage at high levels can be maintained for a long time so long as historical averages are maintained and not interrupted by an extremely severe drought or tapped to meet increased demands.

As Table 5-1 shows, the average annual demands on the Colorado River are 12.5 million acre-feet. Therefore, if deliveries to the lower basin are equal to full compact requirements, upper basin consumptive uses do not increase, and flows do not depart too long or too widely from the average (13.5 million acre-feet), the storage system should be adequate indefinitely to ensure constant lower basin deliveries by smoothing out average fluctuations in annual flows and thus forestalling shortages or lower basin calls on the upper basin. The stability depends in part on there being no surplus deliveries to the lower basin, even in high flow years, and on flows occurring in times and sizes that enable optimal storage.

If the assumptions based on the averages are not realized, however, several years of extremely low flows unmatched by compensating high flows could deplete the reservoirs at present rates of consumption. Depending on how the reservoirs were actually operated, that could occur if the Colorado River experienced another period equal to the lowest ten consecutive years of flows, even with substantial storage in upper basin reservoirs. The following calculations based on that episode are illustrative. Tree ring data indicate that the ten years from 1584 to 1593 produced only 97.1 million acre-feet of virgin flow in the Colorado River, an average of 9.7 million acre-feet a year (Stockton, et al., 1989). We assume that the dry spell begins with 31.2 million acre-feet in storage (about 50% of total capacity), 15.6 million acre-feet in each basin.[29]

Aggregate demand for the ten-year period would be 125 million acre-feet (ten times the average demand from Table 5-1). Aggregate available supply for the period is assumed to be 128.2 million acre-feet (97 million acre-feet inflow and 31.2 million acre-feet in storage). This should result in an overall surplus or 3.2 million acre-feet,[30] but reservoir operations would have become sensitive to the low flow conditions to avoid cutbacks in upper basin diversions. Table 5-2 illustrates two possible methods for operating the reservoir system in a drought. Method A shows that the upper basin would suffer reductions in the water available to it after the seventh year of the drought if equal releases were made each year. Full uses in both basins could be accommodated, however, if the upper basin could rely on water in storage to make deliveries, thus protecting its ability to use limited inflows. Thus, under Method B, the lower basin would draw more heavily on its own storage to satisfy current demands, allowing the upper basin to store a portion of annual inflows rather than delivering a full 7.5 million acre-feet each year to satisfy the compact delivery obligation. In this way upper basin uses could be continued during each of the ten years. The upper basin would then be obligated to compensate for the annual deficits in lower basin deliveries within ten years of when each deficit was accumulated. In the example for Method B in Table 5-2, the deficit is 5.85 million acre-feet which would be due in the next (eleventh) year, for a total lower basin

TABLE 5-1
Colorado River Annual Average Demand
(million acre-feet)

Lower basin compact deliveries	
Article III(a)	7.5
Mexican Treaty delivery	1.5
Upper basin consumption	3.5
	12.5

obligation in that year of 14.1 million acre-feet.

If the assumptions made in the above calculation change, shortages could occur in the system. The assumption that concern for power generation would not affect the overall quantities of water released is questionable under present operating criteria. In addition, upper basin usage is bound to increase, though probably very gradually. As those uses increase, less water will accumulate in storage, removing the buffering effect of the reservoir system. Storage could also be drawn down more rapidly if the lower basin received additional releases for any reason. The lower basin states now have sufficient consumptive demand to use far more than their apportionment. If additional releases were allowed by the Secretary under article III(b) or III(e) to satisfy present lower basin consumptive uses, storage would become depleted much more rapidly, causing the system to lose its present reliability. Moreover, there would be far less water in storage than was assumed at the onset of the hypothetical drought. Similarly, if the Secretary did not charge Indian consumptive uses and evaporative losses entirely to the states' consumptive uses, more water would be released than necessary and storage drawn down more rapidly. The Secretary's present operating criteria can be read to prevent any surplus releases and depletion of storage once a drought is apparent.[31]

Reductions Within the Lower Basin

At the point that reservoir storage plus available flows become inadequate to meet compact delivery requirements and the Mexican Treaty obligation,[32] there must be cutbacks in certain lower basin uses. These cutbacks will first affect Arizona at virgin flows of less than 11 million acre-feet, after reservoir storage is depleted. This is because when less than 7.5 million acre-feet are available for the lower basin, then shortages are to be absorbed by the Central Arizona Project which has been allocated 1.5 million acre-feet of Arizona's 2.8 million acre-feet. Under the Colorado River Basin Project Act, however, California is entitled to receive its full 4.4 million acre-feet. The Secretary is free to reduce other Arizona uses (which are entitled to 1.3 million acre-feet) and Nevada uses (which are entitled to .3 million acre-feet) as soon as water available to the lower basin is inadequate for all. But no cutbacks may be made to California users of its 4.4 million acre-feet until the CAP has been denied its full 1.5 million acre-feet. Arizona conceded this point as part of the political price of securing approval of the CAP. Before the CAP would face reductions, however, the upper basin would be cut back to the point that it could use only water secured by its "presented perfected rights."[33] These rights amount to about 2 million acre-feet. Thus, the beginning point for reductions to CAP is the 11 million acre-feet necessary to meet prior obligations: California, 4.4; Nevada, .3; Arizona, 2.8; upper basin perfected rights, 2.0; Mexico, 1.5.[34]

The only limitation on deliveries available to California will occur after the reservoir system has been depleted and the annual flow is so low that the lower basin has "called" all water available to it under the Compact from the upper basin and service to the Central Arizona Project has been cut entirely off. Thus, if virgin flows in the river dropped below about 9.5 million acre-feet (11 million acre-feet less the 1.5 million acre-feet CAP allocation) and there were no storage left, California would face cutbacks in its share of river water. Virgin flows this low have occurred eleven times since 1896, but never after a period that would totally deplete storage assuming present levels of consumption.

It should be pointed out that the manner in which cutbacks are to be shared in a shortage by lower basin users is subject to the discretion of the Secretary of the Interior and available water need not be prorated according to the apportionment in the Boulder Canyon Project Act.[35] Within California, however, the waters available under the Compact have now been allocated by a recent amendment to the Law of the River. Several years ago the Secretary discretionarily exercised his contracting authority by allocating California's 4.4 million acre-feet according to the "Seven Party Agreement." The Agreement was actually a recommendation of the state Department of Water Resources proposed by the mutual agreement of several agricultural and municipal water users. In 1988 Congress statutorily recognized the agreement as establishing priorities among California users (102 Stat. 4005, 4006). Under the Agreement, agricultural users (Imperial Irrigation District, Palo Verde Irrigation District, Coachella Valley County Water District) have the first three priorities to 3.85 million acre-feet of California's 4.4 million acre-feet share of river water. The Metropolitan Water District of Southern California has the next two priorities (either expressly in the Agreement or by subsequent agreement with Los Angeles and San Diego) for 550,000 acre-feet. Further priorities in the Agreement apply when there is more than 4.4 million acre-feet a year to share.

The Metropolitan Water District of Southern California has been firming up its rights to Colorado River by separate contracts that depart from the allocations under the statutorily adopted Agreement. It has agreed to pay the cost of salvaging water in the Imperial Valley in exchange for the right to use the water saved. A similar arrangement has been made with Coachella Valley County Water District. Other negotiations are being pursued that would also put MWD in the shoes of the Palo Verde Irrigation District and other agricultural beneficiaries of the Agreement.

To the extent that the tribes along the mainstem put a portion of their 900,000 acre-feet of water to use in California or Arizona, the water is not available for use by other users within each state. Tribal uses take priority over all junior uses.
Mainstem Indian tribes now use 340,000 acre-feet a year on Arizona land and 55,000 acre-feet a year within California. This water comes out of the first water allotted to the state in a shortage, diminishing water available for non-Indians. Other tribes have secured rights to CAP water and some Arizona tribes have not yet adjudicated their

TABLE 5-2
Colorado River

Hypothetical Operations -- Extreme Ten-Year Drought
(millions of acre-feet)

Method A -- Constant Upper Basin Reservoir Releases

	Upper Basin					Lower Basin			
	Inflow	Available During Year (Storage + Inflow)	Consumption	Releases to Lower Basin & Mexico	Carryover Storage	Available During Year (Storage + Up. Basin Release	Releases to Mexico	Consumption	Carryover Storage
Beginning of period					15.6				15.6
Year 1	9.7	25.3	3.5	8.25	13.55	23.85	1.5	7.5	14.85
2	9.7	23.25	3.5	8.25	11.5	23.1	1.5	7.5	14.1
3	9.7	21.2	3.5	8.25	9.45	22.35	1.5	7.5	13.35
4	9.7	19.15	3.5	8.25	7.4	21.6	1.5	7.5	12.55
5	9.7	17.1	3.5	8.25	5.35	20.85	1.5	7.5	11.85
6	9.7	15.05	3.5	8.25	3.3	20.1	1.5	7.5	11.1
7	9.7	13.0	3.5	8.25	1.25	19.35	1.5	7.5	10.35
8	9.7	10.95	2.7	8.25	0.0	18.6	1.5	7.5	9.6
9	9.7	9.7	2.0*	7.7	0.0	16.55	1.5	7.5	7.55
10	9.7	9.7	2.0*	7.7	0.0	15.25	1.5	7.5	6.25
Cumulative Totals:	97.0		31.2	81.4	0.0		15.0	75.0	6.25

Method B -- Balanced Drawdown of Upper & Lower Basin Reservoirs**

	Inflow	Available During Year (Storage + Inflow)	Consumption	Releases to Lower Basin & Mexico	Carryover Storage	Available During Year (Storage + Up. Basin Release	Releases to Mexico	Consumption	Carryover Storage
Beginning of period					15.6				15.6
Year 1	9.7	25.3	3.5	8.25	13.55	23.85	1.5	7.5	14.85
2	9.7	23.25	3.5	7.6	12.15	22.45	1.5	7.5	13.45
3	9.7	21.85	3.5	6.95	11.4	20.4	1.5	7.5	11.4
4	9.7	21.1	3.5	8.25	9.35	19.65	1.5	7.5	10.65
5	9.7	19.05	3.5	7.6	7.95	18.25	1.5	7.5	9.25
6	9.7	17.65	3.5	7.6	6.55	16.85	1.5	7.5	7.85
7	9.7	16.25	3.5	7.6	5.15	15.45	1.5	7.5	6.45
8	9.7	14.85	3.5	7.6	3.75	14.05	1.5	7.5	5.05
9	9.7	13.45	3.5	7.6	2.35	12.65	1.5	7.5	3.65
10	9.7	12.05	3.5	7.6	.95	11.25	1.5	7.5	2.25
Cumulative Totals:	97.0		35.0	76.65	.95		15.0	75.0	2.25

* Upper basin consumption cannot be reduced below "present perfected rights" which are about 2 million acre-feet.

** Releases for current year are 8.25 minus 1/2 difference between prior year's carryover storage in lower basin and upper basin.

claims. Increased Indian uses would consume parts of each state's share of Colorado River water. The lowest priority users (under the law of the river) in each state -- CAP in Arizona, MWD in California -- will feel the first effects of increased tribal water consumption. These interests may seek to negotiate with the tribes to secure the use of Indian water in these events (and perhaps to use the Indians' prior rights at other times) through leasing the rights or agreements for non-development of Indian uses.

Salinity

The effects of increased salinity on lower basin uses could be profound. It is impossible to determine the degree to which salinity will increase in a severe, sustained drought without further studies. In recent years salinity levels have dropped when high flows diluted salts and flushed out reservoirs. It is reasonable to expect that concentrations of dissolved solids in the river will increase as flows diminish, reservoir levels drop, and evaporation leaves greater concentrations of salts, though they probably will not increase directly as flows are reduced. High salt concentrations occur during average flow periods, approaching water quality levels that are detrimental to agriculture and that would violate the law. Prolonged low flows would reduce the river's dilutive capacity and lead to exceeding those levels.

Municipal users in both California and Arizona can mix salty Colorado River water with water from other sources to dilute it. They also can treat and desalinate water in properly equipped treatment plants before serving their consumers. The complex delivery network makes this physically possible, though the additional treatment processes would be costly. For agricultural users in the two states, increased salinity may mean failed crops and an outright inability to irrigate with river water. If this were the consequence of a severe, sustained drought, the waters that were too saline for farmers possibly would be reallocated to municipal users who could afford to pay for treatment.

Summary

Arizona's ability to draw its full share of Colorado River water has always depended on construction of a major public works project, the Central Arizona Project, which is now nearly complete. Though it will enable the state to take about 1.5 million acre-feet of water a year that it could not divert in the past, the CAP cannot legally take water when it would result in California getting less than 4.4 million acre-feet. Cutbacks in CAP diversions will occur only when storage is depleted and virgin flows are less than the 11 million acre-feet needed to satisfy the basic lower basin and Mexican delivery requirements plus the upper basin's present perfected rights. At that point, CAP contractors must begin to absorb the necessary reductions. Among the contractors, agricultural users will be cut off before municipal and industrial users.

Other Arizona users of Colorado River water need not suffer cutbacks until CAP diversions have been completely eliminated. Municipalities served by CAP, however, could contract with Arizona's agricultural users on the mainstem and its tributaries to get them to agree to subordinate their uses in times of shortage.

California is virtually guaranteed its 4.4 million acre-feet of Colorado River water each year until the reservoirs are depleted and annual flows are so low that the upper basin's uses are limited to present perfected rights and the full 1.5 million acre-feet allocated to CAP has been cut off. As discussed above, this would occur at a virgin flow of 9.5 million acre-feet. At that point, cutbacks are to be made according to the

Secretary's discretion in contracting for use of river water with Arizona agricultural users in the western counties, California users and Nevada users. within California agricultural users would be preferred under the Seven Party Agreement except to the extent irrigation districts agree to transfer their rights to municipal users.

Although California apportionment of Colorado River water appears the most secure in a drought, present uses in excess of 4.4 million acre-feet are tenuous and are the most vulnerable to termination in drought. Absent a shortage, though, these uses may continue until the CAP demands its full entitlement or the Secretary of Interior changes the operating criteria for river facilities.

Other California Sources

Los Angeles Aqueduct -- Mono Lake and Owens Valley

Southern California's Mono Lake and Owens Valley sources are imported by the Los Angeles Department of Water and Power through the Los Angeles Aqueduct. They are the subject of ongoing legal actions and negotiations. The State Water Resources Control Board must decide, and the courts must agree, that the amounts of water removed from the tributaries to Mono Lake are consistent with the public trust doctrine. It is fair to assume: 1) that the amount regularly available after this determination is made will be less than the full amount of Los Angeles' rights; and 2) that the amount available in a drought will be less than in normal years.

Owens Valley supplies are limited in times of drought. For instance, in 1988-89 they were only 75% of normal, requiring Los Angeles to call on MWD to make up the difference. Furthermore, as explained in more detail in Chapter 3, Los Angeles has recently agreed with Inyo County that it will limit groundwater pumping in the valley when the pumping would endanger vegetation. This limits an important aspect of drought protection since groundwater is usually less vulnerable to drought than surface sources.

State Water Project

The largest source of water used in Southern California other than the Colorado River is the State Water Project, about 1.15 million acre-feet per year. The Metropolitan Water District must share the burden of inadequate supplies with other contractors, but not until agricultural contractors have suffered reductions totalling 100% of their annual allocation in any seven year period or 50% in any one year would MWD experience reductions. After such reductions have been made, MWD will sustain reductions equally with other contractors. The preference in reductions can be illustrated by assuming that a total system reduction of 175,000 acre-feet were necessary. If agricultural contractors have contracts for 1.25 million acre-feet a year, they would have to absorb shortages of 175,000 acre-feet a year for seven years (7 x 175,000 = 1.225 million acre-feet) before MWD would face reductions. They most likely would revert to groundwater pumping for irrigation. More detailed analysis of the effects of various levels of drought on SWP supplies would be useful. However, at present and for the foreseeable future, the principal constraint on deliveries from the SWP is not the quantity of water produced in Central and Northern California. Instead, deliverable supplies are limited by the capacity of facilities to move the water south and the water quality effects of operating those facilities.

Though several features of the SWP as planned have not been built, the main bottleneck preventing fulfillment of contracts is the Bay-Delta water quality problem. The architects of the SWP recognized decades ago that the quantity of water that may be moved through the Delta is physically limited. But more recently it has become apparent that pumping water out of the Delta during low flow seasons can cause immense water quality problems. Saltwater intrusion can be controlled, but this may require diversions to be accompanied by upstream releases of large amounts of fresh water to flow to the Bay from facilities that were constructed for development, storage and transport of water to SWP contractors. Trihalomethane precursors also occur in Bay-Delta waters limiting its utility as drinking water; maintaining sufficient flows may be the solution to this quality problem as well.

In 1991 or 1992, the State Water Resources Control Board will decide on a regime for controlling the SWP's facilities' effects on the Bay-Delta by adoption of the Delta Water Quality Plan. It, in turn, will determine whether diversions to Southern California can be increased at all in the future and, most important to this report, what releases must be made in times of low flow.

Other Arizona Sources

As discussed above, Arizona's share of Colorado River water is rather secure in a drought, especially for users who do not depend on the CAP. Other sources available to those who rely on CAP water include large groundwater reserves and surface water, principally the Salt River Project for the Phoenix area.

Surface Water

In a drought Arizona's surface water sources could become less productive. Even if they produce at average levels, it is clear that seasonal local supplies will not be a dependable cushion for a drought. Historically, storage in the Salt River Project has averaged only about 1 million acre-feet. It could make up for reduced annual runoff within the SRP for a few years but could not compensate for the loss of CAP water.

Groundwater

Arizona's heavy reliance on groundwater has caused major overdraft problems. The state's 1980 Groundwater Management Act mandated conservation and will lead to a gradual phasing out of agricultural uses in many places where groundwater overdraft has been the greatest. The act's strict limits on groundwater uses were motivated by the promise of deliveries of imported water through the CAP. As explained in Chapter 4, imposition of groundwater pumping controls was a precondition on federal funding for the CAP. Although Arizona has reduced its dependence on groundwater, many areas are still in overdraft.

If Arizona loses its CAP water or a significant part of it, municipalities like Phoenix and Tucson will be forced to rely primarily on groundwater. Cities have already embarked on an aggressive program of purchasing farms and ranches to obtain groundwater rights to accommodate future growth. Groundwater reserves are so enormous that they will allow pumpers to survive almost any drought. However, their utility will depend on drilling new, deeper wells and paying high energy costs for pumping. Other ill effects of overdrafting aquifers, such as land subsidence could occur. The concern for containing overdrafts was so great that Arizona's 1980 Act made no exceptions specifically allowing a reversion to overdrafts in a drought emergency. If groundwater pumping is to be the principal supply during a prolonged drought, that purpose should be established in amendments to legislation and reflected in drought plans.

True conjunctive use of groundwater as a back-up for diminished surface flow requires a heavy emphasis on aquifer replenishment. If the drought occurs against a backdrop of heavily overdrafted aquifers, dislocations will be hastened and costs increased. Conversely, the best drought protection for Arizona is to recharge aquifers so that they can be used conjunctively with other sources to survive a drought. This requires shifting reliance away from pumping and toward use of CAP water for both present uses and a recharge program in times of normal or surplus surface supplies. Some interests like Central Arizona Water Conservation District and several municipalities are pursuing recharge programs. However, the attractiveness of these programs is limited by the high cost of CAP water. Furthermore, some areas like Tucson are still awaiting the delivery of CAP water and have no alternative to using groundwater.

Summary: A Composite of System-wide Drought Performance

Identification of the most drought-vulnerable parts of the systems serving Arizona and Southern California is central to any effort to anticipate problems or to make the system more capable of resisting drought. Yields and capacities of these systems in average years are adequate to meet present demands. That conclusion is less optimistic, however, given the inevitability of drought events -- significant departures from the average -- in the study area and the likelihood of growth. Thus, it is important to evaluate the systems under stress.

We have assumed for the purposes of this report that a severe, sustained drought stretches simultaneously over the study area and over the seven-state Colorado River watershed and the huge Central and Northern California watersheds on which the study area depends for a water supply. Though drought events frequently do not coincide in both watersheds, the coincidence is a worst case scenario that illustrates how stresses operate on the system.

At present population levels and patterns of use, both Southern California and Arizona are equipped to cope with short-term dry spells throughout this vast area. But, as a drought wears on, storage will be depleted, alternative supply sources will no longer be available and certain cutbacks in existing uses eventually will be necessary.

While we can predict the sequence in which effects will be felt, it is impossible to describe, with our present information and tools, when and where those effects will occur and with what level of severity. Accurate predictions must be based on more precise data and assumptions about the nature of the hydrologic drought event and possible institutional responses.

Because of the number of variables, the complexity of the system and the likelihood that facts will be in constant flux, an analytical model is needed to test system performance in a drought. A computer model could vary the levels of demand, the patterns of drought and the institutional responses. In this way, the nature, timing and extent of various drought effects can be predicted with reasonable accuracy. Decisionmakers can visualize the consequences of increasing levels of risk of exposure to drought by allowing future growth. The model could also indicate the consequences of applying alternative management strategies, such as limiting future demand growth and reallocating present supplies, to variable fact patterns. This would help decisionmakers find the best responses.

The present project does not have the advantage of such a model, but the following descriptions summarize generally how an area-wide drought might unfold and the sequence in which its impacts might be felt.

Phase 1

Existing consumptive uses generally will continue in the study area. Municipal consumers will not necessarily notice the effects at first; consumer demand might initially increase as lawns and other plants begin to show effects of dryness in a long, hot spell. A few areas with especially vulnerable systems (e.g., Santa Barbara, California) because they are not served by MWD will feel severe effects and their plight will create a drought awareness among other urban users. Such an awareness will aid in promoting conservation efforts. Past experience has shown that urban consumers can conserve and reduce usage by up to 15% without feeling significant negative effects. Reduced local surface flows in most parts of both Southern California and Arizona can be replaced by imports and some increased groundwater use. Imports from the Colorado River system will continue if an average supply of water is in storage, but California's present advantage of additional deliveries will be curtailed to the extent Arizona takes advantage of its share. Southern California will be forced to draw down groundwater in storage within and without the service area; recharge with imported water will decline as more imported water is needed for immediate use. At the same time, natural recharge will be reduced.

In order to make up for shortages in Salt River Project supplies, urban users in Arizona will rely more heavily on direct use of CAP water. Groundwater pumping will be constant and use of CAP water for groundwater recharge will be discontinued.

In California, releases from reservoir storage to meet Bay-Delta water quality requirements might have to be larger to make up for low runoff flows. Although average supplies of water in storage will be adequate for this purpose, water entering the SWP may be limited. Agricultural users of SWP water in the Central Valley will begin to experience reductions, forcing them to pump groundwater.

No significant agricultural losses are expected. Range, fish and wildlife, forests, recreation and agriculture dependent on sustained streamflows and natural irrigation all will sustain adverse effects. Economies dependent on these resources will show losses. As urban supplies from all sources are limited, localized water rationing will occur and mandatory restrictions in outdoor water use may be necessary after a few years.

Phase 2

California's groundwater in storage will be seriously depleted and overdrafts will begin. Mono Lake/Owens Valley sources will be less productive because groundwater pumping will have to be cut back.

California State Water Project deliveries will be reduced as Bay-Delta quality problems increase due to diminished natural flow and MWD will eventually be required to share shortages with Central Valley agricultural contractors; continued releases without replacement from runoff could begin to deplete SWP storage. Arizona groundwater overdrafts will increase as surface storage becomes depleted and surface flows dwindle; recharge programs will end. Pumping costs will escalate and new wells may be necessary. After several years of a severe drought Arizona's CAP water will eventually be threatened with curtailment as

Colorado River water in storage begins to be depleted.

Urban consumers in both Southern California and Arizona will face reductions and water rationing. The most vulnerable California communities, generally outside MWD's service area, will reduce water use to the most basic demands, eliminating virtually all outdoor use and causing losses of exotic plants and lawns. The extent of cutbacks in most urban areas can be limited if water suppliers and the states are willing to tolerate groundwater overdraft.

Agriculture will suffer minimal losses in the Central Valley (based on the 1976-1977 drought experience) and Imperial Valley will be unaffected. Salinity will increase in the Colorado River, however, potentially causing damage to agricultural users.

Great losses will be felt in the recreational industry. Wildlife and fish will suffer serious, perhaps permanent damage. Continued grazing on parched range could destroy soils. Drought would cause large economic losses in these sectors. As operational flexibility of the hydroelectric generating system is limited the overall value of the power produced will decline.

Phase 3

In the extreme situation where a multi-year drought of major proportions blankets the area, serious dislocations will be felt once the many fail-safes planned into the system are exhausted. Southern California will experience further reductions in SWP deliveries as Bay-Delta requirements increase. At some point the SWP Feather River storage system will run out and current Northern California runoff will be inadequate to satisfy both Project demands and Bay-Delta quality requirements. This will lead to reductions in urban and agricultural deliveries.

Owens Valley pumping will be even more restricted and coastal salt water intrusion, concentration of pollutants and aquifer damage could force curbs on groundwater production in the coastal plain of California. California's groundwater overdrafts will cause permanent harm to aquifers by contamination from existing plumes of pollutants and from saltwater intrusion.

Arizona will face subsidence and other localized damage from increasing groundwater overdrafts, although the supply of water will sustain the area for a long time. This probably will coincide with reductions or even elimination of CAP deliveries if the Colorado River storage system runs dry. Only after all CAP deliveries end will California's deliveries be reduced along with deliveries to western Arizona (and Nevada).

Outdoor municipal water use in California and Arizona will have to be nearly eliminated in many areas, causing heavy losses of lawns, golf courses and other water intensive vegetation.

Agriculture will remain productive in the Imperial Valley because of the high priority of agricultural water rights from the Colorado River. Farmers on the lower Colorado River (in both Arizona and California) might have had to reduce their usage of river water not because of a lack of water but because of high salinity. This could incidentally free up some additional water for municipal use in the states where those reductions are made if the municipalities can pay the high cost of treatment. Central Valley farmers, heavily reliant on groundwater by this time, will experience high costs of pumping and well-deepening. Increasingly saline water and lower, less accessible groundwater levels will accompany heavy pumping. Crop failures and especially livestock losses will occur.

Fish and wildlife, wetlands and rangelands will sustain major damages. Forest growth will be noticeably retarded. By this time recreational economies built on fishing, hunting, skiing and the aesthetic attraction of natural systems may collapse. The decline in quality of life will be reflected in real estate prices and sales activity. The demise of reservoir storage will eliminate most power production and increase pumping costs to some users of river water.

The above predictions are summarized in Table 5-3.

Both Arizona and Southern California have potentially great drought protection if their resources and rights are managed to optimize supplies for drought. The area can withstand short-term droughts, even rather severe ones affecting simultaneously all its sources of water supply. Initially, only localized damage will occur; there is no serious threat to existing consumptive uses in most of the study area. Even after a few years of drought, mostly minor damage to outdoor plants would result. There would, however, be noticeable and progressive losses of resources dependent on regular minimum stream flows and runoff. Quality of life also would begin to decline with such losses and with the inevitable restrictions on outdoor water use for irrigation of yards, parks and golf courses.

A relatively optimistic prognosis for the area's resistance to drought is based on present rates of diversion and use. But the population and economy of the area are growing and sources of new supplies are not on the horizon. In light of inevitable pressures for growth as well as inevitable major droughts, decisionmakers must consider a variety of options, many of which go beyond the traditional gambit of water supply decisions that are made in response to droughts. Some require fundamental choices about the future economy, lifestyle and environmental quality of both the study area and the regions from which they draw water. These are choices that must be made at a higher political level and with wider public debate than usually accompany water decisions.

TABLE 5-3

Possible Effects on Water Supplies of Study Area of Various Length Droughts

	Surface Waters-Calif. & Arizona	Colorado River			L.A. Aqueduct (Mono Lake & Owens Valley)	California State Water Project	Groundwater	
		Central Arizona Project	Ariz. & Calif. Agric. Users	S. Calif. Municipal Users			Southern California	Arizona
<u>Phase 1</u> Short-term drought	Reduced	No reductions in basic deliveries; storage is drawn down.	Curtailed surplus deliveries to MWD		Less surface production	Deliveries continue in amounts comparable to recent years; releases increase for Bay/Delta because less runoff	Increased pumping; less natural recharge; imports relied upon heavily for recharge; storage declines	Less natural recharge; CAP use for recharge declines
<u>Phase 2</u> Mid-term drought	Reduced	No reductions in basic deliveries; heavy drafts on storage; increased salinity effects			Reduced ground-water pumping in Owens Valley; less surface production	Reduction of deliveries as shortages must be shared with Central Valley Agricultural Users; Bay/Delta water quality problems arise; storage drawn down by releases	Draw-down of aquifer storage; little or no natural recharge; imports less available for recharge; over-drafts begin	Recharge programs end; overdrafts, deeper wells needed; higher power costs
<u>Phase 3</u> Long-term drought	Reduced, less ground-water recharge	Cutbacks in deliveries to extent needed to supply Calif. Higher pumping costs as hydropower generation is curtailed	Reductions in deliveries only after CAP cutoff; reductions shared per Secretary of Interior's discretion Salinity may be so great water is unusable for irrigation		Marked cutbacks in supply as pumping is curtailed	Further reductions of deliveries; runoff fails to replenish storage	Serious overdrafts; all imports needed for direct supply of con-sumers; saltwater intrusion; production cutbacks; infiltration of contaminant plumes; crop and livestock losses	Damage from overdrafts (subsidence, aquifer collapse, etc.)

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CHAPTER 6

COPING WITH FUTURE DROUGHTS IN SOUTHERN CALIFORNIA AND ARIZONA

Options for Improving Drought Protection

The natural phenomenon of drought exposes the limits of any water supply system; performance in drought tests its weak points. Accordingly, every water decision affects the system's performance in a drought. In virtually all water supply decisions, decisionmakers have four kinds of options:

1. Expand supplies. The study area has historically emphasized this option. Because nearly all the obvious sources potentially available to the study area have been tapped, however, we assume that this option is limited in the foreseeable future. Of course, several new sources of water are theoretically available, though they strain technological and economic feasibility. Large scale desalination of sea water and schemes to import water from distant watersheds (Columbia River, Yukon River, Great Lakes) and cloud seeding all have been discussed. In any event, development of major new sources is not now planned and could not be realized in time to respond to a drought in the next two decades.

2. Manage supplies. Better management of existing supplies requires planning and technology to decide how best to distribute and use seasonal supplies and present facilities. Considerable effort is being made in the study area to improve water management. In many cases, these options are the least costly and most politically feasible choices, though they may have legal or institutional limits.

3. Reallocate supplies. Exchanges and marketing of water rights could reallocate existing supplies from agriculture, Indians and other states to meet growing water demand in the study area. The respective rights of states, basins, and users under compacts, court decisions and statutes do not depend on who makes the most economically efficient uses or, in some cases, even whether the rights holder makes any present uses of water. There is an enormous quantity of water being used in the study area, mostly in agriculture; municipalities now may have to curtail uses in shortages to respect the legal rights of agricultural users, whose uses may be less "efficient" or "productive." Some states and Indian tribes hold unused or underutilized rights. Reallocation of these rights is therefore justified economically but implicates complex existing legal arrangements and important equities that must be considered.

4. Limit demand. The amount of water required to satisfy future needs can be controlled by reducing demand. Reducing per capita demand, requires conservation measures. The potential is enormous and water suppliers in the area have started programs aimed at this goal. Water management techniques can be improved at the system level and at the user level. In addition, physical changes may be necessary, such as construction of facilities to treat wastewater for reuse.

Another approach is to find ways to satisfy the ultimate objectives of water demands in ways that require less water or no water. Thus, aesthetics can be maintained with much less water if native plantings, not bluegrass lawns are used. Dry-land farms can sustain some rural communities without irrigation. Economic growth can be based on educational or technological investment instead of water intensive industries.

A virtually unexplored form of demand reduction in the area is limitation of future population growth. Though now politically sensitive, this option necessarily must be weighed with all the others. There are good reasons, in addition to the limits on water supply, to consider growth control.

Drought protection measures, and solutions to other water problems, can employ some combination of the above options. Their adequacy can be tested by projecting their performance in drought. Every response is effectively a choice of what level of risk of damage and dislocation from drought is acceptable.

Recommendations for the Study Area

It is beyond the scope of this report to prescribe the mix of options that should be chosen from those set out above. Choices depend on economic and political judgments that should be made by those most affected by the decisions. Wise decisions can result in prolonging the ability of the study area to withstand drought. Or they may concede the necessity of taking a greater risk of drought effects. And the outcome of the process is essential to deciding whether and to what extent additional growth can occur within acceptable limits of risk. Inevitably, these decisions determine the quality of life that the region's population will enjoy.

The greatest strength of the study area's water system, its resilience in drought, comes from two sources: immense groundwater reserves, stored naturally and enhanced by recharge efforts and imported water from the California State Water Project, and the Colorado River with its great mainstem reservoirs. Given the nature of these sources, the degree of future vulnerability to drought depends on:

- the amount of water in storage in reservoirs and groundwater at the onset of a drought
- water quality control -- salinity in the Colorado River, saltwater intrusion and toxic pollutants in Southern California coastal plain wells, saltwater intrusion in the Bay-Delta
- level of demand and depletion of storage during non-drought periods
- perceptions of inequity to other areas (Northern California and Colorado River upper basin states)
- uncertainties caused by legal priorities of farmers and Indian tribes

Continued drought protection for the growing study area requires special attention to these limitations on the system's resilience.

The following measures are highlighted for special consideration by decision-making institutions and individuals in the region because they can be effected with reasonably little expense and in a reasonably short time. Some are generally applicable to any area concerned with drought protection; all are related to the situation of the study area.

1. Improved Drought Planning.

Governments in the area must design comprehensive new planning processes that identify alternatives for meeting society's many objectives that depend on water use.

Traditionally, the purpose of water planning, including drought planning, has been narrowly focused on providing a certain level of water supply. Successful water planning now depends on a more comprehensive approach that begins by identifying society's objectives and then analyzes alternative uses of water resources in accomplishing those objectives.

Social and economic objectives implicated by the use of water resources include economic production, equity between regions and people, efficiency, promotion of the family farm, preservation of natural ecological systems, recreation, lifestyle, aesthetics and so on. These objectives have different values for different constituencies, each of which has a claim to be heard in the decisionmaking process.

Water shortages are only a problem because they cause disappointment of expectations that various objectives will be satisfied. There is economic dislocation in a drought if crops die and farmers (and their communities) suffer financial losses. Aesthetic and lifestyle values are damaged if people have an objective of rich, green Kentucky bluegrass lawns. But the economic and lifestyle objectives may also be satisfied with far less water if, in advance of a drought, alternative ways to reach the same objectives are accepted. Farmers may plant less water-intensive crops. Or they may sell their land and water as other economic activities replace farming. Natural landscaping may be substituted for bluegrass. Policies that lead consciously to these ends are drought-related policies.

Legal and institutional arrangements for allocating water are a major part of an overall "plan" for responding to demands. These arrangements are intended to accomplish certain objectives. For instance, interstate compacts allocating water are designed to promote equity among the states. Presumably, equity requires delivering a quantity of water to particular states. But if facts change -- such as in a major drought -- equity may be achieved by other means. Thus, the lower Colorado River basin states may decide to negotiate an agreement to compensate upper basin states or Indian tribes for release of a portion of their apportionment or a promise to retire some uses or lease some undeveloped rights.

Planners should identify the basis for water demand: what objectives people want to accomplish with water. They then should present decisionmakers with alternatives that can satisfy the public's objectives. The planning process should identify the economic, social and environmental consequences of each alternative with respect to society's diverse objectives. Decisions then can be made by the representatives of an informed public. Some changes may require legal measures including legislation and negotiated agreements.

The first step in dealing with drought, then, is to review, revise and expand the scope of water planning processes. These processes at the state, federal, basin and local levels must deal with the broadest possible range of alternatives available to decisionmakers.

Comprehensive water planning includes setting levels of acceptable risks of shortage and recognizing commensurate limits on both per capita use and on the numbers of consumers who can be served by a system. Although limited natural water supply is the most vivid of physical realities of western life, some decisionmakers treat drought as an extraordinary event. Responses to drought are typically temporary; conservation and sharing are accepted as occasional hardships that will cease as soon as it rains. Drought plans are often no more than exercises in disaster management. But planning for drought should consider all parts of the system as tools for forestalling and minimizing the effects of a major drought.

Inherent in every water plan or decision are choices of acceptable risks of exposure to drought. Every choice to allow demand to increase and consume more of a fixed supply is a decision to reduce drought protection. Drought planning should project the levels of risk that exist at various levels of demand assuming hypothetical droughts of various historical frequency in the region.

Water suppliers and management experts should use comprehensive modeling exercises to determine the system's vulnerability to drought. A computer model could quantify and predict the consequences of climatological events of different magnitudes and durations. A model capable of integrating these factors would allow water managers and policy makers to assess the effects of variables on system operations and to determine and manage the risks of drought. It would be an important tool for evaluating options for forestalling drought such as reallocating existing supplies among existing users, controlling demand or expanding supplies. In addition, it could be used to identify and quantify, where possible, the economic and non-economic effects of droughts and not only on water supply but on power generation, fish and wildlife, recreation, range, forests, and other environmental resources. Drought-modeling is an important way to demonstrate the stresses on the system that are created by continual growth in the study area.

A model could also express a "drought risk factor" at various demand levels for the system or for certain parts of it. The factor would indicate the probability that annual supplies would be inadequate to meet demand. Planners can use this information to determine the number of people who can be served at specified levels of per capita demand with what degree of risk. Policy decisions must then be made about the level of acceptable risk, whether and how to reallocate present supplies, allowable per capita demand and how to control it, alternative ways to accomplish the objectives of society, and the maximum number of people to be served.

Drought planning should consider the types and intensity of damage to natural systems that will occur at various levels of reduced supply. There has been no evaluation of the consequences of a severe, sustained drought to natural systems in the study area. Harm will be measured in economic and non-economic terms; some harm will be essentially irreparable. Policy makers need to consider this information in deciding whether to seek less water-dependent alternatives for achieving social and economic goals and in determining how much new growth in consumptive demand is tolerable to society. Furthermore, they need to design measures to protect natural systems against unacceptable levels of harm. The nature and extent of harm from various magnitudes of projected drought have not been identified and therefore the tradeoffs are unknown. Impacts on natural systems have been considered in the context of a few individual proposed actions or projects or in reports on episodic droughts that come within the impact assessment requirements of federal or state laws, and such impact analyses would be desireable on a watershed or regional basis.

Decisionmakers (particularly state and federal governments since this is beyond the mission of water suppliers) should: 1) identify a baseline below which depletion of streams, lakes and groundwater is unacceptable; this would be included in any modeling exercise that is used to determine when the system will be at risk from drought;

and 2) develop programs to achieve the desired levels of protection for natural systems, such as purchases of senior rights, schedules of reservoir releases and restrictions on transfers.

There are now no effective protections for fish, wildlife, recreational uses or environmental resources and values during a drought. Though some impacts are inevitable many can be greatly aggravated by water management decisions in times of shortages. There are virtually no legal requirements that any basic flow or quantity be supplied to streams, lakes and wetlands in the study area. Only some federal reserved rights and relatively insignificant state-protected instream flow rights are senior enough to furnish any protection against total depletion of waterways by diversions for consumptive uses.

There is some incidental protection of flows and the natural resources dependent on them provided by legal requirements that allow a downstream senior user or a downstream state with compact rights to "call" water past other potential diverters. The effectiveness of this incidental protection for natural systems has not been evaluated to see how adequate it would be in case of various degrees of drought. The protection furnished by such calls may depend on state government decisions about whether to allow consumptive water rights to be transferred to another place on a stream and by plans identifying the specific sources of water (i.e., which tributaries and which junior rights will be used) to meet interstate compact calls for water.

2. Groundwater Management.

The ability of the study area to cushion the impacts of drought depends on the amounts of water that are in aquifer storage. Groundwater should be seen first as insurance against shortages -- an emergency supply of water to be conjunctively planned and managed with all other supplies. The effects of drought will certainly be felt sooner and with greater severity if groundwater supplies have been depleted by ordinary demands or by an earlier drought event. Regular overdrafts can leave the area with little drought protection, prolong the recovery period from a drought and cause contamination and permanent aquifer damage.

Storage of groundwater should be a high priority use for any water in excess of essential water demands. Overdrafts should be strictly avoided. Arizona's Groundwater Management Act expresses such a policy, though a long time is allowed for conforming practice to policy and full compliance appears impossible. Innovative programs for groundwater recharge and storage should be pursued; recent efforts of the Metropolitan Water District of Southern California and Arizona municipalities are models. Storage of imported water, such as from the CAP, is an expensive but prudent decision. It could be made more attractive by imposing a pump tax on groundwater users, thereby making pumping costs more comparable to the price of CAP water. Credits against the tax could be allowed to rechargers.

3. Optimizing Colorado River Reservoir Management.

Depletion of Colorado River reservoir storage in a drought triggers a chain reaction of negative impacts and should be minimized. Mainstem reservoirs are adequate for all but the severest droughts. The point at which they become inadequate is a function not only of weather but of prior years' management and levels of demand. Because of the serious dislocations that will be felt within and without the basin as reservoirs are emptied, policies for reservoir operation should lead to optimizing storage to meet future drought needs so far as satisfaction of present needs permits.

Reservoir depletion shifts a burden of risk to CAP users -- farmers, then municipal users -- who will be relegated to overdrafting groundwater if the lower basin deliveries are curtailed. At the point that inadequate water is left in storage to satisfy lower basin and Mexican Treaty delivery requirements, many users in the upper basin states are at the mercy of annual runoff, limiting consumption to the "present perfected rights" that existed as of the 1920's. The apparent inequity of this situation could spark political repercussions. In the most extreme cases cutbacks are felt by Southern California users and by other agricultural interests in Arizona. As these effects occur, greater reliance will be placed on Northern California sources, themselves in short supply in a drought.

Plans should be devised for shifting uses to other sources of water as Colorado River reservoirs are drawn down. Contingency plans should elevate the importance of preserving water in storage as reservoir levels drop. This means revising operational regimes that are now driven strongly by hydropower production to patterns that will preserve storage while accomplishing other important natural resource management goals such as conservation of fish, wildlife and recreation. Of course, the economic consequences of restricting hydropower generation should be evaluated and weighed in decisions.

Although huge quantities of water can be stored in the Colorado River reservoirs, managers in all states that depend on them (and the Department of the Interior as operator of most of the facilities) should jointly decide on appropriate goals for conserving those supplies for drought protection. Those goals can be met only if the basin states exercise restraint in consuming water from the river even in times of normal flows.

4. Coordination Among Colorado River Basin States.

The water supplied by and stored in the Colorado River system is vital to drought protection in the study area. The law of the river is therefore the source of much of the area's water security. A sound working relationship among all the basin states can prevent misunderstandings and minimize the need for outside political intervention. Salinity control efforts are a model for basin cooperation that should be expanded to deal with broader issues.

A Colorado River basin-wide organization should be formed to make plans and decisions concerning drought and other common interests of the basin states. A regularly convened body could deal directly with drought management and planning. It could take responsibility for broad issues of common concern to basin states, all of which are related to the ability to deal with drought. The issues to be addressed might include operation of reservoirs, hydroelectric power production, salinity control, other water quality issues, flood control, recreational concerns, protection of environmental resources, endangered species problems, Indian water rights, interstate water marketing proposals, water project development and conservation, compact interpretation and dispute resolution, Mexican Treaty compliance and identification of alternatives for meeting the full array of objectives sought by the basin states. Such an organization is best created by federal legislation designed with participation of the basin states. An excellent model is the Northwest Power Planning Council in which the states of the Northwest (Washington, Oregon, Idaho), affected Indian tribes and the federal government make decisions jointly concerning the Columbia

River, its dams, hydropower facilities, fisheries, Indian issues, power conservation and environmental standards.

5. Transfers and Marketing.

Firm water supplies that may be vital to surviving a drought can be assured through economically beneficial contractual arrangements. Drought protection -- and larger, dependable long-range supplies -- for the growing population of the study area can be secured by agreements using existing water supplies more fully and efficiently. Agreements, with appropriate payments and other concessions, can reallocate unused or underutilized rights permanently or temporarily.

Water salvage and reuse schemes can be pursued. Other marketing arrangements, like MWD's agreement to install conservation measures in the Imperial Irrigation District in return for the water saved, could be pursued. Urban areas can tremendously increase the supply of available water by reusing treated sewage effluent, a source of water which has only begun to be tapped.

Exchange agreements can allow more flexible use of existing water resources. For instance, by contracting for seasonal use of its State Water Project water with Central Valley Project participants, Southern California can gain rights to use more SWP water at times when CVP users have excess water available from that source.

Agreements for use of agricultural water can increase drought protection for urban areas without permanently impairing agricultural production. Throughout the study area agriculture is the largest water user with the best rights, especially to Colorado River water. Arizona and California municipal users can pursue dry year leases and other marketing arrangements that would give them the use of some of this agricultural water when contingencies of shortage arise. For instance, Arizona CAP users -- particularly cities -- could negotiate for rights to use Colorado River water during a drought that are now used by mainstem agricultural rights holders. The water could easily be delivered to them through the CAP facilities.

Permanent transfers also can be made without destroying agricultural uses. Because of the small quantities of water needed by cities relative to the quantities consumed by agriculture, major impacts on agricultural production are not necessary. Furthermore, many California counties actually showed increases in agricultural income during the 1976-1977 drought as a result of crop changes, more careful use of water and elimination of over-irrigation.

Policy makers should carefully consider the effects on agricultural economies and communities if they decide to expand municipal populations on water obtained from agriculture.

Agreements with upper basin states could make present Colorado River supplies more reliable in the lower basin. The upper basin has a legal right to develop and use considerably greater quantities of water, though demand is now low. As demand grows less surplus water will be available to the lower basin and mainstem reservoirs will be deprived of some of the water that now goes into storage. Agreements could assure that some of this water is not developed for a term of years. Indeed, much of the upper basin consumption is in very low value agriculture and it would be possible to discontinue such uses upon payments and other concessions by lower basin states.

The salinity problem could also be ameliorated by entering into arrangements economically beneficial to upper basin interests so as to delay future development or retire certain existing uses (such as low-valued farms that contribute high salt loads). These agreements need not result in abrogation of present compacts, though the states may ultimately decide that temporary departures from their terms or even re-negotiation of certain aspects of the compacts is desirable. Again, a means should be devised to evaluate the equitable and economic effects of such arrangements.

Urban water users can negotiate agreements with Indian tribes that have presently unused rights to ensure that the water subject to those rights continues to be available to the cities. A variety of arrangements for sale, lease or exchange are possible. For instance, a tribe could agree not to develop a portion of its reserved water rights, thereby securing the reliability of water presently used in Arizona and California. The agreement might be in exchange for money payments or other incentives (e.g., economic development, reservation improvements, public facilities, etc.). Tribal rights, being both very senior in the state priority systems and "present perfected rights" with an absolute priority under the Compact, are especially valuable.

6. Demand Limitations.

Reduced demand, like a source of supply, can furnish drought protection. If less water is consumed more can be stored in reservoirs and aquifers. Policy makers can choose whether to use demand reduction as a way of maintaining a margin of safety for drought or of freeing up water for new growth. Arizona's groundwater law has recently targeted the need to reduce per capita demand and municipalities in California have turned to water conservation programs. Limits on population growth still have not been confronted.

Governments in the study area traditionally have assumed that neither population growth nor per capita demand are subject to limitation. But Southern California and Arizona are simply growing too fast for the existing drought protection to last long; other systems -- air, water quality, transportation, education -- are showing even greater stress than water supply.

Unless adequate new sources are found or there are major reallocations to meet the demands of new growth, restraints on growth appear necessary. A decision not to restrain growth in demand is effectively a decision to increase the exposure of the area to the effects of a drought, to impinge on or alter the quality of life, or both. It narrows the present margin of drought protection and commits the area to more frequent and more serious drought disasters as well as a panoply of other growth-induced problems.

Land use controls can be employed to curb growth in Southern California and Arizona. At a minimum, subdivision approval could be made contingent on acquisition and dedication to a regional water supplier of water sources sufficient to serve the subdivision (such as purchasing rights of an existing agricultural user). Arizona requires new developments in designated "active management areas" for groundwater to demonstrate that they have an adequate source of water. Such requirements must be refined to ensure that only the same quantity of water that was actually consumed in prior uses (i.e., net of return flow) is counted as available for new consumptive demands. Furthermore, since the retirement of agriculture usually means major social and economic changes for rural communities, there should be a way of considering these impacts. Such transfers are essentially policy decisions deserving high level consideration and broad public participation; more than a buyer and a seller are involved.

Land use planning can also be used to prevent, limit, and guide growth away from certain areas and into others. For instance, a major city might decide to revamp existing neighborhoods, opting for high-rise residences instead of single family homes. Besides addressing problems of inadequate affordable housing and transportation difficulties inherent in urban sprawl, high-rise buildings could enable twice as many people to survive on the same water supply because each family would not require water for outdoor use. Land use regulation also can limit yard size and types of plantings to curtail demand.

Water conservation is a high priority for water suppliers and government at all levels. Arizona's Ground water Act is an example of a legislated demand reduction program. Conservation is also becoming a more significant element in the programs of the Metropolitan Water District and other suppliers. Ambitious targets for reducing demand require not only the technical expertise of water managers but considerable political will. They must be ambitiously conceived and vigorously enforced. The public's support must be enlisted through aggressive public education programs. An open, comprehensive drought-planning effort would itself be an exercise in public education.

State and federal governments can adopt agricultural water efficiency programs. Agencies can educate farmers about low cost techniques for reducing their water demand and provide incentives for them to adopt such methods. Incentives could include tying present federal and state subsidies and tax breaks to major reductions in demand. Other measures could include taxes on water consumed, per acre-foot depletion charges and escalating charges for water use based on level of demand.

California has taken steps to remove barriers to transferring agricultural water to high value uses. For instance, water efficiency techniques can be financed for farmers by municipalities who need the saved water.

Major use restrictions, especially on outdoor urban water use, prolong supplies and delay the negative effects of drought. Some new growth can be accommodated without increasing drought risk if urban irrigation or ornamental plants and lawns is reduced. Because watering lawns and plants constitutes the largest segment of non-agricultural water consumption, outdoor water use is an obvious target for reduction. Furthermore, almost all the early damage from a severe, sustained drought in the study area will be to landscaping. Thus drought damage can be contained by curbing the water demand created by outdoor plantings. Requiring xeriscape plantings around public buildings, at parks and schools, and in new residential and commercial developments can lower demand substantially. Incentives may be necessary to induce homeowners to re-landscape with drought resistant plantings.

Water pricing is the most effective means of reducing urban demand. Graduated block rate structures are a disincentive to high water demand. They can lead water users to reduce their per capita water demand permanently.

Conclusion

This report concludes that Arizona and Southern California could now weather a severe, sustained drought without serious dislocations or economic damage. The area is served by legal institutions and water supply facilities conceived earlier in the century which give them ample drought protection. But the optimistic conclusion should be viewed with caution. First, it is based on present levels of demand. Second, it is limited to the study area, not extending to the areas where imported water sources originate. Thus, there is no analysis of the effects on areas such as the Upper Colorado River Basin. Finally, the study does not attempt to identify harm to the many uses (e.g., timber, grazing, skiing, boating, other recreational uses, fish and wildlife) that would be affected besides irrigation, municipal and industrial purposes. All three of these issues merit attention.

There is reason to believe that Arizona and Southern California will continue to experience high rates of population and economic growth. Therefore, major drought preparation and planning in relation to growth is necessary. In the short run, growth in demand can be absorbed by elimination of inefficiencies in the water supply system through improved management and by minor reallocations of the right to use water. Conservation and re-use programs have already begun. These measures can bridge the time needed to plan for the future beyond the next few years.

Planning is no longer synonymous with a search for more water. The most readily available water for the study area is now legally allocated to others, primarily agricultural users. It can be reallocated, but not without important economic and social effects. Reallocations of developed water by agreements allowing municipal use of agricultural water are occurring now. Decisions about the future of agriculture and of rural communities in the region will be made in the context of these water transactions. Opportunities exist for transfers from other states and regions and from Indian tribes. The value of water in municipal uses is so high, relative to present uses (or nonuses) by those with rights, that transfers are likely. These transfers, however, implicitly make "decisions" about the areas from which water originates. Because the study area's water planning implicates the quality of life in much of the West, the interests of others should be consciously considered and accounted for in these transactions. If they are not treated equitably there could be a call for fundamental changes in prevailing laws and institutions.

Studying institutional responses to drought in Southern California and Arizona leads inexorably to the question: how much more demand will they tolerate? If decisionmakers are to maintain protection against drought and obtain major quantities of water in transactions that reallocate existing entitlements, they must have a clearer idea of future demand levels. Those figures depend on vital, difficult decisions being made.

The ultimate water demand of the area can be fixed in a number of ways: the maximum sustainable level of population and economic activity; a level that will allow a decent quality of life for a moderately increased population; no growth; or growth restrained only at the point of catastrophe. Choosing a maximum demand (or not doing so) is terribly important to people within and without the study area. At a most basic level, water managers need to determine whether and when to seek reallocations of agricultural water to municipal and industrial purposes. But the maximum tolerable drought demand must itself be set after contemplating factors that go beyond water supply and demand.

The area has reasons for reaching a decision on a "carrying capacity". Water is but one factor among many in defining the future of the area and it should not be considered in isolation. Of course, choices about the kind of society a region will and should support are driven by much more than concerns for a reliable water supply. For the study area, the scope of these "equality of life" choices is virtually unlimited. In the long run, the area must confront the question of what it aspires to be: the mix of economic uses, the degree of urbanization, the level of environmental quality, and more. These questions should be addressed in the process of determining future water demands and supplies.

Concern for drought preparedness may help provoke discussion of these issues. Hypothesizing a drought can help identify consequences and trade-offs of a variety of options. It follows that, because decisions in this realm touch all aspects of life, they should be made with the benefit of public views and expert evaluation. The decisions themselves should be made by accountable public officials based on all the available information.

In sum, there is no imminent drought crisis in Southern California or Arizona. The plumbing systems and water institutions are capable of coping with the consequences of a severe, sustained drought. Agriculture can survive, but must transfer water to the cities if they are to continue growing. There would surely be adverse consequences for the Upper Colorado River Basin and Northern California, where water for Southern California and Arizona originate. These areas of origin face economic impacts and environmental harm. Eventually, there would be environmental and lifestyle consequences within the study area and resulting social and economic reverberations. Present laws and institutions for allocating, reallocating and administering water rights do not integrate all these concerns and consequences. Although there is no water supply crisis on the horizon, the area could face a crisis in the use of its political and legal institutions. If water decisionmaking is, as in the past, seen as simply a narrow device for securing enough water for whatever demands may exist, the interregional, secondary and environmental issues will fester until they become enormous. Ultimately there may be a backlash against institutions that single mindedly provide water but ignore the effects within and without the region. Major legal and political reordering could result. To avoid such a breakdown, the debate must be broadened to consider these other interests and to seek alternatives to allowing undisciplined growth in demand.

ENDNOTES

1. These figures are for most of the region. Locally, some isolated mountain areas receive up to 40 inches a year, but this is atypical. (Arizona Water Comm'n, p. 3, 1975; State of Cal. DWR Bulletin 160-83, p. 8, 1983.)

2. Between 1985 and 1989, the population of the Metropolitan Water District service area in Southern California increased by 1,427,000, or 11 percent (MWD Analysis, 1989). Arizona's growth rate is even greater: the Phoenix metropolitan area grew 3.6 percent every year, or almost half a million people over the period from 1980 to 1987 (U.S. Dep't of Commerce, 1989).

3. Data from the tree ring studies furnish scenarios to illustrate the physical and legal arrangements for allocating and distributing water within the study area. See Kendall and Dracup (1990). This type of exercise could be expanded to determine what types of alterations, physical and institutional, would optimize the use of resources in light of existing or projected demand and value choices of people in the area.

4. The lowest average 10 year average flows for the Colorado River occurred from 1584-1593, 9.71 million acre-feet per year. The lowest 10 year average flows for northern California were 1624-1634, 13.45 million acre-feet per year. (Stockton, Meko and Boggess, 1989.)

5. This figure is based on tree ring studies covering a 400-year period (Stockton and Jacoby, 1976). Virgin flows based on records since 1922 show an average of 14.4 million acre-feet (Upper Colorado River Commission, 1988).

6. The Compact promises that the upper basin states will not deplete flows at Lee Ferry below 75 million acre-feet in any ten consecutive years. See Colorado River Compact, Article III(d).

7. Article III(b). The usual interpretation of this provision is that the lower basin can use waters of the Gila River, a tributary, in addition to Lee Ferry releases. A less credible interpretation is that further releases will be allowed at Lee Ferry. But even if this argument is accepted, releases presumably would be contingent on the availability of surplus water, a condition that exists when reservoir storage is high after full satisfaction of upper basin demands up to 7.5 million acre-feet. To forego storage for the sake of "surplus" releases any time reservoir levels are low or declining would be inconsistent with compact provisions assuring protection for future basic deliveries to the lower basin states that may depend on storage.

8. The provision assured existing users that they would not be limited by the allocation scheme. Lower basin users of present perfected rights, however, were relegated to the water available in the reservoirs. This gives holders of upper basin "present perfected rights" an important priority in times of shortages (See Article VIII).

9. There is disagreement on a number of points under the Compact, including how much of the evaporation and transportation losses (about 2 million acre-feet a year) should be borne by each basin. As a result, these figures would not be readily conceded by all parties to the Compact (Getches, 1985).

10. The percentage shares are: Colorado, 51.75%; Utah, 23%; Wyoming, 14%; New Mexico, 11.25%; Arizona (which has a small area draining into the river above Lee Ferry), 50,000 acre-feet (Upper Colorado River Basin Compact, 1949).

11. Arizona was using about 4.8 million acre-feet of groundwater a year. Annual aquifer recharge of 2.6 million acre-feet, including artificial recharge from return flows and 300,000 acre-feet of natural recharge from precipitation, resulted in a yearly overdraft of 2.2 million acre-feet.

12. The city and county of San Diego have assigned their rights to MWD.

13. In the 1983 decision, the Court rejected the tribes' arguments that they had been inadequately represented by the United States and that the government had erroneously failed to claim irrigable acreage on the tribes' behalf. This ruling denied the tribes' claim to about 317,000 additional acre-feet which a Special Master had recommended be awarded to them. The Court cited a "strong interest in finality" in determinations of western water rights and rejected the expanded Indian claims. Presumably this judicial policy will guide the courts if the five Colorado River tribes seek additional water in the future and if other tribes seek to reopen determinations on their reserved water rights in other situations. See, e.g., Nevada v. United States, 1983. Thus, to the extent that Indian water rights have been quantified, the maximum demands these tribes will be able to make on the Colorado River are fixed.

14. For instance, one extreme estimate of the claims of the largest reservation in the watershed, the Navajo Reservation, which is located mostly in Arizona, is 15 million acre-feet, considerably more than Arizona's total share of 2.8 million acre-feet. WSWC/WGA, p. 26, 1984. Other estimates for Navajo are more realistic, but all are large. See Back and Taylor, p. 74, 1980 (court might award 2 million acre-feet based on practicably irrigable acreage formula); Getches, p. 439, 1985 (formula would probably yield more limited quantities than Back and Taylor estimate, though still large amounts).

15. Since 1896 there have been 23 years when the virgin flow was inadequate to meet the aggregate demand of: 1) the average annual lower basin entitlement (7.5 MAF); 2) the Mexican Treaty obligation from the upper basin (.75 MAF); and 3) present upper basin demand (3.5 MAF), which total 11.75 MAF. Without storage, lower basin uses also would have been reduced in some of those years. Indeed, fluctuations in annual flow are so wide that there have been five years in which estimated virgin flows at Lee Ferry were less than the amount needed to supply the 8.25 million acre-feet average delivery to the lower basin (for its entitlement plus the annual Mexican treaty obligation), which theoretically would have left no water for consumptive uses by the upper basin in those years. (Upper Colorado River Commission, pp. 22-23, 1988).

16. Lower basin reservoirs account for losses of 599,000 acre-feet and upper basin reservoirs account for 1,120,000 acre-feet a year (U.S. Department of the Interior, 1976-1980 at 34). These estimates are based on reservoir levels for a particular period and presently applicable operating criteria. Reservoirs at lower levels expose less surface area and consequently evaporate somewhat less water; at higher levels, more water evaporates.

17. For example, the Colorado River Storage Project Act gives the Secretary power to determine the acreage for which individual landowners can receive water from certain projects. Likewise, under the Boulder Canyon Project Act, the Secretary can contract for storage and delivery of water from Lake Mead under regulations that he prescribes. He can also use his discretion in regulating use of the Hoover Dam power generating facilities. See also Boulder Canyon Project Adjustment Act and Colorado River Basin Salinity Control Act.

18. The criteria interpret and apply the requirements of the Colorado River Basin Project Act. The criteria also refer to "all applicable laws and other relevant factors." Although this presumably incorporates the National Environmental Policy Act (NEPA), the Secretary has never prepared an Environmental Impact Statement pursuant to that Act. This is largely because the criteria (though not all the annual operating plans) were adopted before Congress passed NEPA in 1969. The requirement would surely apply to new criteria. In 1989, the Secretary decided that he would prepare an impact statement analyzing the environmental impacts of current operating criteria of the Glen Canyon Dam of the Colorado River Storage Project and possible changes in these criteria (U.S. Dep't of Interior, 1989).

19. Many Owens Valley farmers claimed that the City of Los Angeles paid less than fair market value for their lands. While the City has always denied such assertions, there is no question that Los Angeles often bought parcels in a checkerboard pattern, leaving some hold-out farmers with less valuable acreage surrounded by de-watered plots.

20. Inyo County, where Owens Valley lies, sued the City claiming that its pumping violated the California Environmental Quality Act by threatening plants and wildlife and that it constituted a wasteful use of water. The litigation has raged for years. (County of Inyo v. City of Los Angeles, 1973, 1976, 1977, 1981, 1984).

21. The court held that a downstream riparian could command the entire flow of a stream to flood-irrigate riparian pastureland, thus preventing the development of an upstream appropriator's power project (Herminghaus v. Southern California Edison Co., 1926).

22. Like riparian rights, rights gained by appropriation prior to passage of the Act and continuously exercised are not subject to permitting requirements and are limited by the reasonable and beneficial use standard. All rights are presumably subject to the public trust doctrine.

23. The City of Los Angeles largely avoided the superior groundwater claims of landowners in the Owens Valley by purchasing their overlying lands, thus acquiring their extractive rights.

24. The United States Supreme Court upheld the Act's constitutionality in 1896 (Fallbrook irr. Dist. v. Bradley, 1896), and a year later it was modified by the Wright-Bridgeford Act (Wright Act; Wright-Bridgeford Act; Benson, pp. 383-90, 1982).

25. Throughout this report the Salt River-Gila River system is treated as separate from the Colorado River. The Gila River is actually within the watershed of the Colorado River. Arizona has steadfastly maintained that rights to use the waters of this tributary system were

not apportioned by the Colorado River Compact. The question has not been definitely decided by Arizona has always enjoyed the exclusive use of the Gila system. Further, the Colorado River Basin Project Act, and accordingly the Supreme Court in its interpretation of the Act in Arizona v. California (1963), did not include the Gila as part of the Colorado River for purposes of apportioning the river among lower basin states. The Court left open the question of whether the Gila was included in the compact apportionment but suggested that it logically could be included in the Compact and excluded from the Basin Project Act.

26. The Indian uses provided for by the CAP do not include the substantial amounts of water to which the Colorado River mainstem tribes are entitled. Usage of these rights now amounts to about 340,000 acre-feet which is to come from Arizona's apportionment. The state will presumably have to confront the question of how to allocate equivalent reductions as between CAP deliveries and deliveries to farmers in the western counties along the mainstem.

27. In addition, when one upper basin state has used in excess of its proportionate share in prior years, and a lower basin call is made, the overdrafting state must deliver to Lee Ferry an amount of water equal to its excess use before any other upper basin states are required to supply water to a lower basin call (Upper Colorado River Basin Compact, Article IV, 1949).

28. All evaporative losses are chargeable to the consumptive uses of the respective basin states in proportion to the quantities stored in each basin and therefore are included int he figures for the respective basins. Of course this reduces the amounts of water available for actual beneficial uses. It is also assumed that all Indian reserved rights can be satisfied from the deliveries attributable to the states in which their reservations are located. Finally, we assume that reservoir releases will not be influenced by power generating operations.

29. Present reservoir operating criteria call for releases from Glen Canyon Dam to equalize storage in Lake Powell and Lake Mead. It is assumed that the 15.6 million acre-feet in each basin is in "active storage," i.e., is capable of being released.

30. A similar calculation in Kneese and Bonem's interesting study resulted in a basin surplus of 1.5 million acre-feet at the end of the hypothetical ten-year low-flow period (Kneese and Bonem, pp. 103-106, 1986). The authors assumed 30 million acre-feet of water in storage. They also assumed an aggregate runoff for the period of 100 million acre-feet and the recorded low-flow period of 118 million acre-feet (1954-1963). They estimated higher upper basin uses (3.7 million acre-feet), however, than does this report. They caution that their study is based on very favorable assumptions and does "not reveal the tremendous conflicts that would occur among various interests and the stresses and strains that would be put on the region's water allocation institutions."

31. The operating criteria allow additional releases from Lake Mead for consumptive uses but the Secretary is to take into account several factors, including the upper basin's ability to meet compact obligation, actual forecasted storage and inflows to Mead and the upper basin reservoirs. These considerations would militate against additional releases in most years, especially in a progressive drought. See discussion of the operating criteria in Chapter 2.

32. Under the Mexican Treaty deliveries to Mexico can actually be reduced in proportion to reductions in consumptive uses in the U.S. if "an extraordinary drought or serious accident" makes it "difficult" for the full amount to be delivered.

33. "Present perfected rights" are not to be disturbed by the Compact allocation. See Article VIII. The Boulder Canyon Project Act also requires that the Secretary accommodate them in contracting for water from the river.

It is not clear exactly how much water is needed to satisfy "present perfected rights." The Supreme Court created an ambiguity when it is said in Arizona v. California (1963) that the term referred to rights perfected as of the effective date of the Act (1928) but the Act and Compact seem to refer to rights predating the Compact itself (1922). It appears that under either interpretation present perfected rights (exclusive of Indian reserved rights which probably should be included) amount to about 2 million acre-feet for the upper basin, 3 million acre-feet for California and something over 300,000 acre-feet for Arizona.

34. Assuming the treaty obligation has not been reduced which it can be in a serious drought. See note 32.

35. The Special Master in Arizona v. California, 1963, recommended that shortages be prorated according to the Act's apportionments (California, 4.4/7.5; Arizona, 2.8/7.5; Nevada, .3/7.5) but the Supreme Court held that the Secretary had discretion to effect any method of sharing the burden of shortages that serves project purposes (irrigation, flood control, navigation, regulation of flow, and generation and distribution of power) and which respects present perfected rights, Arizona v. California, 1963.