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Colorado River Basin Water Management:
Evaluating and Adjusting to Hydroclimatic Variability

Recent studies of past climate and streamflow conditions have broadened understanding of long-term water availability in the Colorado River, revealing many periods when streamflow was lower than at any time in the past 100 years of recorded flows. That information, along with two important trends—a rapid increase in urban populations in the West and significant climate warming in the region—will require that water managers prepare for possible reductions in water supplies that cannot be fully averted through traditional means. Successful adjustments to these new conditions will entail strong and sustained cooperation among the many entities involved in Colorado River water management and science programs.

This report from the National Research Council resulted from concerns regarding the long-term adequacy of Colorado River water supplies. Severe drought conditions have affected much of the region since the late 1990s, with 2002 and 2004 being among the 10 driest years on record in the upper basin states of Colorado, New Mexico, Utah, and Wyoming. Water storage in the basin's reservoirs dropped sharply during this period due to very low streamflows; for example, 2002 water year flows into Lake Powell were roughly 25 percent of average.

During this same time period, there were several studies that produced "reconstructed" Colorado River flows over the past several centuries. These studies, based on data from annual growth rings of trees, show that there have been many past severe and extended droughts across the region. Just as important, they show that direct measurements of streamflow over the past 100 years, which have guided many administrative decisions for the river's allocation and use, may offer an overly optimistic forecast of future water availability.

The Colorado River basin extends over seven U.S. states and parts of northwestern Mexico.

This report assesses existing scientific information—including temperature and streamflow records, tree-ring based reconstructions, and climate model projections—and how it relates to Colorado River water supplies and demands, water management, and drought preparedness.

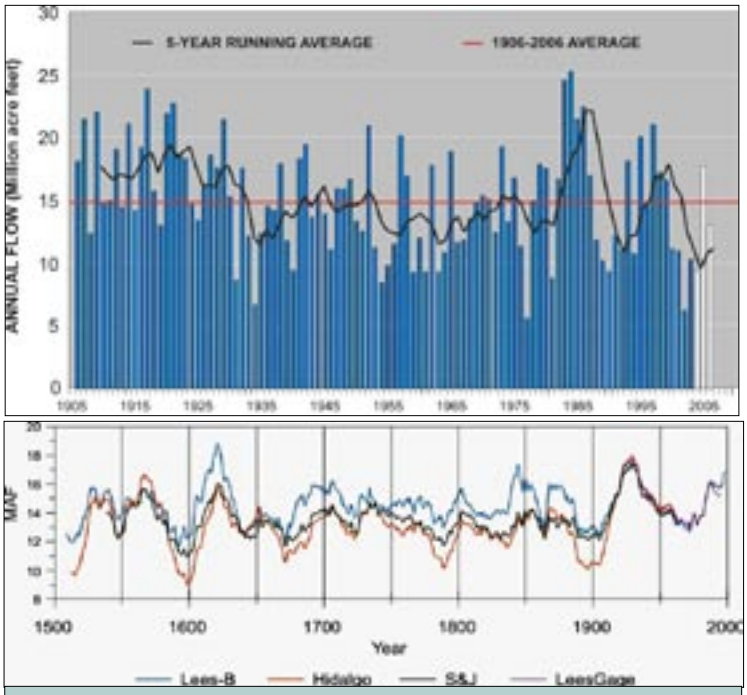
Past Climate Information is Creating a New Water Management Paradigm

For many years, scientific understanding of Colorado River flows was based primarily on measurements of the river's flow at gaging stations along the river. The first gaging stations on the river were established in the 1890s. As records of the river's flow measurements accumulated through the years and as the number of gaging stations grew, a more complete understanding of Colorado River

flows and variability emerged. For example, it is now known that the Colorado River Compact of 1922, which governs water allocations between the upper and lower Colorado River basin, was based on a short record of relatively high annual flows.

Since the 1970s, the gaged record has been complemented by many different studies of past hydroclimate conditions. Some of these studies are based on indirect, or proxy, evidence of past climates. Some of these proxy studies are based on tree-ring data. Because annual growth rings in trees at lower elevations can reflect moisture availability, tree-ring data can be used to reconstruct records of past river flows. Using data from coniferous tree species with long life spans in the Colorado River region, flow records dating back several centuries have been reconstructed.

Past water management decisions have been based largely on the gaged record, and there has been an implicit assumption that there is a single value of the river's average annual flow—about 15 million acre-feet/year—around which inter- annual flow variations occur. Even though the basin experienced wet and dry periods, river flows and weather conditions were expected to return to a "normal" state, largely defined by climate of the early and middle 20th century. However, recent tree-ring based reconstructions demonstrate that Colorado River flows occasionally shift into decadal-long periods in which average flows are lower, or higher, than the supposed mean value of 15 million acre-feet/year. These reconstructions reinforce the point that the gaged record covers only a small subset of the range of natural hydroclimatic variability in the river basin over several centuries. The basin's future hydrology thus may not be reasonably characterized based on the gaged record alone.



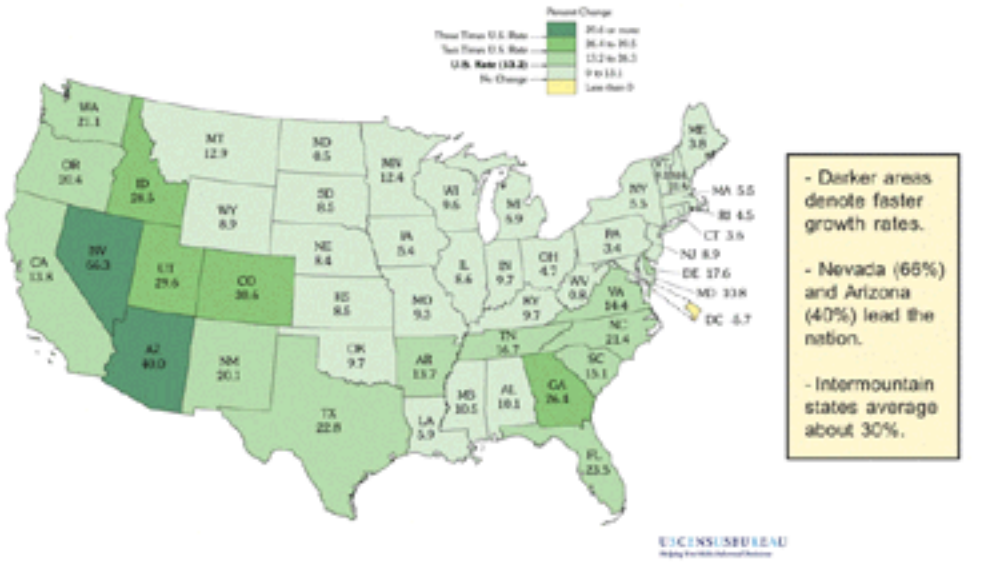
These two records reflect two different time periods of Colorado River flows at Lees Ferry, Arizona. The top panel represents the 1906-2006 record of gaged flows, with figures for annual values (blue bars), a 5-year running average (black line), and the average flow for this period (red line). The bottom panel shows four different reconstructions of Colorado River flows at Lees Ferry, which are based on tree-ring data and that date back roughly 500 years.

Regional Climate Warming Points to Reductions in Water Supplies

Temperature records across the Colorado River basin and the western United States document a warming trend over the past century. These temperature records, along with climate model projections, suggest that temperatures across the region will continue to rise in the foreseeable future. Higher temperatures will result in less upper basin precipitation falling and being stored as snow, increased evaporative losses, and will shift the timing of peak spring snowmelt to earlier in the year. There is less consensus regarding future trends in precipitation. However, based on analysis of many climate model simulations, the preponderance of scientific evidence suggests that warmer future temperatures will reduce future Colorado River streamflow and water supplies. Reduced streamflow would also contribute to increasing severity, frequency, and duration of future droughts.

Increases in Urban Water Demand Will Stress Supplies

Rapid population growth across the western United States is driving increases in water demand. From 1990-2000, Arizona's population increased by about 40 percent, while Colorado's population increased by about 30 percent. Population projections suggest that this trajectory will continue. Although many innovative urban water conservation programs have reduced per capita uses, population growth is driving increases in urban water demands; water consumption in Clark County, Nevada (which includes Las Vegas), for example, approximately doubled in the 1985-2000 period. Steadily rising population and increasing urban water demands in the Colorado River region will inevitably result in increasingly costly, controversial, and unavoidable trade-off choices to



U.S. Population Changes, 1990 to 2000. *Population growth rates in the Colorado River basin states are among the nation's highest and are fueling increases in water demands.*

be made by water managers, politicians, and their constituents.

A significant trend in the quest to meet rising water demand has been the sale, lease, and transfer of agricultural water rights to municipalities, particularly in southern California and Colorado (in Arizona, tribal settlements, with transfers to municipalities, have also been important). With about 80 percent of western U.S. water supplies devoted to irrigated crop production, agricultural water appears to constitute the most important, and perhaps final, large source of available water for urban use in the arid U.S. West. Modest shifts of agricultural water to municipal and industrial uses can do much to help meet increasing urban water demands. At the same time, however, agricultural-urban transfers often entail "third party" effects that include costs for rural communities, ecosystems, and others indirectly dependent on water supplies affected by the transfers. Moreover, even though the amount of water allocated to western agriculture is large, it is finite, and thus there are limits on its ability to satisfy expanding urban water demands.

Technologies and Conservation May Not Fully Meet Future Demands

A wide array of technological and conservation measures can be used to help stretch existing water supplies. These measures include underground storage, water reuse, desalination, weather modification, conservation, and creative water pricing structures. These measures may not necessarily be inexpensive or easy to implement, but many of them show promise and will continue to be pursued and developed as water supplies tighten in future years. However, technological and conservation options for augmenting or extending water supplies—although useful and necessary—in the long run will not constitute a panacea for coping with the reality that water supplies in the Colorado River basin are limited and that demand is inexorably rising.

Sustained Collaboration Important for Better Drought Preparedness

Drought conditions have prompted the Colorado River basin states to move toward a new level of cooperation. This is illustrated by a February 2006 letter from the seven basin states to the U.S. Secretary of the Interior, which was written in response to a request that the states develop guidelines for coping with water shortages. The interstate cooperation and initiative exhibited in this letter represent a welcome development that will prove increasingly valuable—and likely essential—in coping with future droughts and growing water demands.

In addition to interstate cooperation, enhanced communication and collaboration between the scientific and water management communities will be vital. The knowledge base of Colorado River hydrology and climate rivals and may exceed comparable knowledge bases for any of the world's river systems. Some of this information has been incorporated into key legal and operational decisions, but some of it may not be as well integrated in Colorado River basin water policy as it might be. A commitment to two-way communication among scientists and water managers is necessary for improving preparedness and planning for drought and other water shortages. Active communication

among people in these communities should be a permanent fixture within the basin, irrespective of water conditions at any given time. Such dialogue should help scientists frame their investigations around questions and topics of use to water managers, and should help water managers keep abreast of recent scientific developments and findings.

Basin-wide Evaluation Could Enhance Regional Water Management

The Colorado River Compact and many of the other federal and state statutes, interstate compacts, court decisions, and other operating criteria and administrative decisions that define the river's overall governance were framed in an era in which water for irrigation (and municipal uses in Southern California) was of paramount concern. Today, population growth and increasing water demands have moved urban water issues to the fore of the western water landscape, prompting municipal water managers to think creatively about ways to increase supplies and/or limit water use. States and municipalities have sponsored many innovative conservation, landscaping, and educational programs. There have been few initiatives, however, that systematically document and synthesize these efforts to compare and build upon lessons learned in managing limited urban water supplies. A more systematic and coordinated approach to urban water management and drought preparedness could be promoted through a collaborative investigation across the Colorado River basin.

The report thus recommends that a comprehensive, action-oriented study of Colorado River region urban water practices and changing patterns of demand be conducted. The study should evaluate a range of issues, including demographic projections and water demand forecasts, impacts of urban water demands on riparian ecology, and contemporary urban water policies and practices. The study could be conducted by the Colorado River basin states, a U.S. federal agency or agencies, a group of universities from across the region, or some combination thereof. The basin states and the U.S. Congress should collaborate on the commissioning and funding of this study, and they should be prepared to take action based on its findings in order to improve preparedness for future, inevitable droughts and water shortages.

Reservoir storage in Lake Powell, one of the basin's primary reservoirs, declined sharply in the late 1990s and early 2000s.

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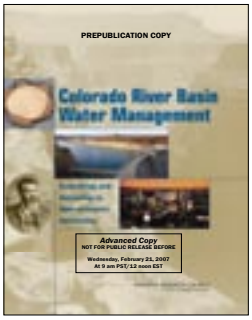

This report brief was prepared by the National Research Council based on the committee's report. For more information, contact Jeffrey Jacobs at (202) 334-3422 or visit http://nationalacademies.org/wstb. Copies of *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.