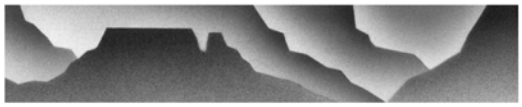
The Colorado:
A River at Risk

Coping with Drought in the Colorado River Basin

2005-2006

Produced by

GRAND CANYON TRUST



MISSION

The mission of the Grand Canyon Trust is to protect and restore the Colorado Plateau—its spectacular landscapes, flowing rivers, clean air, diversity of plants and animals, and areas of beauty and solitude.

VISION

We work toward a region where generations of people and all of nature can thrive in harmony. Our vision for the Colorado Plateau one hundred years from now is:

- A region still characterized by vast open spaces with restored, healthy ecosystems and habitat for all native plants and animals.
- A sustaining relationship between human communities and the natural environment.
- People living and visiting here who are willing and enthusiastic stewards of the region's natural resources and beauty.

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EXECUTIVE SUMMARY

The Colorado River, running 1,470 miles through the arid southwestern United States and Mexico, is the primary water source for the heavily populated region as well as the lifeblood of valuable and increasingly rare ecosystems. This critical river system, already overburdened by the demands of the fastest growing region in the United States, has completed five years of extreme drought. Water years 2000 to 2005 represent the driest five-year period in over 100 years of record keeping. Tree ring studies show that the Colorado River basin has experienced long-term dry periods regularly over the past centuries, prompting scientists to warn that weather patterns may not return to stable wet conditions any time soon.

The situation is further complicated by the fact that more water is allocated to users than the river is likely able to produce long-term. Yet no basin-wide plan exists for dealing with the impacts of multi-state drought. The core issue that must be addressed is how to provide adequate water supplies to a range of stakeholders, particularly if Lake Powell cannot deliver the steady, presumably guaranteed, annual flows it was built to deliver. One reason to develop a comprehensive drought plan is that the lower basin, which has the legal right to require the upper basin to send it water, may do so even when there isn't any water in storage. This report aims to inform discussion among stakeholders that will lead to a comprehensive plan for dealing with the drought before failing water supplies create political, legal and ecological crises in the watershed.

Policy-makers and other stakeholders from the basin states, with strong leadership from the United States Secretary of the Interior, need to confront the potential crises while there is still ample time to take reasoned, constructive steps. The short-term purpose for basin-wide drought planning is to address the looming water crisis and, in doing so, build economic growth considerations and environmental protection into the drought planning process. The long-term purpose for drought planning is to design a new system for sustainable Colorado River use that recognizes the needs of all stakeholders.

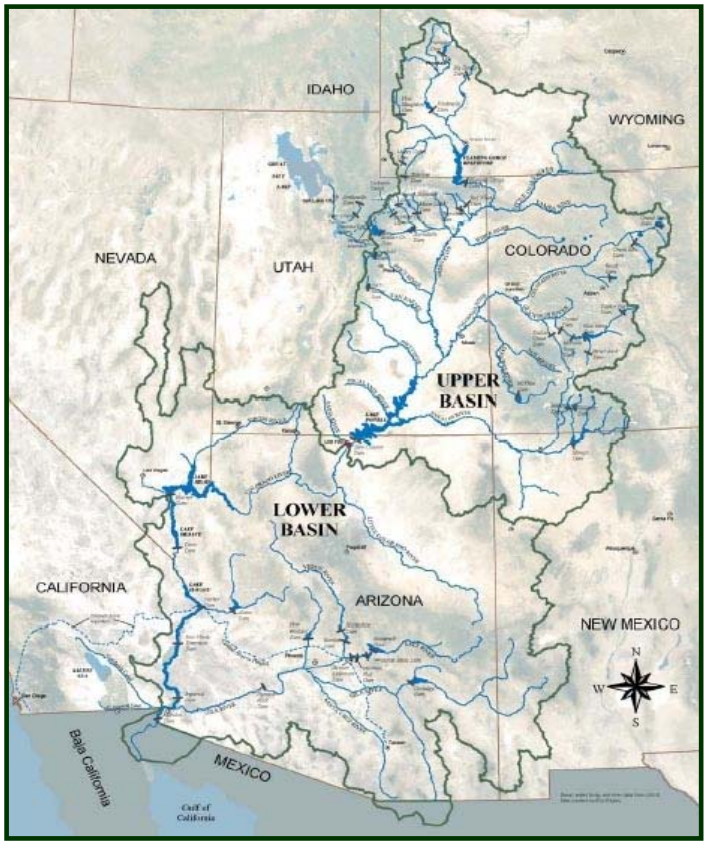
Any plan for sustainable management of the Colorado River must take into account the Law of the River, a tangled skein of laws, court decisions, regulations and other documents guiding the distribution and use of Colorado River water. The core of the Law of the River is the 1922 Colorado River Compact, which divides the assumed flow of the river between the upper and lower basins and acknowledges that Mexico has a claim to a portion of the river's flow. Subsequent laws and court cases further apportion the river among the states within each basin and dictate how and when the water should be delivered and used. Though some consider this legal edifice too complex and fundamental to change, in reality it is not carved in stone. The Law of the River has in fact been modified and amended over the years and it contains flexibilities that could present opportunities for improving overall management of the Colorado River.

With the river fully developed and the region suffering a severe and potentially long-term drought, it is time for a broad review of how Colorado River water is being used, and for

consideration of changes to the present system. The sooner the task is undertaken, the more likely effective solutions can be implemented, such as sales and exchanges among water users, developing conservation and sensible land use plans, creating underground storage facilities and encouraging interstate sales and banking options. Though many viable options for drought relief exist, weakening existing environmental protections is not one of them. Environmental laws provide a base level of protection for the already greatly altered environment of the Colorado River Basin. In fact, weakening such laws would not produce any meaningful additional supplies of water or significantly increase the ability of the water management system to cope with drought.

Regardless of whether the current drought continues for decades or ends tomorrow, the past five years have proven that basin users cannot expect to continue using the Colorado River as they have in the past. The basin states must learn to live within the means of their desert river.

CHAPTER ONE: THE RIVER AND THE LAWS THAT GOVERN ITS USE



The Colorado River originates in the high country of the southwest then flows for 1,470 miles through three major deserts and into Mexico where it historically emptied into the Gulf of California. Fed by dozens of tributaries along the way, the Colorado River drains a watershed of approximately 244,000 square miles.

The Colorado River basin has experienced explosive growth in the decades since the river's waters were divided among consumptive users in 1922. The basin's population has increased nearly nine-fold since that time, and in the foreseeable future demands for water delivery may well exceed river capacity.

More water is currently allocated for consumptive uses alone than the river produces. The over-allocation was not an issue until recently when the basin's growth began to look like it might overrun water supply, at least during the current drought and perhaps over the long-term.

See Appendix A for a detailed map of the Colorado River basin.

History

Just 70 years ago, before the twenty-four major dams and dozens of smaller reservoirs were built on the Colorado River and its tributaries, the entire river system supported vast, diverse ecosystems and a large suite of endemic species.

Today, the Colorado River system is the primary water source for seven arid, heavily populated western states, thirteen Native-American tribes, the Mexican delta, and for already threatened ecosystems such as cottonwood-willow forests, wetlands, dunes and estuaries.

These ecosystems represent some of the last remaining habitat on the continent for many species of reptiles, mammals, fish and birds.

A few of the endangered species that thrive in Colorado River habitats are the desert pupfish, the Yuma clapper rail, the California brown pelican, the jaguar and the vaquita, the world's smallest porpoise. The vaquita and other marine species live some stages of their lives in the estuary created by the freshwater of the Colorado where its current meets the tides of the sea.

Colorado River Compact

The drive to apportion the waters of the Colorado River was led by Herbert Hoover, then serving as the Secretary of Commerce under President Warren Harding. By the time Secretary Hoover and the representatives of the seven basin states met at Bishop's Lodge in Santa Fe, New Mexico on a November day in 1922 to negotiate the Colorado River Compact, the conflict over the Colorado River had already become acute.

Serious controversy over Colorado River water first sparked in the early 1900's, prompted by the struggle to control the wild river to benefit farmers in California's Imperial Valley. In 1901, an irrigation channel was cut from the Colorado to the Imperial Valley but the channel silted up in 1904 and again in 1905. New channels were cut, but then the Colorado flooded in each of the following three years. California's leaders began discussing the need for a dam to prevent flooding, to provide a steady flow of water even in dry years and to impound the tremendous abundance of silt the Colorado carries.

However, securing rights to significant portions of the water when California runoff contributes almost nothing to the Colorado proved to be a political problem. Arizona viewed the Colorado almost as a state resource since nearly half the river's length runs through Arizona; and Colorado had already tried laying claim to as much water from the Colorado River as originates from its runoff, almost half the flow of the river. In the end, the basin states were drawn to the negotiating table by California's potential to consume the river and the presumption that a dam potentially controlled by California would indeed be built, though Boulder Canyon Dam would not be officially authorized for six more years.

The result was the Colorado River Compact ("the Compact"), which defined the basin's "upper" and "lower" divisions in Article II (c): "The term 'States of the upper division' means the States of Colorado, New Mexico, Utah, and Wyoming" and in Article II (d) "The term 'States of the lower division' means the States of Arizona, California, and Nevada."

The Compact further defined the upper and lower basin in Article II (f) as: "The term 'Upper Basin' means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system

which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry. Article II (g) defines the lower basin as: “The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system, which are now or shall hereafter be beneficially served by waters diverted from the system below Lee Ferry.”

The Compact apportioned the first 15 million acre-feet (maf) of water equally between the two basins, and granted to the lower basin the right to increase its beneficial consumptive use by one million acre-feet in addition to its 7.5 maf allocation. It also makes a provision for any future water right for Mexico to be shared by the upper and lower the basin. The purpose of the compact was stated thus:

Secretary of Commerce, Herbert Hoover, 1922

“The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River system; to establish the relative importance of different beneficial uses of water; to promote interstate comity; to remove causes of present and future controversies and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods.”

The heart of the apportionment agreement is in Article III:

> “(a) There is hereby apportioned from the Colorado River system in perpetuity to the upper basin and to the lower basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.…
>
> “(d) The States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years reckoned in continuing progressive series beginning with the 1st day of October next succeeding the ratification of this compact.
>
> “(e) The States of the upper division shall not withhold water, and the States of the lower division shall not require the delivery of water, which cannot reasonably be applied to domestic and agricultural uses.”

The wording of the Compact gives priority for water deliveries to the lower basin via Article III, section (d). The Compact further gives the highest priority to the obligation to Mexico, stating that future rights to Mexico are to be made out of surpluses, but if surpluses are not available, “the burden of such deficiency shall be equally borne by the upper basin and the lower basin...”

The Compact further states, "In addition to the apportionment in paragraph (a) [7.5 maf], the Lower Basin is hereby given the right to increase its beneficial consumptive use of such waters by 1,000,000 acre-feet per annum." In a critical omission, however, the Compact did not anticipate shortages nor did it specify how water would be shared between the states within the basins.

See Appendix B for a copy of the 1922 Colorado River Compact

Further Defining and Clarifying the Compact

The Compact, at just five pages long, left a great deal of detail to be sorted out through subsequent legislation, litigation and policy decisions. Briefly, the most significant actions governing apportionment among the states in each basin and the priorities within each basin are:

The Boulder Canyon Project Act (1928) authorized the construction of Hoover dam and overrode Arizona's objection to the terms of the Compact. Arizona had been concerned that California would take the entire lower basin allocation, and had refused to participate with the other states in the agreement.

The Treaty with Mexico (1944) created a national obligation of the United States to deliver 1.5 million acre-feet to Mexico annually.

The Upper Colorado River Basin Compact (1948) defined consumptive use and allocated 50,000 acre-feet of annual consumptive use to Arizona from upper basin waters; and then proportioned the use of the remaining waters among the upper basin states by percentage. Colorado receives 51.75 percent; New Mexico receives 11.25 percent; Utah is allocated 23 percent; and Wyoming gets 14 percent.

No priorities were set for deliveries to be made to any one state over any other state and no court case has been filed concerning priority in the upper basin. But the 1948 compact established a commission to order curtailments of consumptive uses by upper basin states in the event of shortage as required to meet downstream deliveries. Any state that had exceeded its allocation in the previous ten years would have to deliver the aggregate of its overuse to Lee's Ferry in the year of a call by the lower basin.

The Colorado River Storage Project Act (1956) authorized the large upper basin storage reservoirs: Glen Canyon, Blue Mesa, Flaming Gorge, and Navajo.

The U.S. Supreme court decision in *Arizona v. California* (1963) found that the Boulder Canyon Project Act, and the contracts that the Secretary of Interior had entered into with the states pursuant to the Act, had effected allocations to Arizona of 2.8 million acre-feet; to California of 4.4 million acre-feet; and to Nevada of 300,000 acre-feet.

The Colorado River Basin Project Act (1968) authorized the construction of the Central Arizona Project (CAP) and specified priorities for deliveries in the lower basin. The Act gave California priority for receiving its entire 4.4 million acre-feet before any deliveries can be made to the Central Arizona Project, which delivers the greater portion (1.5 maf) of Arizona's allocation. In

exchange for getting the Central Arizona Project approved, Arizona agreed that CAP would have a lower priority to water than any of the existing users in California.

The Role of the Environment in The Law of the River

The Law of the River is not fixed and unchanging but rather has evolved, and continues to evolve, as changing circumstances, values and needs have prompted new legislation. By definition, any legislation that significantly affects the management of the river is part of the Law of the River.

While the early Law of the River was concerned primarily, if not exclusively, with the allocation and distribution of water for consumptive use, two more recent additions to the Law of the River bring environmental considerations into river management. The first, the Endangered Species Act of 1973, is a law of general applicability that affects the management of lands and waters across the United States. The second, the Grand Canyon Protection Act of 1992, is directed specifically at the Colorado River.

The Endangered Species Act

The Endangered Species Act (ESA) is one of the cornerstones of modern environmental law. Section 7 of the ESA requires all federal agencies to carry out programs for the conservation of threatened and endangered species, and to ensure that their actions do not jeopardize the continued existence of such species or damage their critical habitat. Section 9 of the Act prohibits the "taking" of a threatened or endangered species, where "taking" is broadly defined to include habitat modification that kills or injures wildlife.

Endangered American Bald Eagle

The ESA affects management of the Colorado River because the river is home – in some instances the only home – for several threatened or endangered species, including the humpback chub, the razorback sucker, and the Colorado River pike minnow. As a federal agency, the Bureau of Reclamation, which operates the major dams on the river, is subject to the conservation requirements of Section 7 as well as the "takings" prohibition of Section 9.

The Grand Canyon Protection Act

The Grand Canyon Protection Act (GCPA) was passed in 1992 in response to mounting evidence that the operation of Glen Canyon Dam was negatively affecting environmental and cultural resources in the Grand Canyon, which is just downstream of the dam. The dam eliminates spring floods, removes sediment from the river, and drastically lowers the river's temperature. Moreover, management of the dam to produce "peaking power" resulted in rapidly fluctuating river levels. These changes in the river's character have had devastating effects on fish populations, and have increased erosion, degraded beaches, and threatened archaeological sites.

Glen Canyon Dam

The GCPA requires the Secretary of the Interior to address these problems. It mandates that the dam be operated "under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use."

Understanding the Role of the Endangered Species Act and the Grand Canyon Protection Act in the Management of the Colorado River

As demands for consumptive use of Colorado River water have grown to outstrip the supply, there have been some calls for rolling back the requirements of the Endangered Species Act (ESA) and the Grand Canyon Protection Act (GCPA). These calls have arisen largely from a misunderstanding of the ways in which these two laws affect river management. While both laws have the potential to affect the way dams and reservoirs on the river are operated, they have little effect on the availability of water for consumptive use.

The simple fact behind the current concern over the availability of Colorado River water is that the physical flow of water *in* the river is likely to fall short of the demands for, and the legal allocations of, water *from* the river. The ESA and the GCPA have not decreased the river's flow, they do not create additional demand for consumptive use of water, and rolling them back will not help to meet or stem the demand for water from the river. Therefore, rolling back these environmental laws will not help to avert the impending crisis.

The primary way in which the ESA and the GCPA affect river management is by altering the timing of transfers of water between reservoirs on the river. For example, in an attempt to protect fish habitat in the Grand Canyon, the Bureau of Reclamation reduced the day-to-night fluctuations in the amount of water flowing out of Lake Powell through Glen Canyon Dam into the Grand Canyon. As a result, more water flows through the Canyon at night, and less during

the day, than did when the dam was operated to maximize revenue from power production. But all of the water released from the dam still ends up in Lake Mead, downstream from the Canyon, where it is available for use in Nevada or for release to be used downstream in Arizona and California.

The Bureau of Reclamation has also conducted two "controlled floods" -- unusually high releases of water from Glen Canyon Dam -- in an attempt to rebuild beaches and restore fish habitat in the Grand Canyon. The water released in these "floods," like all water flowing through the Canyon, ends up in Lake Mead, where it is available for use downstream. Neither the controlled floods nor the reduction in daily flow fluctuations have had any adverse affect on water supplies.

Similarly, water released from other reservoirs on the Colorado and its tributaries in the Upper Basin to meet the streamflow needs of endangered fish is subsequently captured and stored in reservoirs farther down the river and made available for use. This water would have to be released anyway to meet water delivery commitments downstream; the flow requirements for the benefit of the fish affect only the seasonal and daily patterns of release.

The largest diversions of Colorado River water for consumptive use – the Central Arizona Project, California's All-American Canal and Colorado River Aqueduct, and Mexico's Morales Canal – are all on the lower river and therefore receive and use the same water that meets the streamflow needs of fish upriver. It is the required delivery from the upper basin to the lower basin under the Colorado River Compact as well as the operating criteria, not the ESA or the GCPA, that largely determine the amount of water that is released each year from Lake Powell and other reservoirs in the Upper Basin. In short, there is no conflict between meeting instream flow needs upriver and supplying water for consumptive use downriver.

Nor do efforts to restore the Colorado River delta impact drought planning. The Law of the River makes delivery to Mexico a priority. This delivery neither increases nor decreases the amount of water rights to the states. Even increasing delivery to Mexico by an average annual amount of 150,000 acre-feet—the amount needed to begin restoration of the upper riparian corridors—amounts to little more than one percent of the river's flow.

Even if quality-of-life considerations and the zero-impact of environmental restoration on water supply are ignored, the economic contributions of a healthy environment cannot be ignored. Rafting, bird watching, camping, hunting, fishing, and other forms of outdoor recreation are important to basin state's economies.

In sum, a healthy environment is important in the Colorado River Basin both economically and intrinsically. Protecting and restoring the environment has a value all its own and the drought is not a reason for ignoring the environment or for backing away from environmental restoration efforts already underway.

CHAPTER TWO: NEW CONDITIONS IN THE COLORADO RIVER BASIN

A Faulty Foundation

> *The drought gripping the West could be the biggest in 500 years, with effects in the Colorado River basin considerably worse than during the Dust Bowl years, scientists at the U.S. Geological Survey said.*
>
> - Associated Press, June 18, 2004

When water from the Colorado River was first apportioned among the basin states and across the border into Mexico, the allocations were based on measurements taken during a very wet period in the early 1900's. Average annual production at that time was approximately 18 million acre-feet.[1] Total allocations granted to the basins in the 1922 Colorado River Compact, the core of the *Law of the River*, were based on that data.

The Compact allocated 15 million acre-feet, with 7.5 million acre-feet each going to the upper and lower basin. The Compact also sets forth the right for the lower basin to use an additional one million acre-feet of "such waters," referred to earlier in the Compact as waters of the "Colorado River *system*" [italics added]. This language may refer to the development of the Colorado River's tributary flows in the lower basin, although this interpretation is currently a subject of dispute. An additional 1.5 million acre-feet was later allocated to Mexico. The total of the allocations granted in the Colorado River Compact is 17.5 million acre-feet when the additional rights granted to the lower basin are included.

But in recent decades, the river has produced only about 13.5 million to 15 million acre-feet per year. During years 2000 through 2004, annual natural flow at Lee's Ferry averaged only about 9.82 million acre-feet. The river produced only six million acre-feet in 2002, about equivalent to natural flow in the years 1934 and 1977 -- the lowest years of production since river flow data collection began about a century ago.

Scientists suspect that the lower flows may be more normal than past wetter decades based on tree ring studies, which estimate the river's average annual flow over the past 2,000 years at roughly 13.5 to 14.5 million acre-feet. *(See page 15)*

Drought Impacts on Lake Powell

Low inflows into Lake Powell during years 2000 through 2004 reduced water storage from 27 million acre-feet (maf) capacity to a low of 7.97 maf on April 8, 2005. At that point, the reservoir held only 33 percent of its storage capacity.

The elevation as of April 8, 2005 was 3,555.1 feet, 144.9 feet below the "full pool" elevation of 3700 feet.

This is the lowest level seen at the reservoir since it was first being filled in 1963 through 1980.

Current Drought in the Basin

Water year 2004 marked the fifth year of a Colorado River basin drought, as defined by the U.S. Bureau of Reclamation using basin snow pack and runoff into Lake Powell as indicators.

[1] Bureau of Reclamation, data for virgin flows at Lee's Ferry for Water Years 1906 through 1917.

Unregulated inflow in water years 2000, 2001, 2002, 2003 and 2004 was 62 percent, 59 percent, 25 percent, 51 percent and 51 percent of average, respectively. During the water years 2000 to 2005, storage in Lake Powell fell to a low of 33 percent of active or usable capacity.

Hydrologic conditions improved as of year-end 2004 in the Colorado River Basin. Since September 2004, precipitation in the basin has been above average. Data shows that precipitation in the Upper Colorado River Basin was nearly 200 percent of average in January 2005. Snow pack in the basin above Lake Powell was 118 percent of average as of April 1, the beginning of the snowmelt run-off period in the Colorado River basin. (*For updated Upper Basin Hydrology information, see http://www.usbr.gov/uc/water/crsp/cs/gcd.html*)

The elevation of Lake Powell is projected to increase from April 2005 through mid-July of 2005. Current projections (using the National Weather Service April 2005 final inflow forecast) show Lake Powell reaching a peak in July 2005 of about 3,600 feet.[2] At an elevation of 3,600 feet, however, storage in Lake Powell still equals only 49 percent of capacity.

Long-term weather patterns are extremely difficult to predict. Predicting future precipitation, in particular, is the most difficult part of climate change research. The research community is therefore much more comfortable predicting future temperature increases and increased variability (droughts and floods) for the region than predicting a dryer future for the Colorado River basin.

Declining water levels at Lake Powell 2005 expose side canyons, sandbars, and petroglyphs

Studies by the U.S. Geological Survey and university-based laboratories, however, can provide some potential drought scenarios for the purpose of state and regional planning. A study by the USGS, for instance, warns that the current drought may last "several decades," and indeed, there may not be a return to what had been considered normal weather patterns in the Colorado River basin.

Some tree ring studies indicate that long-term drought was a recurring pattern in the basin in the past, though how accurate the past is as a predictor of the future remains unknown. For the purpose of planning for long-term survival and perhaps reasonable levels of growth in the southwest, however, water users should assume that the current conditions could well be part of a longer drought, even if Lake Powell levels rise significantly.

Historical Drought in the Basin

Several tree ring studies have indicated that over the very long-term, mean flows on the Colorado River were lower than the 17.5 million acre-feet granted in the Colorado River Compact. The tree ring history of drought in the upper Colorado River Basin is recorded in the reconstruction

[2] Glen Canyon/Lake Powell Update, Bureau of Reclamation, Tom Ryan, April 6, 2005.

of annual flow of the Colorado River at Lee's Ferry for the years 1520-1961 (Stockton and Jacoby 1976)[3]. The long-term reconstructed mean annual flow was only 13.5 million acre-feet, well below the most recent 96-year average is 15.2 million acre-feet, considerably less than the estimated 18 million acre-feet flow recorded in the early 20th century.

More recently, the Laboratory of Tree Ring Research at the University of Arizona reconstructed a 2,200-year precipitation record and a 500-year stream flow record using tree ring data in the Colorado River at what is now Lee's Ferry.[4] *The graphs indicate that the period from year 1800 to year 2000 has been the wettest period in the last 2,200 years.*

Figure 1, (*see below)*, indicates that the amount of precipitation in the study area varied dramatically over the centuries. Perhaps more significant is that the last twenty years shown on the graph -- approximately years 1980 to 2000 – were the wettest of all, more than 23 percent over the long term average. It was during those same twenty years when the southwest experienced its most explosive population boom, growing ever more dependent on the unpredictable and perhaps short-lived generosity of the Colorado River.

The Science of Tree Rings

Tree ring growth can be observed in long-lived trees or the timbers from archeological sites for up to 2,500 years in the past.

The density and thickness of tree rings provides a natural history of past temperatures and precipitation including wet periods, droughts and stream flows.

Wider tree rings, for example, correspond to wet years and narrow rings to drier years.

The precipitation record in Figure 1 also shows that long-term droughts - indicated by below-average precipitation - occurred every century or every other century. Several droughts over the 2,200-year record of study lasted eighty to one hundred years. Some droughts lasted 200 years.

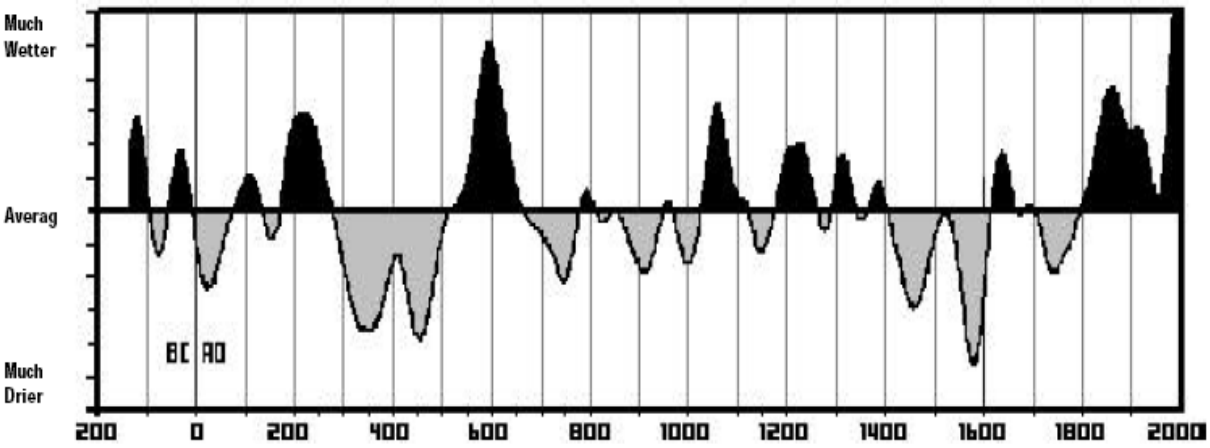


Figure 1. A Two-thousand Year Precipitation Record for Northern New Mexico Based on Tree-Ring Data
Source: Grissino-Mayer, 1996.

[3] Water Resources Bulletin, Journal of the American Water Resources Association, October 1995.

[4] A Primer on Climatic Variability and Change in the Southwest, by Robert Merideth, Udall Center for Studies in Public Policy, University of Arizona; supported by the U.S. Department of the Interior and US Global Change Research Program and the National Oceanic and Atmospheric Administration. March 2001.

Figure 2, below, graphs the data from a tree ring study that mapped the stream flow on the Colorado River for the past 500 years at what is now Lee's Ferry. The data points indicated by the black lines show variation in stream flow. The white line in the foreground shows the mean or average flow.

This data show not only dramatic decadal fluctuations, but also that the years 1900 to 2000 produced consistently higher flows than at any other time during the past 500 years. The most obvious spike in the average flow is in the early 1900's, when the U.S. Geological Survey was first measuring Colorado River flow at Lee's Ferry. It was this data that was used to negotiate the Colorado River Compact.

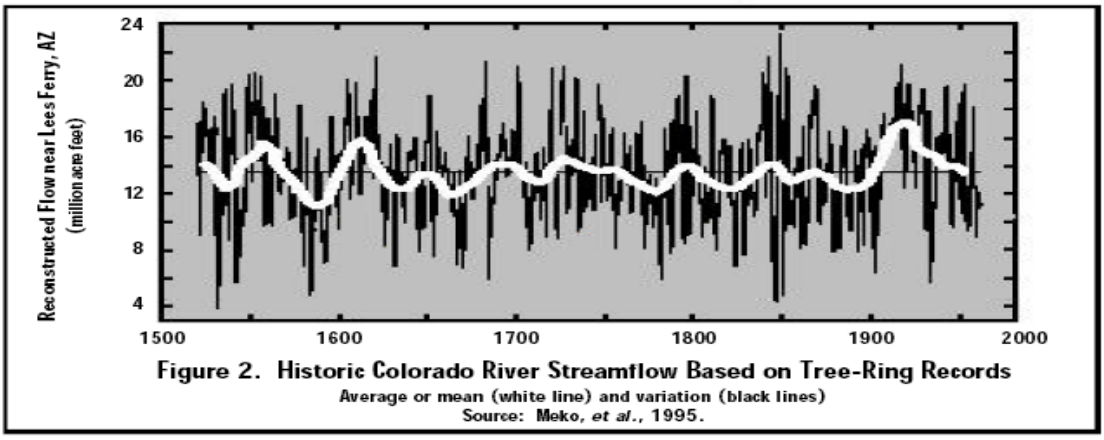


Figure 2. Historic Colorado River Streamflow Based on Tree-Ring Records
Average or mean (white line) and variation (black lines)
Source: Meko, *et al.*, 1995.

The Colorado River cannot be expected to change its nature and begin delivering historically unprecedented flows. The clear message is that modern society in the West must adjust its water consumption to fit what's actually provided by the river.

A Changed Landscape

Economic and social restructuring has taken place in the southwest in an intensely and, according to these tree ring studies, unusually long wet period. If the past is an accurate indicator of the future, the paleo-climatic studies have serious implications for future water delivery and use in the Colorado River basin.

While there have been variations in flow over the decades and likely over the eons, a period of Colorado River abundance for the southwestern United States may be ending while the population—and resultant demands on the river—continue to boom. The economic and social environment of the Colorado River basin is now vastly different than could have been envisioned by the authors of the Colorado River Compact. Nearly everything about the basin—population, economy and culture—has changed dramatically since the Compact was signed.

Population Growth

When the Compact was written, the basin was home to only 5.7 million people. By contrast, in year 2000, the basin population was estimated at nearly 50 million people, with about 30 million of those people dependent on the Colorado River for at least a portion of their water supply.

In only 80 years the population of the seven Colorado River basin states has increased by 800 percent, adding 44 million people. Nevada, Arizona, and Colorado, all in the Colorado River basin and heavily dependent on Colorado River water for municipal and agricultural uses, were the fastest growing states in the nation between 1990 and 2000, as measured by percentage increase, as shown on Table 1.

Table 1: Basin States Population Growth, 1920 – 2000

	Year		Numeric Change	Change	
	1920	2000	Year 1920-2000	1920-2000	1990-2000
Lower Basin^					
AZ	334,000	5,130,000	4,796,000	x 15.36*	+40.0%
CA	3,426,000	33,871,000	30,445,000	x 9.88	+13.8%
NV	77,000	1,998,000	1,921,000	x 25.95	+66.3%
Upper Basin^					
CO	940,000	4,301,000	3,361,000	x 4.58	+30.6%
NM	360,000	1,819,000	1,459,000	x 5.05	+20.1%
UT	449,000	2,233,000	1,784,000	x 4.96	+29.6%
WY	194,000	494,000	300,000	x 2.55	+ 8.9%
Total	5,780,000	49,846,000^^	44,066,000	x 8.62	

*Multiplicative Change. For instance, Arizona's population increased by over fifteen times between 1920 and 2000.

^ Some states span both basins. Such states are assigned to the basin where that state has the largest water allocation.

^^ Approximately 30,000,000 people of the total basin population use Colorado River water.

Sources: U.S. Census 2002, PHC-T-2. Ranking Tables for States, 1990-2000. The World Almanac & Book of Facts; 1995 edition of The World Almanac, Publisher, Mahwah, NJ; Editor R Famighetti. pp.376-377.

Changes in Economy and Culture

Tourism, housing, retail and wholesale trade and services now make up more than 90 percent of the regional economy.[5] The agricultural sector - due in part to global trade, in part to expansion of artificial irrigation works, and in part to U.S. farm subsidies – has experienced a shift away

[5] U.S. Census Bureau, "Population Projections: States, 1995-2025," Current Population Reports P25-1131, May 1997U.S.

from arid land crops for human consumption and towards high-water-use crops, primarily alfalfa, feed grains and cotton.

There are now intense political conflicts and differences in values concerning water and land use in the region including struggles over consumptive use versus environmental protection; local versus regional versus federal control; urban lifestyles versus rural livelihoods. Recreation, environmental issues and Native American rights, which went largely unconsidered in the Compact, have become huge economic and intrinsic values in the southwest.

Population analysts believe the rate of growth for the basin states will remain high. U.S. Census Bureau projections for the period from 1995 to 2025 predict an increase of over 50 percent for the basin states resulting in a total of 70 million people. By comparison, the national population as a whole is expected to increase by 28 percent.

Though only portions of some Colorado River basin states are in the Colorado River water service area, the growth in the basin demonstrates the likely additional demands on the Colorado River in the future. Each new family of five in the basin needs approximately one acre-foot of water every year to sustain their domestic needs.

"The earth has some unsettling news…the earth is heating up right now, and fast. The results aren't pretty. Ice is melting, rivers are running dry, and coasts are eroding threatening communities. These aren't projections; they are facts on the ground.…

Already we've pumped out enough greenhouse gases to warm the planet for many decades to come… The signs of warming are striking enough, but they are just a taste of what the next century could bring."

—Tim Appenzeller, Sr. Editor, Science, "The Heat Is On", *National Geographic*, Sept. 2004, pgs. 2-75

Impact of Global Climate Change

A two-year study funded by the Department of Energy predicts, based on modeling, that the flow of the Colorado River could be reduced by about one third by the middle of this century.[6] Though it is difficult to predict the exact temperature increase, even a very slight temperature increase has a profound effect on trans-evaporative loss and results in a subsequent significant loss in runoff.[7]

[6] Climatic Change, 2004,Vol. 62, p. 337-363. "The Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin," Niklas S. Christensen, Andrew W. Wood, Nathalie Voison, Dennis P. Lettenmaier and Richard N. Palmer. Department of Civil and Environmental Engineering, University of Washington, Seattle, WA.

[7] Water is removed from the surface of the Earth to the atmosphere by two distinct mechanisms: evaporation and transpiration. It is often difficult to distinguish between evaporation and transpiration. So we use a composite term evapotranspiration. Michael Pidwirny, Ph.D., Physical Geography.net, Department of Geography, Okanagan University College. Kelowna, British Columbia, Canada.

Some scientists predict that, in addition to diminished river flow, all the components of droughts will increase in severity as global warming progresses, creating drastic water shortages particularly in the heavily populated deserts of the southwestern United States.

Models predict that areas like the interior of the U.S. are likely to grow hotter and drier. Some scientists expect China, southeast Asia and the western U.S. may get more rainfall but less snow pack, "jeopardizing the drinking water of people in cities like Los Angeles…Heat waves, like the one Europe experienced [in 2003], may become the summer norm."[8]

If global climate change does have an impact, it will compound the effects of drought, generating a still greater cause for concern. The critical nature of the issues presented by the drought does not depend upon global climate change occurring. However, if global climate change proceeds as predicted, it almost certainly will worsen the water use issues highlighted by the drought.

Dry River Bed, Western U.S., 2001

Colorado River water users have relied upon the 1922 Colorado River Compact as though water rights would guarantee that river flows matched the legislated requirements. The present reality is that basin states may have to survive with less overall water. How much less each state would receive is somewhat uncertain because of ambiguities in the Law of the River and, of course, how much water the river produces.

One thing, however, is certain. The length or brevity of the current drought won't change the fact that the way in which basin users have utilized the Colorado River in the past cannot continue. The focus for the future must be on long-term sustainable use of the Colorado for the benefit of all stakeholders.

[8] "The Heat Is On", *National Geographic*, Sept. 2004, pg. 31 and 75.

CHAPTER THREE: DROUGHT SCENARIOS

Drought Scenarios for the Basin Under the Law

The current law puts the burden of the drought on the upper basin by requiring it to deliver the lower basin's allocation as a priority over its own use. The upper basin currently estimates its use at about 3.98[9] million acre-feet of its total allocation of 7.5 million acre-feet, so it does not currently experience a need to reduce consumptive use under mild drought scenarios.

Under a scenario that requires full deliveries in a more severe drought (such as 10 million acre-feet natural annual flow long-term), however, the upper basin would have to reduce its consumptive use under the current Law of the River. In an even more severe drought, such as 6 million acre-feet natural annual flow, with storage exhausted, the upper basin must deliver the entire flow, plus it begins running an actual physical deficit as shown in Table 2, assuming that 8.25 million acre-feet must go to the lower basin annually (8.23 maf of which is delivered by the upper basin through Glen Canyon Dam and 20,000 acre-feet of which enters below the dam).

Table 2: Water available under various flow scenarios for delivery from the upper basin to the lower basin

State	Compact Allocation	Acre-Feet Available at Various Flows* 16 maf	13.5 maf	10 maf	6 maf	Actual Use**
Arizona	**50,000 AF**	**.05**	**.05**	**.05**	**.05**	**.04**
Colorado	**51.75 %**	**3.86**	**2.72**	**.88**	**<1.16>**	**2.38**
New Mexico	**11.25 %**	**.84**	**.59**	**.19**	**< .25>**	**.36**
Utah	**23.00 %**	**1.71**	**1.21**	**.39**	**< .52>**	**.77**
Wyoming	**14.00 %**	**1.04**	**.74**	**.24**	**< .32>**	**.43**
Upper Basin Total	**100%**	**7.5**	**5.25**	**1.75**	**<2.25>**	**3.98**
Arizona	**2.8 maf**	**2.80**	**2.80**	**2.80**	**1.30**	**2.80**
California	**4.4 maf**	**4.40**	**4.40**	**4.40**	**4.40**	**5.16**
Nevada	**.3 maf**	**.30**	**.30**	**.30**	**.30**	**.32**
Add'l consumption^^	**1.0**	**--**				
Lower Basin Total	**8.5 maf**	**7.5**	**7.5**	**7.5**	**6.0**	**8.28**

*Assumes that a minimum of 8.25 million acre-feet must ***go*** to the lower basin annually, 8.23 maf of which is ***delivered*** by the upper basin through Glen Canyon Dam and 20,000 acre-feet of which ***enters downstream*** of Glen Canyon Dam via the Paria River.

** Source: Bureau of Reclamation, Colorado River System Consumptive Uses and Losses Report, 2003. Data based on water years 1996-2000.

^^The 1922 Colorado River Compact grants the lower basin the right to increase its beneficial consumptive use by 1 maf per year. Depending upon interpretation of Compact language, i.e. whether this refers to water from tributaries originating in the lower basin, this may not apply to the upper basin obligation.

[9] Upper Basin Consumptive Uses and Losses Report, 1996-2000, produced by the Bureau of Reclamation

Under the Law of the River, some drought scenarios do not have an impact on the basins until no more water exists in Lake Powell. However, it is realistic for the upper basin to contemplate an empty Lake Powell. A point is reached as Powell drains, when only the sideflow between Lee's Ferry and Lake Mead would be available for delivery.

The burden of shortage as stipulated by the Law of the River technically falls on the upper basin. The risk of shortage to the upper basin is the fixed obligation to deliver 75 million acre-feet every ten years plus one-half of the deficiency of the obligation to Mexico. (The exact amount to be contributed by each basin is a point of legal contention between the upper basin and lower basin.) The upper basin would have to curtail its use to make the deliveries when not enough water is in the system.

But the risk of variability in the system falls on the lower basin. The lower basin is more vulnerable in a shortage situation because it has developed uses that depend on deliveries of more water than it is entitled to, demanding more than 7.5 million acre-feet in years of high flow. *The lower basin has become especially vulnerable to drought-induced shortages by supporting populations and uses that are beyond its allocation.*

Need for a Framework for Sustainable Water Use

During the past 75 years of Colorado River management there has been a lack of attention to potential drought conditions, impacts, and responses in the Colorado River basin until very recently. Even with mounting evidence of a severe and perhaps sustained drought, the focus for water distribution has been on allocating surplus water more so than on developing shortage scenarios. Agencies have done some foundational planning for dealing with shortages but these provisions can only become explicit via planning and cooperation among the states and basins and other stakeholders - likely predicated by strong leadership from the Department of the Interior.

Optimism about the river's steady production coupled with confidence in the engineered water delivery system reigned for the first 70 years. When drought took hold in 2000, even when inflow into Lake Powell fell to 25 percent of normal in 2002, the 'unlimited human capacity to ignore reality' (*Water Follies*, Robert Glennon, Island Press 2002), apparently drove continued denial of drought conditions surrounding the river. Consequently, water users in the basin have demanded too much from the Colorado River, which is proving to be an unsustainable source for meeting unchecked demand. Moreover, until recently, there were proposals for more major water development projects in the basin, and the possibility of similar proposals in the future still looms.

Although the situation is critical, the Colorado River is generous for a desert river. The challenges exist not because the Colorado doesn't provide enough volume for multiple uses and growing populations in the basin, but because of a fragmented, wasteful, and outdated way of allocating and using water. Leaders have a broad spectrum of alternatives to assess before communities suffer water shortages. With a plan for proper management, even in a situation of continued drought, enough water exists to sustain reasonable levels of growth as well as to protect and restore river habitats, and preserve recreation.

CHAPTER FOUR: UNCERTAINTIES AND FLEXIBILITIES IN THE LAW

It is clear that continued drought would pose difficult questions about the allocation and use of Colorado River water. To cite one example, in the event that storage at Lake Powell is exhausted, the lower basin states will still have the legal right to require deliveries from the upper basin, even if that shuts off critical upper basin diversions. How the Law of the River will perform in a shortage situation remains to be tested. The Law of the River includes some dictates for sharing shortages between the basins and between states within each basin. However, these provisions are typically not explicit or have not been evaluated in relation to stakeholder needs, which were not considered at the time of the Compact. The needs of endangered species and recreation as well as Indian water rights were largely neglected.

Below, we describe some of the Law of the River's ambiguities and flexibilities that, through various interpretations or applications, could impact the declaration and distribution of "shortages."

Delivery Requirements

The Colorado River Compact says: "*The States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive years...*" This gives the upper basin the flexibility to withhold water in any given year or years as long as the 10-year delivery total equals 75 million acre-feet or more, plus the upper basin's portion of the obligation to Mexico.

The Operating Criteria developed by the Department of the Interior effectively remove that flexibility by specifying that the ten-year total of 75 million acre-feet, plus 0.75 million acre-feet per year for Mexico be delivered in an annual "minimum objective release" of 8.23 million acre-feet[10]. The lower basin tends to focus on the term "minimum" and would argue that 8.23 maf is the minimum required amount to be delivered. Conversely, the upper basin tends to focus on the word "objective" and would argue that the 8.23 maf is a goal, rather than a minimum requirement.

Nevertheless, the amount is annualized by Department of the Interior policy, not by the Compact or the specific requirements of any other legislation. Current operating criteria also anticipates surpluses but deals only vaguely with the shortages caused by inevitable droughts. There are factors mentioned in the Operating Criteria that are meant to deal with shortages, but the factors lack specificity.

A likely interpretation of the law is that the upper basin has an option of delivering less than 7.5 million acre-feet in some years as long as it delivers 75 million acre-feet over a ten-year moving average, plus the (disputed) apportionment from the upper basin to the lower basin for Mexico's

[10] Seventy-five million acre-feet divided by 10 years = 7.5 million acre-feet/year + .75 million acre-feet allocation to Mexico from the upper basin = 8.25 million acre-feet less 20,000 acre-feet which enters the river system just below Glen Canyon dam via the Paria River in Arizona, credited to the upper basin, equals 8.23 million acre-feet.

share. This could offer upper basin states a cushion in times of extreme drought, allowing it to over-deliver in earlier years, or make smaller deliveries in dry years that then depend on wet years to repay in the future. This could cause uncertain and uneven deliveries for the lower basin and create periods of several years when deliveries were substantially less than 7.5 million acre-feet plus the Mexican apportionment -- so long as the other years of the ten-year run caused the total to be at least 75 million acre-feet plus enough to meet the Mexican obligation.

Both basins would suffer from a shortage in the long term. The Operating Criteria put most of the burden of shortage on the upper basin by removing the flexibility of withholding water in any given year and specifying a minimum objective annual delivery of 8.23 million acre-feet. It is worth considering developing revisions in the Long Range Operating Criteria to make the annual delivery requirement more flexible within the terms of the Compact, if that would more equitably distribute the burden of shortages.

Further uncertainties exist in the Law of the River concerning storage and evaporation. The issue of underground storage is a case where the Law of the River, specifically the 1922 Compact, is not clear. The Compact clearly states: "*The States of the upper division shall not withhold water, and the States of the lower division shall not require the delivery of water, which can not reasonably be applied to domestic and agricultural uses*." The ambiguity lies in whether underground storage for future agricultural and domestic use qualifies as a purpose for which the lower basin can require the upper basin to deliver under Article III (e). For instance, in a shortage, can the upper basin be required to cut back its consumptive use in order to deliver water to the lower basin for storage underground? Domestic use is defined in the 1922 Compact as "*household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electric power."* Therefore, an important and unresolved question is whether this allows the lower basin to call for water to recharge groundwater that will eventually be used for domestic and agricultural purposes.

Evaporation losses and bank seepage become a significant consideration when calculating required deliveries. For example, the Compact in Article III (c) requires that each basin provide one-half the allocation to Mexico: "such waters shall be supplied first from the waters which are surplus…; and if such surplus shall prove insufficient for this purpose, then the burden of such deficiency shall be equally borne by the upper basin and the lower basin, and whenever necessary the States of the upper division shall deliver at Lee Ferry water to supply one-half of the deficiency..."

The upper and lower basins continue to disagree on the delivery requirements to Mexico, with some stakeholders in the upper basin arguing that they have no delivery requirement to Mexico since the lower basin has never actually demonstrated that there is a deficiency under the terms of the Compact. A different upper basin argument (oversimplified here for the sake of brevity) is that the upper basin obligation is something less than 750,000 acre-feet because of over-deliveries to the lower basin - sometimes passed on to Mexico - in past years. The lower basin, however, tends to interpret the requirement to mean that 750,000 acre-feet must reach Mexico from the upper basin. This would require the upper basin to deliver the 750,000 acre-feet plus enough 'extra' to provide for evaporation and channel losses during transport.

The Secretary of the Interior's Powers in Distributing Water Shortages

In the 1963 *Arizona v. California* Supreme Court decision, the Secretary of the Interior was determined to be in charge of allocating water among the lower basin states. The decision gave the Secretary enormous discretion including the power to apportion the river and to contract for specific water deliveries within the confines of Colorado River legislation. The decision also gave the Secretary the discretion to distribute surpluses according to a set formula.

The 1968 Colorado River Basin Project Act (CRBPA), however, modified the *Arizona v. California* decision and set limits on what the Secretary could have done under the Supreme Court decision. The CRBPA basically made Central Arizona Project's priority junior to some other lower basin users, resulting in shortage apportionment being potentially distributed differently than envisioned by the Supreme Court decision. The CRBPA now may control how shortages are apportioned in the lower basin. The question is whether the Secretary of the Interior's discretion for apportioning shortages in the lower basin overrides the 1968 Act. The only way this could occur is if the Supreme Court decision continues to apply notwithstanding the 1968 Act, a very unlikely scenario.

The Secretary's powers also vary from basin to basin. In the upper basin, it is not clear what powers the Secretary would have, as there has never been a test of the law in the upper basin. In contrast to the lower basin, Colorado River water delivery in the upper basin is covered by the terms of the Upper Basin Compact, not by the Secretary of the Interior.

At present, the Secretary has no explicit guidelines by which to declare a shortage in the lower basin**.** The Bureau of Reclamation had assumed some time ago that a shortage would exist when Lake Mead reached an elevation of 1,095 feet, based on the presumption that power could not be reasonably generated if the lake's elevation fell much below that level. More recently, the trigger elevation has been presumed to be 1,083 feet, but the trigger elevation varies over time and with various conditions. In yet another scenario, it is estimated that power could be produced when Lake Mead is as low as 1,050 feet due to recent upgrades to the turbines at Hoover Dam.

Obviously, the exact numbers at which a shortage would be declared, requiring deliveries out of Lake Mead to be curtailed, have never been determined. The basin states are working presently to give direction to the Secretary of the Interior concerning the elevation of Lake Mead that should signal a shortage. The states are currently considering recommending a range of elevations at Lake Mead of between 1,000 feet and 1,050 feet as the shortage trigger. At that point, deliveries to the Central Arizona Project (CAP) would drop abruptly.

The exact amount of reduction in delivery to CAP has not been determined, though the basin states are considering recommending reductions to Arizona and thus to CAP of between 500,000 acre-feet and 600,000 acre-feet in the case of a shortage. Adding to the complexity, adjudicated tribal water rights on the river total about 900,000 acre-feet, most of which are charged against Arizona and which have a higher priority than many of the other water rights in Arizona. Assuming a 500,000 acre-foot reduction in deliveries to Arizona and assuming that the entire shortage is passed along to CAP, deliveries to the state would become 2.3 million acre-feet,

down from the current 2.8 million acre-feet; and deliveries to CAP would become 1.1 million acre-feet, down from 1.6 million acre-feet.

Even if the drought continued at its current intensity, assuming an 8.23 maf release from Lake Powell, the elevation at Lake Mead would drop only about ten to 13 feet per year, making the likelihood of a shortage declaration before the year 2012 virtually impossible. However, if the shortage strategy includes maintaining power production at both Lake Powell and Lake Mead, a shortage could occur as early as 2007. In any case, historical drought conditions in the basin, as well as speculation about potential reductions in river flow from climate change, make planning for such reductions both prudent and urgent for the basin states.

Mechanisms for Dispute Resolution

The basin states and other stakeholders have one common interest: avoiding continuous internal conflict. Conflict among the stakeholders, especially if it must be resolved through the court system, would be lengthy, expensive, and distracting from the real issues arising as the drought-growth scenario plunges the basin further into crisis. The framework of the Law of the River includes sufficient flexibilities for dispute resolution. Absent Congressional legislation, better use of the river's resources and less conflict could be fostered in the following ways:

Basin-wide consensus

Given the history of contentious water sharing in the basin it is extremely unlikely that, without strong central leadership, the basin states and other relevant parties will be able to negotiate an agreement that fundamentally changes and improves overall water distribution and use.

Even in 1922, when the situation was far less complex and many stakeholders were not even represented at the negotiations, Herbert Hoover had to provide aggressive leadership to achieve agreement. Unfortunately, if the stakeholders must resolve water use issues without equally powerful leadership, these issues will likely only be resolved through litigation.

> "The seven western states that depend on water from the Colorado River will not have a drought management proposal in hand by the Friday [April 1, 2005] deadline set by the U.S. Department of the Interior, Nevada's top water official said.
>
> No such proposal has been developed and representatives from the seven states are not slated to meet again until next week, said Pat Mulroy, general manager of the Southern Nevada Water Authority."
>
> -*" Western States to miss drought plan deadline," Henry Bream, Las Vegas Review-Journal, March 31, 2005*

Interior Secretarial discretion

The major issues involved in developing a sustainable use plan for the river are, to a significant degree, federal issues. The Upper Basin Colorado River Compact controls the upper Colorado River. Although the Secretary of the Interior functions as the "water master" of only the lower Colorado River, the Secretary effectively, through the Bureau of Reclamation, operates most of the major dams and reservoirs throughout the basin and therefore controls the river flow as dictated by the Law of the River.

Further, under the Colorado River Basin Project Act of 1968, Congress directed the Secretary of the Interior to develop a regional water plan for ensuring adequate water supply for the basin states. The Secretary therefore has statutory authority to develop such a plan, though the Secretary has never exercised that authority. Ex officio, the Secretary is in a position to take a leadership role.

Legal challenges and court decisions

The Secretary's decision could be challenged by the basin states in the Supreme Court or other courts, subjecting water allocation, distribution and other issues to decisions of the court.

Congressional action

An act of Congress would be required in order to make changes in the Secretary's designated powers.

No matter how shortages are shared and disputes resolved, states will likely have to make do with less water. The hydrological reality is that states are going to have to make major adjustments to accomplish overall basin goals.

CHAPTER FIVE: OPTIONS FOR DEALING WITH THE DROUGHT

Intra-State Solutions

Without waiting for action at the regional or federal levels, individual basin states and other stakeholders have a wide array of tools and techniques to begin addressing shortages within the boundaries of their state laws and geographic borders.

Conservation

Home xeriscaped with New Mexican Locust bush

Basin states can cushion the impacts of water and energy reductions through conservation, a reasonable starting point for responding to the reality of living in arid lands. Options include replacing spray and flood irrigation with drip irrigation; requiring low flow toilets and showerheads in new developments; requiring xeriscaping; eliminating ornamental fountains and lakes; and implementing water reclamation or gray water systems beyond the current industrial uses.

The amount of water needed to service a community of 100,000 people decreases with conservation. In Tucson, Arizona, for instance, where water conservation is a key part of land use planning as well as community culture, per capita daily water use was 160 gallons in 2002.

Just two hours away in Phoenix, where the climate is very similar, per capita water use is 226 gallons per day, 40 percent more than in Tucson. In Paradise Valley, a high-income suburb of Phoenix with large houses and large building lots, per capita consumption is 400 gallons per day, 150 percent higher than in Tucson.

Las Vegas, also with a climate similar to Tucson, has one of the highest per-capita rates of water consumption in the nation, at over 240 gallons per day, although Las Vegas has achieved reductions in water use in recent years. By comparison, U.S. per capita consumption is 100 gallons a day.[11] Water consumption is of course inevitably higher in the arid, hot region of the Colorado River basin than elsewhere in the U.S. where there is more precipitation and milder

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[11] U.S. Geological Survey, Estimated Use of Water in the United States in 2000**.** Susan S. Hutson, Nancy L. Barber, Joan F. Kenny, Kristin S. Linsey, Deborah S. Lumia, and Molly A. Maupin**.** Released March 2004, revised April 2004, May 2004.

temperatures. Las Vegas water use is also driven up by high visitor rates, though resorts used just eight percent of what Las Vegas took from the river in 2004. The rest was used by homes and businesses off the resort corridor.

Some states are aggressively pursuing municipal conservation that has resulted in reduced water consumption per person. Yet the states are experiencing overall increases in use and demand as new development overwhelms savings.

Unfortunately, in many places there are significant disincentives by cities in the basin for conserving water due to 'use it or lose it" policies. Simplistically stated, "use-it or lose-it" refers to some situations in which surface water rights have to be used in order to maintain future rights to that water. If cities conserve now for the benefit of reducing overall use in the basin, they may have to find other supplies when they experience growth. In the meantime, other cities that are not conserving water may develop that conserved water, creating a situation in which there is no incentive for individual cities to conserve. Because most cities in the basin are anticipating future growth, they focus on developing new supplies as long as they can. Changes to these policies must be made before conservation can be widely successful.

Complicating the situation is steady economic pressure for continued statewide growth at pre-drought levels. Upper basin states, particularly Colorado and Utah, are still discussing developing water as though there were no shortage. The upper basin, with its third tier priority after the lower basin and Mexico in the current Law of the River, may not be able to maintain current allocations or levels of use let alone develop its full Compact-designated allocation.

The bottom line is that there is not now enough water to fulfill the promises made in the Law of the River. Mitigation measures can extend diminished supply, but will not solve the fundamental problem. The focus must be on more efficient, prioritized use of available water and energy resources.

Animas-LaPlata dam and pumping plant, Durango, CO. Estimated cost: $500 million

Agricultural Conversions

Agricultural use consumes nearly 80 percent of what remains of the Colorado River's flow after evaporation from reservoirs. Supplementing urban and in-stream uses with agricultural water holds great promise because of the sheer quantity of water used by agriculture and because water sharing can be done without serious disruption of agricultural economies.

Almost incredibly, the Colorado River is run largely for cattle production. It takes thousands of gallons more water to produce a pound of edible beef than to produce a loaf of bread or a pound of fruit or vegetables. Colorado River water irrigates approximately 3.7 million acres of crops per year; with more than half of that water being used to irrigate non-food crops such as water-gluttonous, low-value alfalfa for cattle feed. Agricultural subsidies coupled with water -- that

Lower Colorado River Water Use

Evaporation:	Approx 20% of total flow
Uses After Evaporation:	
Agriculture*	77%
Municipal/ Industrial	23%

*Includes Native American agricultural uses

Source: Estimates based on Bureau of Reclamation, Lower Colorado Region and USGS data, 2000.

was once thought endless -- made cattle feed production in the desert financially viable. Yet the question remains of whether we should continue propping up this system in the arid Colorado River basin when such crops can be more efficiently grown in the rainy southern United States for example.

Philip L. Fradkin, author of *A River No More* (Alfred A. Knopf, 1981) asked rhetorically, "Should the Colorado River basin be a vast feedlot?"

A common concern with converting agricultural water to urban use is the potential impact to the economic viability of rural economies. There are a number of ways to increase availability of urban and in-stream water, plus sustain or even improve rural economies. First, only a small percentage of agricultural water needs to be conserved in order to provide for significant municipal needs. In most areas, saving just *seven to ten percent* of agricultural water *doubles* the availability for urban use.[12]

Second, payments to willing sellers for the lease of their water will, and in some cases already are, sustaining rural economies. Willing sellers of water typically lease through short-term forbearance agreements, making a return to farming viable in future years if the sellers so choose. To stabilize long-term access to agricultural water sources by municipal buyers, a Colorado River Water Trust could be formed to buy or lease in-stream rights from senior users. Idled farmland could continue to benefit society as open space, while farmers who chose to sell or lease their water would be compensated.

Third, no crops need be changed or fields fallowed if drip irrigation is used to replace flood irrigation or other similarly inefficient techniques. For example, shifting just 50,000 acres of alfalfa from sprinkler to drip irrigation would save nearly 200,000 acre-feet of water per year, enough to sustain one million people. Fifty thousand acres represents about 1.35 percent of the lands irrigated by the Colorado River. It is not economically viable for most small farmers to install drip irrigation systems, but if cities fund the systems for farmers, municipalities could gain access to the water saved, state law permitting.

Not all crops can be grown with drip irrigation due to such factors as the need for deep watering. Even if

> *"…some water consumers and administrators are panicked by the notion of dedicating water to non-consumptive uses. At the same time, however, an enormous amount of Colorado River water is wasted. The examples of inefficient and uneconomical irrigation practices are legion. For example, according to the Bureau of Reclamation… the Imperial Irrigation District alone wastes 200,000 acre feet of water every year. Simply put, the sense of panic is not always well-founded."*
>
> -Scott Miller, Stanford Environmental Law Journal, January 2000

[12] Charles Wilkinson, *Crossing the Next Meridian: Land, Water and the Future of the West at 287* (1992).

taking certain crops out of production altogether is the most cost-effective and efficient way of producing municipal supplies, few acres need to be fallowed. Removing 17,200 acres of alfalfa from production in the arid west saves approximately 150,000 acre-feet of water, enough to provide for a municipality of 750,000 people or to accomplish significant environmental restoration.

With a plan for proper management, even in a situation of sustained drought, enough water exists to sustain reasonable levels of urban growth as well as to preserve farming lifestyles and economies while also protecting and restoring river habitats.

With such significant potential for solving drought-induced shortages (at least in the short term), any state laws and policies that impede agricultural to urban or to in-stream conversions should be re-examined and, if necessary, reformulated to facilitate such conversions.

Demand-Side Management

Water has been largely insulated from market forces by agricultural subsidies, municipal incentives designed to lure manufacturing industries, and a plethora of state and federal policies aimed at facilitating economic growth. This has caused dramatic variability in water prices. For example, in some irrigation districts in the basin, water is sold for as little as $3 per acre-foot (326,700 gallons), or one cent ($.01) per one thousand gallons. By contrast, should the mothballed desalting plant in Yuma, Arizona ever be restarted, usable water coming out of the plant will cost somewhere between $380 and $700 per acre-foot.

If market forces were allowed to drive water prices, even marginally, incentives to conserve would be *dramatic*. State water policy makers can consider rate structures or creative pricing plans as a demand control measure. Some techniques include surcharges on water use for municipalities, commercial and industrial users or individual users, pump fees for both new and established pumps, or declining block pricing, which encourages reduced water use by graduating prices for each additional 'block' of water used by a single customer.

Land Use Planning

The 30-year Colorado River basin population projection by the U.S. Census Bureau, from 1995 to 2025, shows over a 50 percent increase for the basin states for a total of 70 million people. At current average per capita water use rates, the additional 20 million people will require an additional four million acre-feet of water just for municipal needs. While not all of the growth in the basin will be within the Colorado River water service area, the growth in the basin overall is indicative of new demands that will be made on the river.

Meanwhile, most basin cities and states lack serious growth planning. Sprawl is ignored or even

> *In a study to be released today, the nonpartisan Arizona Policy Forum recommends that developers not be allowed to build homes where a long-term water supply can't be proved and that local governments be given the authority to reject projects if water isn't there.*
>
> *Without those measures, the group warns, the demand for water will produce new conflicts, strain fragile economies and ultimately spawn long-term water shortages.*
>
> - "Proposal: No water, no rural growth", *The Arizona Republic*, Sept. 23, 2004

encouraged and, according to Department of Energy global warming predictions, the river will likely be producing ever less water. It is a situation that demands a more thoughtful approach.

In some cases, drought can provide a trigger for realistic well-planned growth in order to ensure long-term water supplies for communities. For example, Arizona requires reasonable proof of a water supply for new developments inside its five Active Management Areas (AMAs), not as a limit on growth but as an assurance of long-term sustainability of communities. Concerns about the sustainability of groundwater pumping led to the adoption of a comprehensive groundwater management system within AMAs. Within an AMA, developers must demonstrate the existence of a 100-year assured water supply for proposed developments.

Outside of AMAs, however, there are few state requirements for conservation measures and, if developers cannot show adequate water for 100 years, the developer must simply disclose that fact and can still proceed with subdividing the land.[13] Arizona is not alone: no state in the basin has comprehensive land use planning that is linked to water supply.

Highlands Ranch, new development south of Denver

It may be necessary to adopt more widely the kinds of restrictions imposed in Arizona's Active Management Areas, or to introduce the precepts of smart growth throughout the Colorado River watershed, because *how* communities grow determines *how much* they can grow.

In some parts of the basin, growth will need to be constrained until sustainable plans for development, including water supply and demand, can be developed.

Interstate and Inter-Basin Options

Interstate and inter-basin options are more difficult because of the confines of the Law of the River and other federal policies and legislation, as well as the interaction between states necessary to adjust laws. But flexibilities do exist to help the basin deal realistically with the short-term drought issues and longer-term sustainability goals.

Underground Storage

Evaporation from the large Colorado River system reservoirs consumes an astonishingly large portion of the river. Lake Powell alone, at full capacity, is estimated to lose between 566,000 acre-feet to 756,000 acre-feet of water per year, enough to supply the domestic needs of

[13] Arizona's Drought Preparedness Plan, draft revised June 10, 2004. Governor's Drought Task Force, Governor Janet Napolitano.

approximately three million to four million people in the arid west—nearly the entire population of the Phoenix metropolitan area.[14]

To reduce the enormous evaporative losses, basin states should consider underground storage as a responsible, technologically feasible storage alternative to reservoirs. Underground storage does involve losses to seepage and presents other technological challenges regarding the infrastructure required for transmission of water to storage facilities. However, it is worth exploring as an alternative to open surface reservoirs because of evaporation considerations, especially in the hotter climate of the lower basin, but also because underground storage capacity is immense.

As discussed earlier there is an ambiguity concerning whether underground storage for future agricultural and domestic use qualifies as a purpose for which the lower basin can require the upper basin to deliver water. With certain limits, an interpretation of the law that recognizes underground storage as a legitimate use could benefit the basin's overall water situation by minimizing evaporative losses. The Arizona Water Bank is currently engaged in a project to store millions of acre-feet of water delivered by the Central Arizona Project in underground aquifers to mitigate against future shortages.

Re-Examine Federal Policies

Drought planning could benefit from an examination of federal policies that hamper water management in the basin during drought. Federal subsidies, for instance, may need to be shifted to help agricultural entities respond to drought pressures as well as to pave the way for more valuable uses of water for municipalities, environmental values, recreation and wildlife. A study of federal policy might include:

- Drought payments. Perhaps money given to agricultural entities to sustain them through the drought should be shifted to capital improvements that will survive past the duration of the drought and result in long-term, sustainable farming methods. For instance, via the Farm Bill or other mechanisms, drought payments should be shifted to subsidize drip irrigation systems for farmers willing to invest in them.

- Agricultural subsidies. The federal government should reexamine what kinds of water-use, if any, it should be subsidizing in a drought. A fundamental question is whether it should maintain incentives for overusing water when the resource has evolved from one previously viewed as unlimited to one of the highest premium. The federal government

[14] *Undamming Glen Canyon: Lunacy, Rationality or Prophecy*, Scott Miller, Stanford Environmental Law Journal, Vol. 19, No. 1, January 2000. Comparison of BUREAU OF RECLAMATION, U.S. DEP'T OF THE INTERIOR, COLORADO RIVER SYSTEM CONSUMPTIVE USES AND LOSSES REPORT: 1986-1990 (estimating annual evaporation at 566,100 acre-feet front 1986-1990), *with* David *R.* Dawdy, *Hydrology of GlenCanyon and the Grand Canyon,* in COLORADO RIVER ECOLOGY, (reporting the United States Weather Bureau's evaporation estimates of 650,000 to 730,000 acre-feet per year), and Trevor C. Hughes, *Reservoir Operations,* (calculating an adjusted evaporation figure of 756,400 acre-feet per year). According to the National Research Council, the differing calculations are explained by the fact that they are estimating two different things. The higher estimates are the simple total amount of evaporation from Lake Powell, and the Bureau's estimate is the simple total *minus* the amount of water that would have been lost from "the evapotranspiration from the land surface that was inundated by the reservoir (mostly from phreatophytes)." Therefore, while the Bureau's calculation "may provide a correct estimate of depletion caused by dam construction," it "is not, however, the total evaporation from the reservoir."

has an obligation to reformat policies that encourage water waste, particularly in a drought.

- Incentives to grow salinity-resistant crops. Reducing salinity damage from inefficient flood irrigation is a vicious circle, simply pushing the salts and toxins further down the system to the next farm where salts will accumulate in even higher concentrations. Perhaps salinity control measures should be replaced with incentives to produce crops less subject to salinity damage and more viable to produce with drip or spray irrigation systems.

Water Marketing and Water Banking

A step towards a basin-wide sustainable water use plan could be voluntary interstate agreements that alter existing allocations of Colorado River water. A market-based allocation system or formal structure, which empowers states to more readily buy or lease water beyond their Compact allocation from willing sellers, would provide a flexible mechanism for dealing with drought impacts, at least short-term.

Lower basin states have already put water banking into practice. The Metropolitan Water District of California and the Central Arizona Water Conservation District, which operates the Central Arizona Project, pioneered an agreement in 1992 that stored surplus Arizona allocation in underground reservoirs for future use by both states.

> *"The water bank will serve as a critical bridge for Nevada while it develops new intrastate supplies to meet the growing demand in the Las Vegas metropolitan area."*
>
> —Rita Maguire, The Arizona Republic, July 25, 2004

More recently, Nevada struck an agreement with Arizona to buy as much as 1.25 million acre-feet of Arizona's Colorado River allocation under a deal endorsed by the Central Arizona Project (CAP) board of directors. The deal is a revised version of an existing water-banking agreement between Arizona and Nevada. Under the original terms, Arizona promised its best efforts to supply Nevada with as much as 1.25 million acre-feet of water but there was no guarantee. Under the current deal, Arizona would guarantee the water to Nevada, to be delivered over about 20 years for a price of about $330 million. Arizona would also receive from Nevada a pledge of political support for Arizona's efforts to secure a higher-priority status to the Colorado River water delivered through the CAP canal.[15]

The Arizona-Nevada deal represents a creative market-based solution to Nevada's tight Colorado River water budget. But in some cases momentum and creativity on interstate agreements has been hampered by restrictions assumed to be in the Law of the River. The Law of the River should create a structure to encourage and support creative voluntary solutions between willing states seeking a market-based solution to specific water shortage situations.

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[15] "State may deal water to Nevada: CAP board OKs $330 mil plan", Shaun McKinnon, The Arizona Republic, Dec. 3, 2004.

Combine Upper and Lower Basin Supplies

One storage option that would reduce current evaporative losses and thereby increase supplies for consumptive and in-stream uses would be to temporarily combine water from two or more reservoirs into a single reservoir. In the case of Lake Powell and Lake Mead, combining the supplies to fill Lake Mead, for the duration of the drought for example, would reduce total surface area and consequently evaporation and seepage. Hydropower production could also benefit as the extra water in Lake Mead was used to produce additional power at Hoover Dam.

Lake Powell water policy and politics are rapidly changing in the face of a severe and sustained drought. The loss of 566,000 acre-feet to 756,000 acre-feet of water annually to evaporation and seepage from a single reservoir has become so economically unviable that temporarily combining upper and lower basin supplies into one more efficient containment basin on the river system, if the drought continues to empty Lake Powell on its own, should be considered.

Should the supplies of Lake Powell and Lake Mead be combined, the requirements of the Compact could be met by changing the Upper Basin's point of delivery from Lee's Ferry to the foot of Hoover dam. The upper basin's excess water could be stored in Lake Mead and tracked through an accounting system.

There are, of course, local and regional implications that would have to be addressed even if Glen Canyon Dam was only out of service for a relatively short period. Water from Lake Powell is used as a coolant for the Navajo Generating Station, which supplies the power to pump Central Arizona Project water. Pumping the water directly from the riverbed rather than from Lake Powell is possible but would cost significantly more. Also, recreation on Lake Powell has provided financial benefit to Arizona and, to a lesser extent, to Utah.

According to the National Park Service, tourism-associated recreation at Lake Powell contributed approximately $400 million to the regional economy when water levels at the reservoir were higher. It has the potential of again contributing to the economy if water levels rise. The larger question is: how much water and related economic benefit should the basin states contribute to subsidizing recreation at the reservoir? If water is quickly becoming our most valuable resource, driving everything from growth throughout the basin to quality-of-life for 30 million citizens, should we allow significant amounts of water, perhaps enough to sustain millions of people, to be lost to evaporation and seepage? If there is ever enough water to fill Mead beyond its average elevation, surface area and thus evaporative loss would of course increase, but even at full pool the savings are estimated to be significant.

Consideration of combining the supplies of two or more half empty reservoirs has not focused solely on Lake Mead and Lake Powell. Similar efficiencies could be achieved by combining the supplies of several reservoirs on the system in both the upper and lower basins. If the drought ceased and demand for water fell, reservoirs taken temporarily out of service due to drought shortages could be refilled if the need to avoid evaporative losses becomes less critical.

Actions Not Considered

Building more large reservoirs, constructing extensive pipeline systems and importing water from across or outside the basin tend to be the most immediate reactions to the drought. However, these options are not viable politically, practicably or economically especially when the unacceptably high level of environmental damage is considered.

Dams are Costly and Ineffective

New dams are being considered by some states in response to drought and growth pressures. A simple starting place for living on a reduced water budget is to reject proposals for further water development. With the possible exception of small, strategically located reservoirs, constructing new dams in the arid southwest is expensive and unrealistic for a number of reasons, including:

- The number of dams already exceeds the law of diminishing returns. The Colorado River produces between 12 million acre-feet and 15 million acre-feet of water per year, while sporting over 62 million-acre-feet of storage.

- The Colorado River is already the most dammed river in the nation. There are no remotely acceptable potential major dam sites left on the Colorado River system.

- There is no purpose in building more storage if there is no water to store. Evaporation and seepage from current reservoirs is estimated to cost the system 15 to 20 percent of the river's total production. To illustrate the enormity of the loss, evaporation from Lake Powell on a single Labor Day weekend would satisfy the domestic water needs of 17,000 western homes for an entire year.[16] Further, at "dead pool," the point where there is not enough elevation in the reservoir to push water through the penstocks to create hydropower, the reservoir becomes a pure liability in terms of storage and power. For Lake Mead, the Bureau of Reclamation estimates annual loss of 1,045,000 acre-feet to evaporation.[17]

- Climate change predictions throw into doubt the value of the storage systems already built.

- The simple construction costs of dam building are enormous. Technology cannot reduce the cost of the materials and raw labor required to insert a concrete and steel structure into a river corridor. Plus, dams are environmentally destructive, necessitating expensive environmental mitigation efforts, often of questionable value.

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[16] Based on Bureau of Reclamation calculation of evaporative losses of 8,568 acre-feet over the three-day Labor Day weekend 1997. Estimate of families served is based on *The River of Controversy: Persistent Issues*, New Courses for the Colorado River, David H. Getches and Charles J. Meyers. One acre-foot of water is sufficient to supply the domestic needs of an average family of five in the West for a year.

[17] W. O. Smith, Comprehensive survey of sedimentation in Lake Mead, 1948-49. Publisher: Washington: U.S. Govt. Printing Office, 1960.

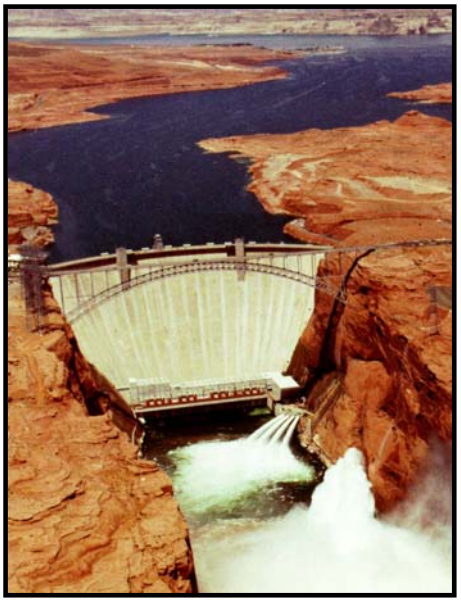
In the race to secure the allocations promised in the Law of the River, states often fail to consider the common state of the basin, as evidenced by discussions about building more storage. It appears that the river may not be able to provide the amount of water needed to fulfill the allocations. In this situation, there is no opportunity for the federal government to buy the states out of their drought/growth conundrum by building more dams. Developing large reservoirs would not only be ultimately ineffective in solving the drought problems, but would aggravate impacts of the drought by increasing evaporative loss and diverting limited funds to dam building rather than to more effective options.

Trans-Basin Pipelines Infeasible

Similarly, water importation via trans-basin pipelines is a speculative concept that can be considered off the table for Colorado River states' short-term drought planning and long-term water use reform. It is simply not feasible. The notion of importing water into the Colorado River basin from outside the basin has had a long history of thought and consideration and has always been rejected.

Importation is unrealistic both in terms of political and environmental considerations. There might already be a consensus in the basin because no governor has seriously called for consideration of water importation either to resolve short-term drought crises or to play a part in long-term planning. As in the case of new dams, because trans-basin pipelines are so infeasible, focusing on them as a possible solution detracts attention from other more promising ideas.

Hydropower Issues in Drought Scenarios



Glen Canyon Dam Hydropower Production

The major impact of drought in the Colorado River basin will be felt first when Glen Canyon Dam cannot produce power due to low water elevations. In a severe drought situation, the value of hydropower must be balanced against the value of water for consumptive or in stream uses.

The Colorado River Compact, in Article IV (b) subjugates production of hydropower to other uses of Colorado River water: *"Subject to the provisions of this compact, water of the Colorado River system may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes."*

Although cheap hydropower has been a benefit of the Colorado River reservoir and dam system, there is a ready substitute for hydropower, which is easily replaceable with alternative sources such as wind, solar and geothermal techniques or simply through basic conservation. Further,

there is arguably a significant surplus of power in the system currently, [18] and there are at least six new power plants under construction or permitted in the southwest alone.

However, the cost of operating a thermal plant is higher than the minimal direct costs of operating Glen Canyon Dam for power. Also, the peaking character of hydropower is not easily replaced by coal-fired plants, though peak load demand-side management, such as incentives offered by utilities for using less power during peak business hours, would help ease the transition away from dependence on hydropower. Further, hydropower creates a revenue stream currently utilized in both basins to fund environmental projects such as fish recovery programs. There is currently no plan for replacing those revenues should hydropower production cease at Glen Canyon Dam.

Falling water levels in Lake Powell have already caused a decrease in power production at Glen Canyon Dam. Because releases through the dam are less than they would be under average conditions -- 8.23 million acre-feet currently versus an average 11.5 million acre-feet in the past -- hydropower production is already down by approximately 30 percent at Glen Canyon Dam.

As a whole, the Colorado River upper basin hydropower system produces, on average, 6,000 gigawatt hours (GWh) of power. In 2005, with reservoir levels down at every major hydropower facility, Western Area Power Administration estimates that only about 3,400 GWh will be produced.

Wind farm near Palms Springs, CA

There are approximately 16,000 wind turbines operating in California. These turbines generate over 3,000 million kWh of electricity per year, enough to meet the residential electricity needs of over 1.3 million Californians.

Photo courtesy National Renewable Energy Laboratory, Photographic Information Exchange

Glen Canyon Dam alone produces about 5,100 GWh of power annually when the turbines are operating at full capacity. This equals about three percent of the energy on the western transmission system grid. (The grid covers the Missouri River to the California coast and Canada to Mexico, while the power from Glen Canyon is delivered primarily to the western United States.) The power from Glen Canyon produces about $110 million per year in revenues.

The cost of replacing Glen Canyon Dam power is likely to be borne by the approximately 1.7 million customers who receive power from the Dam. The increased cost could be borne by the federal government through tax subsidies. However, a report commissioned by the Bureau of Reclamation argues, "*if the beneficiaries of Glen Canyon Dam have*

[18] David A. Hartman, Glen Canyon Dam Beach/Habitat Building Test Flow: An Ex Post Analysis of Hydropower Cost, U.S. Bureau of Reclamation, Rep. EC-97-01, 1997.

traditionally been subsidized at the expense of taxpayers and the environment, it is acceptable that they [taxpayers] *bear the cost of altered operations.*"[19] Even under that scenario, the increased cost to each customer is estimated to be minimal, on the order of 65 cents per person, per year.[20]

While the southwest has taken advantage of the cheap power to help fuel its growth, and revenue of $110 million is notable, the economic return from hydropower is not significant to the economy of the basin states. Much of the power produced by the Colorado River hydropower system is used to pump water to irrigation districts at highly subsidized rates and with little benefit to the public. Continuing these subsidies for what most economists believe is the least economically productive use of water in the basin is not wise.

Consideration of the environmental cost of hydropower adds another concern regarding the efficacy of hydropower production as a use of Colorado River water. A case in point of the environmentally destructive nature of hydropower and the consequential need for expensive mitigation measures is Glen Canyon Dam's impact on the Grand Canyon. The dam prevents 95 percent of the nutrient-rich sediment -- necessary for building beaches and supporting native wildlife and vegetation -- from entering the Grand Canyon river corridor; drastically reduces water temperatures; and eliminates the natural variation in flow regime necessary for ecosystem health. As a result, the Adaptive Management Program was put in place to design mitigation measures at a cost to taxpayers of approximately $100 million so far. Yet, implementation of experimental measures has done little to revive Grand Canyon species and ecosystems.

Hydropower production should not, therefore, drive policy making on the Colorado River for the simple reason that it's not worth it. The fact that hydropower is readily replaceable; its production is not essential to the economic prosperity of the southwest; and it is environmentally destructive creating the need for expensive mitigation measures, makes adjusting water use and delivery during a potentially long-term drought for power production purposes a costly and illogical option.

Indian Water Rights

Fifty-foot panel of petroglyphs on Wright Bar at Colorado River Mile 24.5

The stream of human history in the Colorado River basin stretches back at least 13,000 years and some archaeologists now speculate that native inhabitation of the Colorado River basin began as long as 30,000 years ago. Dozens of tribes have inhabited the Colorado River basin and its tributaries over the centuries, using its water for

[19] National Research Council, River Resource Management in the Grand Canyon, EC-70, 1996

[20] Richard Ingebretsen, Ph.D. "A Declaration of Independence for the Colorado River," The Canyon Country Zephyr, April-May 1998.

farming, drinking and basic survival needs long before the European occupation of the continent began. The river system's cultural, spiritual and practical significance to native people is reflected in the archeological records of tribes long extinct and in the oral history of modern Native Americans. Today, thirteen Native American tribes reside along the Colorado River and its tributaries.

Beginning in 1963, the claims of five Indian tribes to Colorado River water were decided by the Supreme Court under the Reserved Rights Doctrine. Indian water rights represent one of the most complex and lengthy dispute resolutions in the history of the country. But as of today, many tribes have resolved their reserved water rights claims through settlement agreements on the Colorado River and on other rivers throughout the West. On the Colorado, the Hopi and Navajo rights have not yet been quantified, and they could be significant.

Indian water rights are unlikely to provide significant relief from drought impacts either short or long-term. Tribes have senior rights to Colorado River water. But, on a practical level, some tribes currently do not use a substantial amount of their entitlement. Nor do most tribes have the financial capacity to develop the huge amounts of water to which they may be entitled. There are some situations in which current and future Colorado River water users may be able to negotiate the purchase of water supplies from tribes that gain water rights, though many claim settlements have restricted tribes to selling water only to certain pre-determined entities.

Some water interests view Indian water rights as a barrier to the continued development of Colorado River water. While provisions can be made for marketing tribal water, the quantification of tribal rights may leave important development decisions in the hands of the tribes. That water was promised to tribes generations ago and has never been delivered. Resolving remaining claims on Colorado River water by Native American tribes remains a national obligation and Colorado River stakeholders have a responsibility to see that those rights are quantified, preferably through settlement rather than through protracted litigation.

Colorado River Mile 162.7: Fort Moki Indian ruin, view upstream from left bank

March 1963 photo by Dr. Felix E. Mutschler

CHAPTER SIX: RECOMMENDATIONS

For over 80 years the Law of the River has remained relatively untouched and even unstudied in terms of flexibilities for dealing with a severe, sustained drought coupled with the explosive population boom.

The drought that many thought the region would never experience is here now—and perhaps is here to stay. Meanwhile, the basin states struggle under the burden of a law designed to allocate abundant water in a sparsely populated agrarian economy that disappeared decades ago. This is the time for creativity, the time for asking hard questions and certainly the time for an immediate response to the potentially critical situation.

Some basic steps must be taken to lay the foundation for short-term crisis planning and, perhaps more important, long-term Colorado River water use reform.

Address potential shortages through intrastate planning

Separate from basin-wide planning at the federal level, individual basin states and other stakeholders within state boundaries have a wide array of tools and techniques to begin addressing future shortages within the boundaries of their state laws and geographic borders.

Conservation

Basin states and stakeholders may cushion the impacts of water and energy reductions through conservation measures such as drip irrigation, xeriscaping, and use of water reclamation or gray water systems. While conservation is a fundamental first step, mitigation measures extend diminished supply but do not solve the fundamental problem. The focus must be on more efficient, prioritized use of available water and energy resources.

Agricultural Conversions

Agricultural use consumes nearly 80 percent of the Colorado River's flow. Supplementing urban uses with agricultural water holds great promise because of the sheer quantity of water available and because water sharing can be done without serious disruption of agricultural economies. Payments to willing sellers for the lease of their water will sustain agrarian economies and, in some cases, are already doing so. Other measures include conversion to drip irrigation where possible or allowing very small percentages of croplands, which consume a disproportionate amount of water to grow crops incompatible with arid landscapes or drip irrigation, to go fallow. State laws and policies that impede agricultural to urban or to in-stream conversions should be re-examined and, if necessary, reformulated to facilitate such conversions.

Demand-Side Management

Water pricing has not been subject to the usual market forces of supply and demand. Instead, the market for water has been manipulated by agricultural subsidies; and local, state and federal policies originally designed to foster economic growth. If western water were priced according to actual market forces, it would create a dramatic incentive to conserve. Policy makers may also control demand by implementing rate structures and other creative pricing plans including user surcharges, fees for new and established pumps, or declining block pricing.

Land Use Planning

The U.S. Census Bureau population projection shows an increase of over 50 percent for the basin states by 2025, equaling a total of 70 million additional people. And, according to Department of Energy global warming predictions, the river will likely be producing ever less water. Meanwhile, most basin cities and states lack serious growth planning: no state in the basin has comprehensive land use planning that is linked to water supply.

It may be necessary to more widely adopt the precepts of smart growth throughout the Colorado River watershed. In some parts of the basin, growth will need to be constrained until sustainable plans for development, including water supply and demand, can be developed.

The Secretary of the Interior should take a leadership role

Strong leadership at the federal level is absolutely necessary to sort out the sometimes-opposing goals of the participating states and stakeholders. The Colorado River Basin Project Act gives the Secretary of the Interior ("the Secretary") the statutory authority to develop a regional water plan. Each of the states and other stakeholders must recognize the limits of the river and its productivity as indicated by the recent drought. But the Secretary must recognize that the parochial desires of state leaders are often not in the best interest of the basin as a whole. The Secretary should encourage solutions that states and other stakeholders may not undertake unilaterally. The federal government designed and promoted the Compact in 1922 and now has an obligation to return to the table in a leadership role and bring together all the critical parties to resolve the issues.

Given the enormous social, economic and political restructuring in the basin since the Law of the River was written, the existing arrangements, including dispute resolution processes for resolving the ambiguities in the Law of the River, are inadequate for the task of facing long-term drought. The Secretary, therefore, should be a convener of the states, environmental interests, Indian tribes, the recreation community, and other stakeholders to discuss both developing a structure for living within the limits of the natural productivity of the river as well as a dispute resolution process.

Alternatively, the basin states' governors and other relevant parties might try a new approach by convening a forum and inviting the Secretary to participate. The stakeholders could present options to the Secretary for both short-term drought responses and long-term Colorado River water sustainable use plans. The Secretary should then take action in a sufficiently short time frame dictated by the urgency of the situation.

Consider adjustments within the Law of the River

Any and all changes in the way the Law of the River operates that will result in sustainable Colorado River water use should be considered. Operating criteria developed by the Department of the Interior specify an annual delivery requirement of 8.23 million acre-feet from the upper basin to the lower basin. However, a likely interpretation of the law is that the upper basin has the option of delivering less than 7.5 million acre-feet in some years so long as it delivers 75 million acre-feet over a ten-year period, plus its apportioned amount for Mexico This could offer upper basin states flexibility in times of drought but cause the lower basin to suffer the deficits for as long as ten years. Further, current operating criteria anticipate surpluses but give inadequate attention to drought and impacts of drought. Revisiting both annual and long-range operating criteria to make specific provisions for shortages is imperative.

Negotiate acceptable shortage criteria

Planning for the past 80 years has revolved around Colorado River water surplus. Yet the basin drought began in earnest five to nine years ago. In this situation, the basin states, federal agencies and other stakeholders have recently begun to discuss plans for a severe and potentially long-term drought. Such planning should be held publicly for the purpose of public interest input, and should be a priority.

Undertake interstate solutions

Water marketing and water banking offer market-based opportunities that allow cooperating states within each basin to resolve water shortage issues, at least in the short-term. Market-based agreements between states, which allow states to buy or lease water beyond their Compact allocation from willing sellers, provide a flexible mechanism for dealing with drought impacts. Examples include such agreements as the Metropolitan Water District of California and the Central Arizona Water Conservation District; and the Arizona –Nevada agreement. (See *Land Use Planning*, Chapter Five.) But, in some cases, momentum and creativity on interstate agreements is hampered by restrictions assumed to be in the Law of the River. The Law of the River should create an accepted formal structure that encourages and supports states and other stakeholders who want to enter into voluntary solutions for specific water shortage situations.

Consider alternate storage options

Basin storage options including underground storage and combining supplies to reduce the enormous evaporative losses sustained by the system should be considered. Within certain limits, an interpretation of the law that recognizes underground storage as a legitimate use could benefit the basin's overall water situation by minimizing evaporation. A second storage option that would reduce current evaporative losses and increase supplies for consumptive and instream uses would be to temporarily combine water from two or more reservoirs into a single reservoir and deal with allocations via a water accounting system.

Re-examine federal policy

Drought planning could benefit from an examination of federal policies that hamper water management in the basin, particularly during drought. Federal subsidies, for instance, may need to be shifted to help agricultural entities respond to the pressures of a drought as well as to pave the way for more valuable uses of water for municipalities. A primary emphasis needs to be on reducing demand through addressing excessive agricultural use, a function of federal farm policy.

CONCLUSION

The Colorado River is the foundation on which the West was built. It fuels growth in every community that it touches; it has sustained Native American tribes through the ages; it has created canyons, wetlands and estuaries that support some of the most diverse wildlife on earth; and it feeds the human experience, adding an immeasurable dimension to our quality-of-life. Yet in the post-modern race towards prosperity and progress, some stakeholders have failed to recognize that the river is limited in what it can produce. Today, even as the river begins to reveal its limits in the face of ever-increasing human demand, some seek to further develop water that doesn't exist, and that perhaps never really existed except on paper.

At the end of the day, we have to recognize that there are environmental systems dependent upon the water of the Colorado River. For the most part, none of those systems have any recognized legal entitlements to the water. Those systems exist irrespective of any documents we've created and or any geographic boundaries, which are largely biologically irrelevant. As we begin to think about sustainable use of the river, we have to foster some mechanism that recognizes those environmental systems and that creates an entitlement for them.

The current drought has made it clear that the basin states and other stakeholders cannot use the Colorado River in the future as they have in the past. There simply is, and likely will continue to be, less water than was promised by the Colorado River Compact. It is encouraging that the basin stakeholders have begun discussions about developing drought criteria and that the Secretary of Interior appears willing to step in if the situation requires action. With careful planning, there will be enough water for all stakeholders.

Colorado River water users have the opportunity and the responsibility to make historic leaps in water management that will result in sustainable levels of growth, healthy wildlife habitats, recreational opportunities and a magnificent river that provides a vibrant experience for all who encounter it.

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The Grand Canyon Trust produced this report to promote preservation of the Colorado River and sustainable use of its waters in support of our mission "*to protect and restore the Colorado Plateau – its spectacular landscapes, flowing rivers, clean air, diversity of plants and animals, and areas of beauty and solitude.*"

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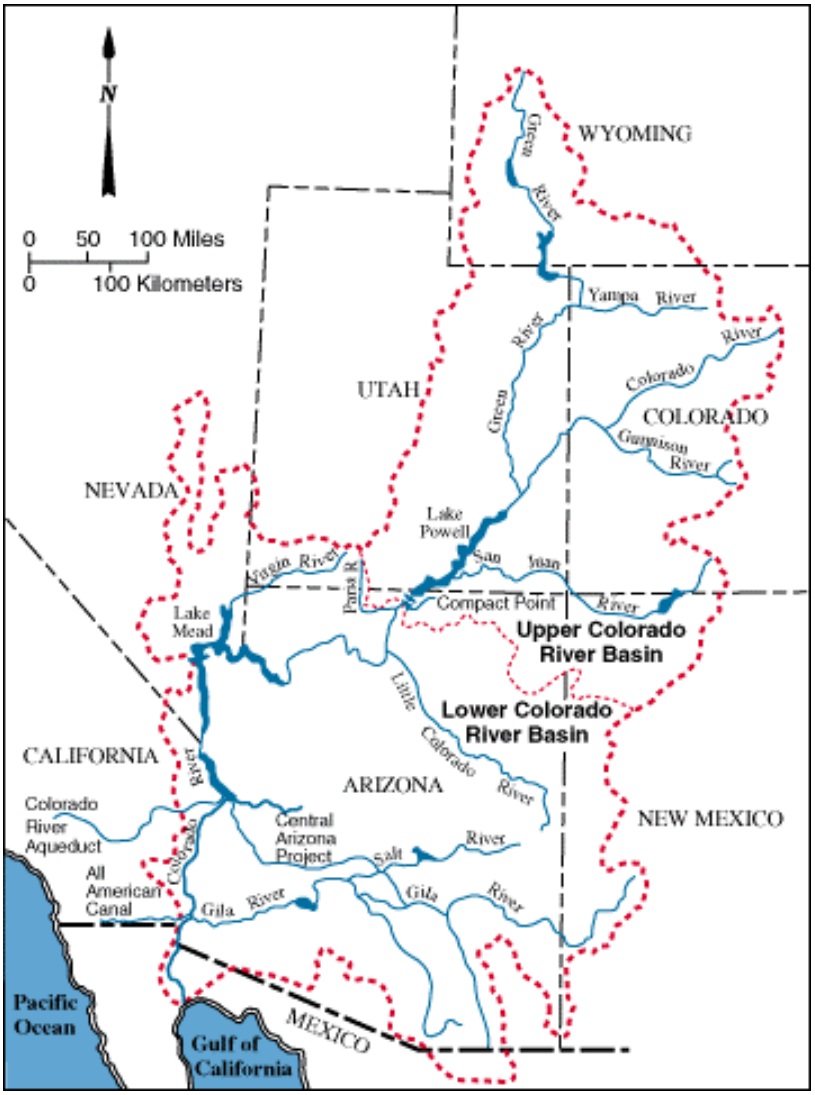
Final Note

This report is a work in progress. As conditions on the Colorado Plateau change and policy decisions are made, the facts associated with protection and use of the Colorado River will evolve. We are continually working to understand those changes in order to promote long-term sustainable use of the Colorado River for the benefit of all communities, creatures and habitats dependent upon it.
This paper and any updates will be posted to our website at: www.grandcanyontrust.org

APPENDICIES

Appendix A: Colorado River Basin Map



Appendix B: 1922 Colorado River Compact

COLORADO RIVER COMPACT
signed at Santa Fe, New Mexico,
November 24, 1922

The States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, having resolved to enter into a compact under the act of the Congress of the United States of America approved August 19, 1921, (42 Stat. L., p. 171), and the acts of the legislatures of the said States, have through their governors appointed as their commissioners: W. S. Norviel for the State of Arizona, W. F. McClure for the State of California, Delph E. Carpenter for the State of Colorado, J. G. Scrugham for the State of Nevada, Stephen B. Davis, Jr. for the State of New Mexico R. E. Caldwell for the State of Utah, Frank C. Emerson for the State of Wyoming, who, after negotiations participated in by Herbert Hoover, appointed by the President as the representative of the United States of America, have agreed upon the following articles.

ARTICLE I

The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River system; to establish the relative importance of different beneficial uses of water; to promote interstate comity; to remove causes of present and future controversies and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two basins, and an apportionment of the use of part of the water of the Colorado River system is made to each of them with the provision that further equitable apportionment may be made.

ARTICLE II

As used in this compact:

(a) The term "Colorado River system" means that portion of the Colorado River and its tributaries within the United States of America.

(b) The term "Colorado River Basin" means all of the drainage area of the Colorado River system and all other territory within the United States of America to which the waters of the Colorado River system shall be beneficially applied.

(c) The term "States of the upper division" means the States of Colorado, New Mexico, Utah, and Wyoming.

(d) The term "States of the lower division" means the States of Arizona, California, and Nevada.

(e) The term "Lee Ferry" means a point in the main stream of the Colorado River 1 mile below the mouth of the Paria River.

(f) The term "Upper Basin" means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry.

(g) The term "Lower Basin" means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system below Lee Ferry.
(h) The term "domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power.

ARTICLE III

(a) There is hereby apportioned from the Colorado River system in perpetuity to the upper basin and to the lower basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.
(b) In addition to the apportionment in paragraph (a), the lower basin is hereby given the right to increase its beneficial consumptive use of such waters by 1,000,000 acre-feet per annum.
(c) If, as a matter of international comity, the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River system, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus shall prove insufficient for this purpose, then the burden of such deficiency shall be equally borne by the upper basin and the lower basin, and whenever necessary the States of the upper division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph (d).
(d) The States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years reckoned in continuing progressive series beginning with the 1st day of October next succeeding the ratification of this compact.
(e) The States of the upper division shall not withhold water, and the States of the lower division shall not require the delivery of water, which cannot reasonably be applied to domestic and agricultural uses.
(f) Further equitable apportionment of the beneficial uses of the waters of the Colorado River system unapportioned by paragraphs (a), (b), and (c) may be made in the manner provided in paragraph (g) at any time after October 1, 1963, if and when either basin shall have reached its total beneficial consumptive use as set out in paragraphs (a) and (b).
(g) In the event of a desire for further apportionment as provided in paragraph (f) any two signatory States, acting through their governors, may give joint notice of such desire to the governors of the other signatory States and to the President of the United States of America, and it shall be the duty of the governors of the signatory States and of the President of the United States of America forthwith to appoint representatives, whose duty it shall be to divide and apportion equitably between the upper basin and lower basin the beneficial use of the unapportioned water of the Colorado River system as mentioned in paragraph (f), subject to the legislative ratification of the signatory States and the Congress of the United States of America.

ARTICLE IV

(a) Inasmuch as the Colorado River has ceased to be navigable for commerce and the reservation of its waters for navigation would seriously limit the development of its basin, the use of its waters for purposes of navigation shall be subservient to the uses of such waters for domestic, agricultural, and power purposes. If the Congress shall not consent to this paragraph, the other provisions of this compact shall nevertheless remain binding.

(b) Subject to the provisions of this compact, water of the Colorado River system may be impounded and used for the generation of electrical power, but such impounding and use shall be subservient to the use and consumption of such water for agricultural and domestic purposes and shall not interfere with or prevent use for such dominant purposes.

(c) The provisions of this article shall not apply to or interfere with the regulation and control by any State within its boundaries of the appropriation, use, and distribution of water.

ARTICLE V

The chief official of each signatory State charged with the administration of water rights, together with the Director of the United States Reclamation Service and the Director of the United States Geological Survey, shall cooperate, ex officio.

(a) To promote the systematic determination and coordination of the facts as to flow, appropriation, consumption, and use of water in the Colorado River Basin, and the interchange of available information in such matters.

(b) To secure the ascertainment and publication of the annual flow of the Colorado River at Lee Ferry.

(c) To perform such other duties as may be assigned by mutual consent of the signatories from time to time.

ARTICLE VI

Should any claim or controversy arise between any two or more of the signatory States: (a) With respect to the waters of the Colorado River system not covered by the terms of this compact; (b) over the meaning or performance of any of the terms of this compact; (c) as to the allocation of the burdens incident to the performance of any article of this compact or the delivery of waters as herein provided; (d) as to the construction or operation of works within the Colorado River Basin to be situated in two or more States, or to be constructed in one State for the benefit of another State; or (e) as to the diversion of water in one State for the benefit of another State, the governors of the States affected upon the request of one of them, shall forthwith appoint commissioners with power to consider and adjust such claim or controversy, subject to ratification by the legislatures of the States so affected.

Nothing herein contained shall prevent the adjustment of any such claim or controversy by any present method or by direct future legislative action of the interested States.

ARTICLE VII

Nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes.

ARTICLE VIII

Present perfected rights to the beneficial use of waters of the Colorado River system are unimpaired by this compact. Whenever storage capacity of 5,000,000 acre-feet shall have been provided on the Main Colorado River within or for the benefit of the lower basin, then claims of such rights, if any, by appropriators or users of water in the lower basin against appropriators or

users of water in the upper basin shall attach to and be satisfied from water that may be stored not in conflict with Article III.
All other rights to beneficial use of waters of the Colorado River system shall be satisfied solely from the water apportioned to that basin in which they are situated.

ARTICLE IX

Nothing in this compact shall be construed to limit or prevent any State from instituting or maintaining any action or proceeding, legal or equitable, for the protection of any right under this compact or the enforcement of any of its provisions.

ARTICLE X

This compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination, all rights established under it shall continue unimpaired.

ARTICLE XI

This compact shall become binding and obligatory when it shall have been approved by the legislatures of each of the signatory States and by the Congress of the United States. Notice of approval by the legislatures shall be given by the governor of each signatory State to the governors of the other signatory States and to the President of the United States, and the President of the United States is requested to give notice to the governors of the signatory States of approval by the Congress of the United States.
In witness whereof the commissioners have signed this compact in a single original, which shall be deposited in the archives of the Department of State of the United States of America and of which a duly certified copy shall be forwarded to the governor of each of the signatory States.
Done at the city of Santa Fe, New Mexico, this twenty-fourth day of November, A. D. one thousand nine hundred and twenty-two.

W. S. Norviel
W. F. McClure
Delph E. Carpenter
J. G. Scrugham
Stephen B. Davis, Jr.
R. E. Caldwell
Frank C. Emerson

Approved: Herbert Hoover

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