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Municipal Deliveries of Colorado River Basin Water

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Cover Photo: Aerial view of the Whitsett Pumping Plant, Courtesy © The Metropolitan Water District of Southern California

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This report is available online at no charge at http://www.pacinst.org/reports/co_river_municipal_deliveries/. Also posted at this website is the spreadsheet compiling water use and population data and calculating per capita use rates. The spreadsheet also lists the sources for the data used in this report.

About the Author

Michael Cohen is a senior research associate at the Pacific Institute and is based in Boulder, Colorado. He is the lead author of several Institute reports and the co-author of several journal articles on water and the environment in the border region.

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Executive Summary

The iconic Colorado River supplies water to millions of people in fast-growing cities in the Colorado River's watershed, such as Las Vegas, Mexicali, Phoenix, and St. George, Utah (see Figure ES-1 at the end of the Executive Summary). Tens of millions of people outside the watershed, from Denver to Albuquerque and from Salt Lake City to Los Angeles, San Diego, and Tijuana, also receive water exported from the basin to meet at least some of their residential and commercial water needs. More than half of the people receiving water from the basin live in southern California. In fact, about 70 percent of the people that receive water from the basin do not actually live in the basin. This study reports population and water delivery data and trends for 100 cities and water agencies that use Colorado River basin water, compiling such information for the first time in one location.

These municipal deliveries – which include deliveries to the residential, commercial, industrial, and institutional sectors, as well as some landscape irrigation, but do not include deliveries to agriculture, energy producers, or mining – comprise only about 15 percent of total Colorado River use (agriculture uses more than 70 percent). However, municipal deliveries are the fastest-growing sector, driving demands for additional water supplies, placing pressure on a river system that is over-allocated and facing a supply-demand imbalance, as well as the prospect of long-term declines in run-off due to climate change.

The number of people relying at least in part on water from the Colorado River basin increased by roughly 10 million people from 1990 to 2008, to a total of almost 35 million. Much of this increase occurred in areas experiencing extraordinary population growth: several cities in Arizona and Utah more than tripled in population between 1990 and 2008. The Las Vegas metropolitan area added upwards of a million people, more than doubling in size. Tijuana also roughly doubled in size, adding more than 800,000 people reliant on Colorado River water for an estimated 90 percent of their water supply.

Total water deliveries by these 100 agencies increased from about 6.1 million acre-feet in 1990 to about 6.7 million acre-feet in 2008. The volume of Colorado River basin water deliveries by these agencies also increased by about 0.6 million acre-feet over this period, from 2.8 million acre-feet to 3.4 million acre-feet, rising from 46 percent to 51 percent of total deliveries. The agencies delivering water in southern California actually delivered four percent less water in 2008 than they had in 1990, despite delivering water to almost 3.6 million more people. In fact, 28 water agencies in five different states delivered less water in 2008 than they had in 1990, despite population growth in their service areas.

Almost every one of the water agencies included in the study experienced declines in per capita deliveries from 1990 to 2008. People and business are demanding less water than they did in 1990. This report does not attempt to determine the causes of these declines, but it does quantify these changes over time, giving a picture of trends for municipal water providers. The majority of people receiving water from the Colorado River basin live in areas where per capita deliveries dropped an average of at least one percent per year from 1990 to 2008, generating substantial long-term declines. Many of these areas showed substantial reductions in per capita deliveries from delivery rates that were already much lower than average for the 100 agencies; it was not just the high per-capita-use agencies that demonstrated large reductions in per capita deliveries. Because of these substantial per capita declines, municipal water deliveries were roughly two million acre-feet lower than they would have been had per capita deliveries remained constant from 1990 to 2008.

Nine agencies' per capita deliveries actually increased from 1990 to 2008, though these agencies provide water to only about two percent of the total population receiving water from the basin. If the water agencies in this study had all experienced per capita declines of at least one percent, total deliveries would have increased by about 300,000 acre-feet, only half as much as the actual increase in municipal deliveries by these agencies. While small in comparison with the two million acre-foot reduction already achieved, 300,000 acre-feet is still a sizeable volume of deliveries that could have been avoided if the agencies with less than one percent average annual per capita reductions had been more efficient.

Total municipal water deliveries by agencies delivering water from the Colorado River basin increased by more than 600,000 acre-feet between 1990 and 2008, taking water from a basin that faces a future challenged by diminished supply and continued population growth. Yet the water delivery trends of many of these water agencies offer a route forward, where growth can be accommodated within existing supplies and total demands on the basin actually decline over time. The large number of water agencies from many parts of the Colorado River basin states and Mexico that have already achieved substantial declines in per capita deliveries demonstrate what increased water efficiency and conservation can accomplish and should encourage the less successful agencies to promote conservation and efficiency more aggressively in their own service areas.

Figure ES-1. The Colorado River Basin and Service Areas of Agencies Delivering Colorado River water[1]

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Abbreviations and Acronyms

ADWR	Arizona Department of Water Resources
AF	acre-feet
CO R	Colorado River
CRWUA	Colorado River Water Users Association
GPCD	gallons per capita per day
IID	Imperial Irrigation District
Metropolitan	The Metropolitan Water District of Southern California
MWD	Municipal Water District
Reclamation	Bureau of Reclamation
SDCWA	San Diego County Water Authority
SNWA	Southern Nevada Water Authority

Municipal Deliveries of Colorado River Basin Water

Introduction

The iconic Colorado River evokes images of thundering whitewater crashing beneath the towering walls of the Grand Canyon, limning the landscape of the rugged West. But the Colorado River is a working river, the lifeblood of seven states and parts of Mexico. Frank Waters wrote that the Colorado "is the greatest single fact within an area of nearly a quarter million square miles."[2] In fact, the river's importance extends well beyond its basin (see Figure ES-1). More than three million acre-feet[3] of its waters help meet the annual needs of millions of people who live outside of the Colorado River basin, from Cheyenne, Denver, and Albuquerque to Salt Lake City, San Diego, and Tijuana. The waters of the Colorado River mainstem and its tributaries have helped fuel the growth of some of the fastest-growing metropolitan areas in the U.S.,[4] including Los Angeles, Phoenix, Las Vegas, San Diego, California's Orange County and Inland Empire, Albuquerque, and Tucson. Since 1990, the total number of people in the United States and Mexico that use Colorado River basin water[5] has increased by more than ten million.

This study reports 1990, 2000, and 2008 population and water delivery data and trends for cities that use water from the Colorado River basin, compiling such information for the first time in one location. Figure 2 shows the extent of the Colorado River basin, as well as some of the locations outside of the basin that receive Colorado River basin water. As described in the following sections, Colorado River basin water encompasses diversions from the mainstem of the Colorado River and from its tributaries throughout the basin – including water exported from the basin for municipal deliveries – and also includes groundwater pumped from within the Colorado River basin. Municipal deliveries means water delivered by municipal providers or wholesalers, not including agricultural deliveries. Generally, such municipal deliveries go to the residential, commercial, institutional, and industrial sectors and for landscape irrigation, but do not go to energy producers, mining, heavy industry, or for stock watering.

This study tracks municipal deliveries rather than consumptive uses; cities within the basin typically return 40 percent or more of their deliveries back to the Colorado River system, for re-use downstream. Municipal demand is the fastest-growing of the various sectors that rely on water from the Colorado River basin, but agriculture still consumes more than 70 percent of Colorado River water. In the year 2000, when the Colorado River mainstem reservoirs were nearly full, total reservoir evaporation (a consumptive use) was equivalent to more than half of the total volume of basin water delivered to municipalities. Municipal deliveries are a fast-growing demand on the system, but are not the major demand.

This winter saw unusually heavy snowfall in the northern portion of the Colorado River basin. Total run-off in the basin this year could exceed 128 percent of average. In late 2010, Arizona and Nevada water managers faced the prospect of shortage declarations[6] as early as 2012, based on run-off projections of the time and the rapidly diminishing storage at Lake Mead.[7] Thanks to this year's very high run-off, the surface elevation of Lake Mead will rise to more than 30 feet higher than 2010 elevations, pushing the prospect of Arizona and Nevada shortages several years into the future. But one wet year does not overcome the Colorado River's long-term supply-demand imbalance. As shown in Figure 1, total demands on the Colorado River now exceed supply: Colorado River users now face a structural deficit. To date, basin water users have overcome this supply imbalance by drawing from storage, but this is not a sustainable approach over the long term. Rapid population growth in the region and the likelihood that climate change will diminish supply[8] will only exacerbate this imbalance in coming years.

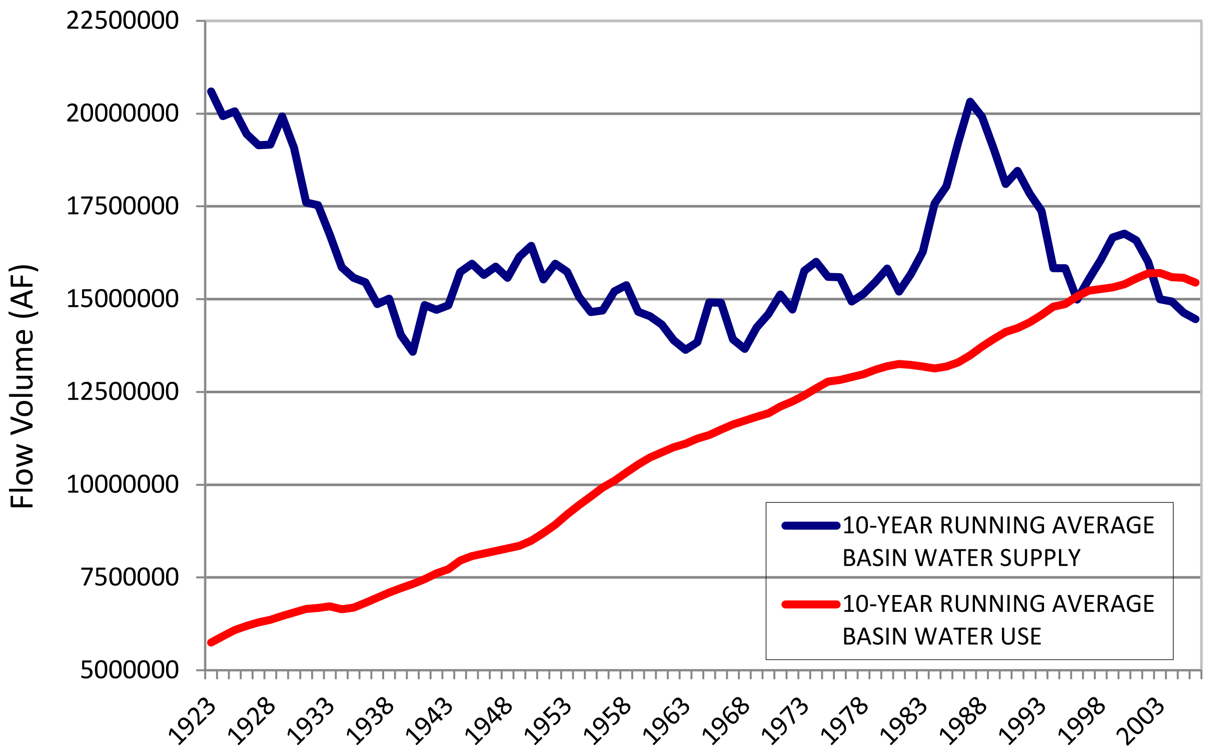

Figure 1. Supply and Demand on the Colorado River[9]

Partly in response to these projected shortages and the long-term supply-demand imbalance, the Bureau of Reclamation's Upper Colorado and Lower Colorado Regions, in collaboration with representatives of the seven Colorado River basin states (Arizona, California, and Nevada in the lower basin and Colorado, New Mexico, Utah, and Wyoming in the upper basin), initiated a "Colorado River Basin Water Supply and Demand Study" in 2010 to define current and future imbalances in water supply and demand in the Colorado River Basin and the adjacent areas of the Basin States that receive Colorado River water, and to develop and analyze adaptation and mitigation strategies to resolve those imbalances.[10]

The Pacific Institute has long promoted water conservation and water-use efficiency as inexpensive and effective means to mitigate the increase in demand associated with population growth and, by extension, with water supply-demand imbalances.[11] Due to a variety of factors, including rising industrial and irrigation efficiency and increasingly stringent federal water-use efficiency standards, per capita water use across the nation, calculated as total water withdrawals (including those for agriculture and for energy uses) divided by population, fell by 28 percent from 1975 to 2005.[12] The total volume of water withdrawn nationwide in 2005 was lower than it was in 1975, despite substantial economic and population growth. This is a significant achievement, demonstrating that water demand can be successfully delinked from growth.

In the seven Colorado River basin states as a whole, per capita water use declined by 21 percent from 1975 to 2005, less than the national average of 28 percent. Total annual public water supply withdrawals for domestic uses in the seven basin states actually doubled over this period.[13] The decline in per capita water use in the Colorado River basin states is an important, positive development in a basin that is frequently described as headed towards crisis. Many municipal residents in the West have decreased their water use, in response to increasingly stringent plumbing codes and fixture replacements, as well as to utilities' efforts to decrease consumption and in the face of the decade-long drought affecting the Colorado River basin. For example, total system-wide per capita water deliveries in The Metropolitan Water District of Southern California (Metropolitan) service area decreased by more than 23 percent from 1990 to 2008;[14] total system-wide per capita water deliveries in the Southern Nevada Water Authority's (SNWA's) service area decreased by almost 31 percent in the same period.[15] These decreases represent more than a million acre-feet of reduced demand each year relative to what demand would have been had water delivery rates remained constant. That is, if residents, businesses, and institutions in the Metropolitan and SNWA service areas demanded water at the same rates in 2008 as they had in 1990, they would have required an additional million acre-feet of water in 2008. This dramatic reduction in system-wide per capita deliveries means that pressure on the over-allocated Colorado River is not as great as it would have been had historic water-use rates continued, diminishing the need to augment supplies and build costly, energy-intensive new capital projects or implement new water transfers from agriculture. These per capita reductions in water deliveries help demonstrate how the Colorado River basin can make the transition to a drier future.

This study describes the volumes of water delivered by cities and water providers using Colorado River basin water to meet at least some portion of their municipal and industrial demand. The study reports population and both Colorado and non-Colorado water delivery data (as available) and trends for cities that use Colorado River basin water, compiling such information for the first time in one location. The following sections describe the objective, scope, methods, and data sources for this research. Section 4 lists water deliveries, population, and per capita deliveries by water provider (organized by state, in alphabetical order, followed by Mexico) for the years 1990, 2000, and 2008, where available.[16] Section 5.0 offers comments and conclusions on the changing delivery rates and trends in water deliveries in the Colorado River basin states and in Mexico.

Sidebar 1: Colorado River Basin Water

This study broadly defines "Colorado River basin water" to include all surface water and groundwater originating in the Colorado River basin. In many cases, it is difficult to determine the hydrologic connections between surface water and groundwater extracted from within the Colorado River basin. For example, groundwater supplies about 43 percent of Arizona's total municipal water demand; much – but not all – of this groundwater is extracted from regions with active management programs that include groundwater recharge, recharge that typically comes from effluent or from surface water diverted from the Colorado River mainstem or major tributaries. The actual groundwater extracted may not have any natural connection to Colorado River basin surface water, but there may be an institutional connection, via the recharge programs, that creates such a hydrologic link.

Study Objective

The objective of this study is to document changes in the per capita and total volumes of municipal deliveries of Colorado River basin water from 1990 to 2008, and to estimate the total volume of water conserved by such changes in municipal deliveries.

Scope

This study reports total municipal deliveries, generally for the years 1990, 2000, and 2008, for 62 cities and water providers with service area populations greater than 10,000 in the year 2000 that directly use Colorado River basin water to meet at least some portion of municipal demand, and for another 40 water providers with more limited data. This study includes the full hydrologic extent of the Colorado River delta – and the watershed supplying that delta – as part of the basin, including the cities within the Coachella Valley, the Imperial Valley, and the Mexicali Valley, as shown in Figure ES-1.

This study reports total water deliveries, including diversions from surface streams and extraction from groundwater,[17] but does not report return flows or consumptive uses. While this focus on diversions and groundwater pumping is consistent with municipal water-use planning, it does not reflect return flows and downstream re-use of water; in parts of the basin, more than 40 percent of water diverted for municipal use makes its way back to the system as return flows. Direct municipal uses constitute a small fraction of total consumptive uses of Colorado River basin water.

Municipal water agencies typically project future water needs as a function of total water demand – that is, total deliveries – rather than net consumptive use.[18] To be consistent with municipal water agency demands and projections, this study reports total municipal water deliveries and, to the extent possible, excludes agricultural water and water delivered for thermal electric power generation, stock watering, self-supplied industrial uses, and mining. Water providers deliver water to meet various municipal demands, including residential, commercial, institutional (such as schools, hospitals, and government facilities), and some industrial. Some providers deliver water for landscape irrigation and for golf courses, while in other areas these outdoors uses are self-supplied or come from irrigation companies supplying untreated “ditch” water and are not reported by this study.

This study is *not* an effort to compare different cities’ water delivery rates. Such a comparison would control for the various factors affecting total municipal water deliveries, such as the relative percentages of single-family and multi-family residences, tourism, and commercial, institutional, and industrial demands. Many providers argue that such comparisons should also control for climatic differences, though as more and more cities encourage climate-appropriate landscaping, this becomes less of a factor. The system-wide demand of urban core cities such as Phoenix and Salt Lake City includes deliveries to hotels, hospitals, universities, and large government buildings that often do not exist in outlying bedroom communities, increasing core cities’ per capita delivery rates relative to those of the bedroom communities. Inter-city comparisons of single-family residential demands or multi-family residential demands can be valuable, and may encourage greater conservation by the less efficient cities, but they do not reflect total municipal demand, one of the greatest single factors driving questions about the sufficiency and reliability of future Colorado River basin water supply.[19]

This study is also not an effort to determine the factors affecting changes in delivery rates for individual cities. As shown by the two long-term examples included in Appendix A, reported annual deliveries can show large inter-annual variability. Determining the causes of such variability would require in-depth analysis on a city-by-city basis, well beyond the scope of this study.

The broad definition of Colorado River basin water used here is not the legal definition of Colorado River water.[20] This broad definition is intended to capture the uses of such water throughout the Colorado River basin states and in Mexico, and is not an interpretation of the Law of the River.[21]

Table 1 lists the municipal areas included in the study and their water service area populations, generally for the years 1990, 2000, and 2008, and their percentage growth from 1990 to 2008. Note especially the growth rates for areas served by water from the Colorado River basin. Some areas grew by more than 600 percent over this period; even many of the larger cities experienced very high growth rates, doubling in population in 18 years.

These water service area populations are generally self-reported; some agencies base their estimates on census data, while others calculate populations as a function of the number of residential accounts multiplied by an estimated number of people per account. This study reports municipal data for most of the larger cities using Colorado River basin water, but is not a comprehensive listing of all such cities. Despite repeated inquiries, some water agencies never provided requested data. Many cities receive water from private companies, which did not provide requested data and which often serve (portions of) multiple cities. Multiple providers serve several of the larger cities within the basin, complicating efforts to determine deliveries for the city as a whole; in some cities, more than 20 different water companies provide water to portions of the city. In Mexico, many residents do not have water service and rely on water trucks or other informal water providers. This study generally does not include rural communities with populations under 10,000 using basin water (often groundwater); in many areas, domestic wells are exempt from reporting requirements, challenging efforts to collect information on such water use.

Colorado River basin water meets the total water needs of about one-third of the number of people in Table 1; about two-thirds of the 33.5 million people listed below receive a blend of water, much or most of which comes from sources other than the Colorado River basin. The total service area population shown in Table 1 does not account for an additional million people in Arizona who rely on Colorado River basin water, but are not included in the above service area populations due to difficulty obtaining data,[22] and also does not include another 250,000 people included in service area populations with 2008 data but not 1990 data (described in the following sections). Including these people raises the total population relying on Colorado River basin water to meet at least a portion of their demands to almost 35 million people.

Table 1. Municipal Water Agencies Delivering Water From the Colorado River Basin

Water Agency/Provider	Agency-reported populations			
	1990	2000	2008	Growth 1990-2008
The Metropolitan Water District of Southern California (Metropolitan)	14,393,420	16,145,476	17,987,917	25%
Southern Nevada Water Authority	750,621	1,364,248	1,922,069	156%
Tijuana & Rosarito, Mex.*	829,233	1,323,214	1,632,508	97%
Phoenix, AZ	997,096	1,339,501	1,566,190	57%
Denver Water	891,000	1,000,000	1,154,000	30%
Tucson, AZ	662,251	835,504	952,670	44%
Mexicali, Mex.	363,149	568,983	890,932	145%
Albuquerque, NM	423,371	497,916	538,586	27%
Mesa, AZ	288,104	410,202	469,989	63%
Coachella Valley	235,722	332,485	462,386	96%
Colorado Springs, CO	303,522	382,693	424,416	40%
Salt Lake City, UT**	333,000	372,192	391,515	18%
Aurora, CO	222,103	276,393	313,144	41%
Chandler, AZ	95,288	180,536	250,619	163%
Glendale, AZ	148,873	209,099	248,731	67%
Scottsdale, AZ	130,880	204,680	242,790	86%
Gilbert, AZ	29,805	111,600	214,820	621%
Yuma, AZ	106,512	152,928	181,600	70%
Tempe, AZ	144,000	164,250	175,000	22%
Peoria, AZ	46,328	100,280	158,081	241%
Pueblo, CO	123,051	141,472	157,224	28%
Farmington, NM	107,381	133,287	146,597	37%
Grand Junction, CO	93,145	117,985	140,928	51%
San Luís Río Colorado, Mex.	95,461	126,645	138,796	45%

El Centro, CA	86,920	115,343	137,449	58%
Thornton, CO	75,950	99,874	136,510	80%
Fort Collins-Loveland, CO	95,900	118,300	128,700	34%
Greeley, CO	74,706	95,074	122,944	65%
Provo, UT	83,000	112,000	116,000	40%
Boulder, CO	98,065	110,073	114,963	17%
Prescott AMA, AZ	56,668	90,061	112,359	98%
Westminster, CO	75,000	101,052	110,938	48%
West Valley, UT	86,976	98,000	110,000	26%
Arvada, CO	89,700	103,200	106,400	19%
West Jordan, UT	42,892	65,000	102,000	138%
Payson, AZ	59,771	89,309	101,898	70%
Sandy, UT	87,304	118,107	99,750	14%
Orem, UT	68,000	90,000	93,202	37%
Sierra Vista-Douglas, AZ	64,645	78,013	87,671	36%
Longmont, CO	52,372	73,344	86,194	65%
St. George, UT	31,000	75,000	83,364	169%
Avondale, AZ	17,000	35,883	76,087	348%
Silver City, NM	56,874	70,270	72,659	28%
Flagstaff, AZ	45,857	52,894	64,200	40%
Cheyenne, WY	50,197	53,011	56,951	13%
Lake Havasu City, AZ	24,363	41,938	56,355	131%
Broomfield, CO	24,638	38,272	53,807	118%
South Jordan, UT	12,419	33,010	53,281	329%
Lehi City, UT	8,400	21,148	48,624	479%
Nogales, AZ	28,413	37,049	47,201	66%
Safford, AZ	32,081	42,281	45,110	41%
Montrose, CO	27,000	37,000	45,000	67%
Commerce City, CO	16,500	26,000	42,500	158%
Rock Springs, WY	38,823	36,500	39,944	3%
Riverton, UT	12,000	26,500	37,500	213%
Springville, UT	14,000	24,500	30,000	114%
Pleasant Grove, UT	13,000	24,300	29,104	124%
American Fork, UT	15,000	23,000	27,000	80%
Mesquite, NV	2,930	10,403	20,512	600%
South Salt Lake, UT	13,025	10,275	18,000	38%
Durango, CO	12,430	14,151	16,787	35%
Blythe, CA	8,125	12,335	13,467	66%
Total (rounded)	**23,500,000**	**28,800,000**	**33,500,000**	43%

*Rosarito became a separate *municipio* in 1995. **Combines data from two water providers serving Salt Lake City; see *Utah* section below for more information.

Methods

The guiding assumption driving this study was that water delivery data for any particular water agency could be compared with data for the same agency in a different year, but that water deliveries by different water agencies were not suitable for direct comparisons, due to differences in accounting methods, water use sectors, periods of measurement, and climatic differences.

Generally, the study developed in the following manner. First, using census records, I compiled a list of all metropolitan and micropolitan statistical areas[23] within the Colorado River basin itself. I then expanded the list with the statistical areas receiving trans-basin diversions, informed by Reclamation's decree accounting reports and the Colorado River Water Users Association website.[24] Identifying the agencies that actually deliver water to municipalities was an iterative process that involved reviewing agencies' service areas and, in some cases, conversations with water agency staff. In some cases, wholesale distributors such as Metropolitan deliver a mix of Colorado River and water from other sources to other wholesalers such as the San Diego County Water Authority, who in turn deliver water to municipal water agencies, creating several layers of water delivery data that often are not consistent due to differing accounting procedures, such as deliveries to or withdrawals from storage.

The study generally uses the years 1990 and 2000, because detailed census records exist for those years, and the year 2008, because this is the most recent year for which many agencies have published water delivery data. Selecting three years for comparison, rather than analyzing trends over multiple years, was simply a function of the limited scope of this study. Appendix A shows longer-term annual water delivery volumes by sector for two cities in Utah (because Utah's Division of Water Rights has an excellent website providing extensive data). Water deliveries in 2008 declined in some areas due to the recession. This inter-year comparison offers a picture of general trends for the large number of water providers included in the study, but is not definitive for any particular water agency.

We used several methods to obtain records of water deliveries and service area populations. Where available, we used non-agricultural water deliveries from agencies' published annual reports and annual financial reports, or state agency compilations of such data. When these reports were not publicly available, we requested such records directly from water agency staff via email and telephone. Table 2 lists data sources, by state, for the water providers included in this study. Please see *Data Sources* (on page 52) for a more complete list of the sources used in this study.[25]

Table 2. Data Sources

State	Sources
Arizona	*Arizona Water Atlas*,[26] individual water providers, Reclamation annual decree accounting reports, Arizona Corporation Commission reports
California	Metropolitan Annual Reports, individual water providers
Colorado	Individual water providers
Nevada	Individual water providers
New Mexico	New Mexico State Engineer Office's technical water use reports[27]
Utah	Utah Division of Water Rights
Wyoming	Individual water providers
Baja California (Mexico)	Comisión Estatal del Agua de Baja California
Sonora (Mexico)	Comisión Estatal del Agua de Sonora

No new measurements were made for this study. Unlike end-use studies designed to directly measure water use in individual homes or businesses, we simply compiled existing information on water deliveries and service area populations. In most cases, this information was reported by the individual water agencies.

Per capita water use was calculated from the service populations reported by the water agencies themselves. Some water agencies use census data to determine their service area populations. Others calculate populations as a function of the total number of residential connections multiplied by an assumed average number of persons per household.

Many water agencies delivering Colorado River water project total future water needs as a function of estimated future demand (in volume per capita per unit time, such as acre-feet per capita per year or gallons per capita per day) times projected population.[28] Typically, total system deliveries divided by total population yields per capita use,[29] though other methods to calculate per capita water use also exist.[30] To calculate per capita use, total reported deliveries[31] were divided by total reported service area population for each of the three years and multiplied by 893 to convert to gallons per day.[32] Per capita rates are reported as gallons per capita per day (GPCD). The change between 1990 and 2008 was calculated by subtracting the 2008 per capita use value from the 1990 per capita use value. The total municipal water deliveries that would have been required, had municipal demands continued unchanged at 1990 per capita rates, were estimated using this equation:

$$(\text{Per capita use rate}_{1990} \times \text{Pop}_{2008}) = \text{Projected Water Demand}_{2008}$$

Subtracting actual 2008 water deliveries from the projected water demand yields the net reduction in demand, which can be seen as the volume of water conserved due to changing water use behavior, increasingly efficient appliances, changing price structures, as well as economic factors, such as the effects of the ongoing recession and climate variability. These conserved water volumes were added together to yield a total for the Colorado River basin water users as a whole.

Climate

As shown in Appendix B, average monthly temperatures and total precipitation during the typical May-September irrigation season vary tremendously across the cities included in this report. Temperature and precipitation also vary between years in the individual cities, affecting their total water demand. However, this study reports actual water deliveries. No effort was made to adjust or normalize reported water deliveries to reflect annual climatic variations. Instead, this report uses the color coding shown in Table 3 to highlight climatic variations and provide a quick visual clue as to the magnitude such variations likely had on total water deliveries. Please see Appendix B for a detailed discussion of the methods used to develop this color coding.

Table 3. Climate Color Coding

>10% decrease
5-10% decrease
+/- 5% of normal
'5-10% increase
10-15% increase
>15% increase
No data

As discussed in Appendix B, assuming that a one degree monthly temperature rise increases water deliveries by one percent and that one additional inch of monthly precipitation decreases deliveries by two percent yields the projected climate impacts for the water providers shown in Table 4. Note that these projected impacts on total municipal deliveries are based on research in California and only reflect projected changes to deliveries during the months of May to September. Total annual impacts would be lower. The last column in Table 4, labeled "2008:1990," reports the relative difference in water deliveries between the two years as a function of climatic differences between the two. For example, climate variations in Colorado Springs in 1990 and 2008 likely increased water deliveries in both years relative to average conditions, but the relative difference between these two years was small, suggesting that climate was a negligible factor in any difference in actual water delivery rates between the two years. The table also shows that the year 2000 was hotter and drier than average for almost all cities listed, suggesting that water deliveries that year were higher than they would have been under average conditions.

Table 4. Estimated Effects of May-September Climate on Water Deliveries

City	Climate Effect on Deliveries			
	1990	2000	2008	2008:1990
Albuquerque, NM	-0.1%	15.3%	1.1%	1.2%
Blythe, CA*	1.5%	9.9%	10.4%	8.9%
Cheyenne, WY	2.6%	20.7%	-1.4%	-4.0%
Colorado Springs, CO	7.7%	16.6%	12.0%	4.3%
Denver Water, CO	6.9%	15.4%	1.5%	-5.4%
Farmington, NM*	6.6%	11.5%	3.6%	-3.0%
Flagstaff, AZ*	-4.4%	12.9%	8.9%	13.3%
Fort Collins-Loveland, CO*	8.3%	12.6%	-1.2%	-9.5%
Grand Junction, CO	13.9%	18.3%	7.0%	-6.9%
Imperial Valley, CA	-0.8%	9.6%	9.1%	9.9%
Metropolitan – north coastal	1.9%	10.6%	2.8%	0.8%
Metropolitan – north inland	3.5%	3.3%	6.4%	3.0%
Metropolitan – south coastal	0.3%	-1.9%	-3.0%	-3.2%
Metropolitan – south inland	3.4%	9.0%	10.8%	7.4%
Montrose, CO	5.2%	7.1%	3.4%	-1.8%
Phoenix, AZ	4.7%	16.7%	5.2%	0.4%
Rock Springs, WY	14.2%	15.2%	6.3%	-7.9%
Salt Lake City, UT	14.9%	15.1%	13.0%	-1.9%
Silver City, NM*	-5.0%	8.0%	-6.4%	-1.5%
SNWA, NV	-2.9%	12.1%	13.6%	16.5%
St. George, UT*	3.0%	18.6%	8.0%	5.0%

Note: Color coding per Table 3.
*Incomplete data.

Table 4 suggests that differences in temperature and precipitation may have generated measurable impacts on total municipal water deliveries for several water agencies, increasing 2008 deliveries markedly above what would have occurred had 1990 climate conditions repeated in 2008 in southern Nevada and Flagstaff, and to a lesser extent in several other areas. Conversely, lower temperatures and more precipitation may have depressed 2008 water delivery volumes relative to what would have occurred had 1990 climate conditions repeated in 2008, to a limited extent, in portions of Colorado and Wyoming.

Data Limitations

Given differences in reporting and data collection methods and incomplete records, the statewide summary values presented in this study should be considered general estimates only. Some agencies report water delivery data by calendar year, others by an October-September water year, others by a November-October water year, and still others by fiscal year, so annual summaries reflect a mix of reporting periods. Some agencies report total deliveries, including system losses and unmetered uses, while other agencies only reported total production volumes (as produced by water treatment plants or by groundwater wells). Some municipalities include converted agricultural lands that retain raw water rights that continue to be used for landscape irrigation, though such deliveries are not reported as municipal water use, meaning that reported municipal water deliveries are too low. While reports of water deliveries typically are consistent by agency, they preclude comparisons between agencies. We attempted to obtain water delivery data that did not include agricultural, mining, or thermo-electric volumes. In some cases, however, these end-uses were not specified and may be included in an agency's reported deliveries, increasing its system-wide per capita use relative to agencies that do not make such deliveries and to those that reported such deliveries separately. We did not attempt to verify that agencies' reporting methods remained consistent between 1990 and 2008.

Municipal Populations and Water Deliveries

How many people rely on water from the Colorado River basin? Estimates vary. According to some recent estimates, the Colorado River provides for at least a portion of the water needs of 30 million people in the United States and Mexico.[33] The Colorado River Water Users Association (CRWUA) website[34] lists total U.S. populations served by Colorado River water by state (except Wyoming, which does not list populations or acreages), as shown in Table 5, though the website does not specify a year for these values. Note that, for Arizona, these figures reflect populations and acres served by mainstem Colorado River.

Table 5. CRWUA-Reported U.S. Populations and Acres Served by Colorado River Water

State	Population	Irrigated acres
Arizona	3,080,000	560,000
California	Over 16 million	900,000
Colorado	2,300,000*	1,900,000
Nevada	1,700,000	-
New Mexico	1,000,000	100,000**
Utah	1,180,000	340,000
Wyoming	*not listed*	*not listed*
Total	***over* 25,000,000**	***over* 3,800,000**

*80% of this population served by trans-basin diversions
**Irrigated with San Juan River water.

As shown in Figure ES-1(page vi), the Colorado River basin also includes some 2,000 square miles in Mexico, containing the cities of Mexicali, Nogales, and San Luís Río Colorado. Like California to the north, Baja California exports Colorado River water out of the basin to its coastal cities of Tijuana and Rosarito, as well as to Tecate. In the following sections, this study describes deliveries of Colorado River basin water by U.S. state and for Mexico and offers estimates of the numbers of people served by this water. Consistent with Reclamation's accounting for most of the upper basin, this study includes water diverted and extracted from the Colorado River basin (including tributaries and groundwater), even though the direct hydrologic connection of some groundwater to surface water may be remote. This is not a legal interpretation of groundwater use or of Colorado River consumptive use.

Arizona

Arizona is the only state to lie almost entirely within the Colorado River basin. According to the Arizona Department of Water Resources (ADWR),[35] total water deliveries in 2006 (the most recent statewide data available) included 3.94 million acre-feet of surface water, 2.70 million acre-feet of groundwater, and 0.22 million acre-feet of effluent, for a total of 6.86 million acre-feet. Of this, approximately 1.7 million acre-feet (25 percent) were delivered for municipal and turf-related purposes. The only portions of the state not within the Colorado River basin are the Douglas and San Bernardino Valley basins in Cochise County in the southeast corner of the state and the San Rafael and the San Simon Wash basins along the border with Mexico. The City of Douglas is the only municipality with a population greater than 10,000 outside the Colorado River basin in Arizona. The combined populations in these four non-Colorado River basins in 2000 was 32,270, roughly 0.5 percent of the state's population as a whole; total municipal water deliveries in these four basins in the year 2000 was less than 0.5 percent of the state total.[36]

This study reports municipal water deliveries and generally does not include rural uses. This municipal focus therefore undercounts rural populations, including many Native American communities. For example, the Navajo Reservation covers more than 27,000 square miles – more than 10 percent of the Colorado River basin as a whole, primarily in Arizona but also extending into New Mexico and Utah. With the exception of a small amount of land in the Rio Grande basin at the easternmost edge of the reservation, Navajo lands lie almost entirely within the Colorado River basin. Navajo populations are overwhelmingly rural: Tuba City, the largest community in the Navajo Reservation, had fewer than 10,000 people in 2000. As much as 30 percent of Navajo households lack access to public water systems; many must purchase and haul water from distant sources.[37] In 2006, the total number of residential and institutional water service connections was 40,766, serving roughly 130,000 people, but total water deliveries were less than 10,000 acre-feet. Commercial water use on the reservation in 1995 was 6,695 acre-feet.[38]

Table 6 lists Arizona municipalities and water providers, service area populations, and reported water deliveries, generally for the years 1990, 2000, and 2008. All of the water deliveries listed in Table 6 are from the Colorado River basin. Note that some water wholesalers and private water companies deliver water to many cities, while in other cases, several different utilities may deliver water to a single city. Note also the extremely rapid population growth rates in many of the cities listed: for example, according to census estimates, Surprise grew from about 7,000 people in 1990 to more than 93,000 in 2008, a 15 percent annual growth rate. Many of these fast-growing cities do not have water-delivery records for the full study period. The listings for Payson, Sierra Vista, Nogales, and Safford reflect populations and water deliveries for ADWR-designated water basins, rather than just for the municipality listed. Note that the information for Payson reflects water deliveries for the Verde River basin, which includes Sedona, Cottonwood, Camp Verde, and other towns. The reported water deliveries for the City of Payson in 2008 (population about 16,000) was only 1,662 acre-feet, entirely from groundwater.

Table 6. Arizona Municipal Populations and Water Deliveries[39]

Service Area	Estimated Population			Water Deliveries (Acre-feet)		
	1990	2000	2008	1990	2000	2008
Phoenix	997,096	1,339,501	1,566,190	277,436	348,101	305,577
Tucson	*662,251*	835,504	952,670	*154,490*	179,600	194,000
Mesa	288,104	410,202	469,989	65,667	94,691	89,937
Chandler	95,288	180,536	250,619	24,385	49,289	63,070
Glendale	148,873	209,099	248,731	33,653	51,449	49,414
Scottsdale	130,880	204,680	242,790	49,017	77,091	83,603
Gilbert	29,805	111,600	214,820	7,780	28,996	47,357
Yuma	106,512	152,928	181,600	37,100	45,800	42,800
Tempe	144,000	164,250	175,000	50,734	59,703	49,894
Peoria	46,328	100,280	158,081	10,514	21,294	28,269
Prescott AMA	*56,668*	90,061	112,359	*10,000*	13,100	18,700
Payson	*59,771*	89,309	101,898	*11,800*	13,800	17,000
Surprise†	7,122	30,975	93,013	*458*	*1,332*	*2,864*
Sierra Vista-Douglas	*64,645*	78,013	87,671	*17,500*	19,300	19,500
Avondale	17,000	35,883	76,087	3,411	7,140	12,137
Flagstaff	45,857	52,894	64,200	8,541	8,912	8,485
Lake Havasu City	24,363	41,938	56,355	12,290	14,630	16,973
Nogales	*28,413*	37,049	47,201	*7,700*	8,600	9,300
Safford	*32,081*	42,281	45,110	*4,046*	4,271	5,136
Kingman[40]	?	?	44,000	5,504	7,294	8,720
Arizona Water Company[41]			156,000			33,885
Arizona American Water Company[42]			191,600			59,656
TOTAL††	**2,985,000**	**4,207,000**	**5,144,000**	**786,500**	**1,047,000**	**1,064,000**
Arizona Colorado River Basin Total‡	**3,647,000**	**5,105,000**	**6,161,000** (2006 estimate)			**1,700,000** (2006)

Note: Color coding per Table 3. ? = Unknown. *Italics represent ADWR-reported data for 1991*, underlined represents ADWR-reported 2005 populations, from the Arizona Water Atlas. †There are 13 drinking water service providers within the Surprise special planning areas; delivery volumes listed above are only for one such provider, to illustrate growth in water deliveries. ††Note that TOTAL does not include populations or delivery volumes for Kingman or for the private companies. ‡Colorado River basin total assumes that 99.5% of census-reported population lives within the Colorado River basin, consistent with totals reported by the Arizona Water Atlas.

All the areas shown in Table 6 experienced significant population growth and large, though lower, rates of growth in water deliveries. The total volume of water deliveries listed for 2008 reflects about 63 percent of total municipal water deliveries in 2006, as reported by ADWR, though total population served is about 86 percent of the reported 2006 population. This suggests that the city totals reported here undercount total municipal deliveries, or that the ADWR volume may include other industrial uses not counted in this report. Figure 2 shows the locations of Arizona municipalities and basins.

Figure 2. Arizona Water Atlas Planning Areas[43]

Table 7 shows system-wide per capita water consumption for the municipalities shown in Table 6. Per capita use has declined since 1990 in every city, though rates of decline and absolute per capita rates vary by more than a factor of three, from a high of 307 gallons per capita per day (GPCD) in Scottsdale to a low of 102 GPCD in the Safford area. Note that some of the water providers listed in Table 6 did not include sufficient information to calculate per capita reductions and therefore have not been listed below. The rates of decline are instructive, and can indicate which cities have made great strides in water conservation and which could do more.

Table 7. Per Capita Deliveries in Arizona

Service Area	Gallons per Capita per Day (GPCD)			Change 1990-2008	
	1990	2000	2008	GPCD	%
Phoenix	248	232	174	-74	-30%
Tucson	*208*	192	<u>182</u>	-26	-13%
Mesa	203	206	171	-33	-16%
Chandler	228	244	225	-4	-2%
Glendale	202	220	177	-24	-12%
Scottsdale	334	336	307	-27	-8%
Gilbert	233	232	197	-36	-16%
Yuma	311	267	210	-101	-32%
Tempe	315	325	255	-60	-19%
Peoria	203	190	160	-43	-21%
Prescott AMA	*158*	130	<u>149</u>	-9	-6%
Payson	*176*	138	<u>149</u>	-27	-15%
Sierra Vista-Douglas	*242*	221	<u>199</u>	-43	-18%
Avondale	179	178	142	-37	-21%
Flagstaff	166	150	118	-48	-29%
Lake Havasu City	450	311	269	-181	-40%
Nogales	*242*	207	<u>176</u>	-66	-27%
Safford	*113*	90	<u>102</u>	-11	-10%
Arizona Colorado River Basin		**246** (2006 estimate)			

Note: Color coding per Table 3. *Italics represent AZ DWR-reported data for 1991*, <u>underlined represents AZ DWR-reported 2005 populations</u>, from Arizona Water Atlas. Red represents calculated change from 1991 to 2005.

California

California has the largest number of people relying, at least in part, on Colorado River basin water of any state. The Metropolitan Water District of Southern California (Metropolitan), a large water wholesaler, indirectly delivers Colorado River water to most of these people, via the Colorado River Aqueduct. Figure 2 shows the general location of the Metropolitan service area, along the southern California coast.[44] Metropolitan blends Colorado River water with water from northern and central California for delivery to its member agencies. Member agencies supplement these deliveries with local surface and groundwater sources, varying by district; Los Angeles also imports water from the Owens Valley. Local groundwater recharge and surface storage projects further complicate the accounting of water deliveries and sources, as Metropolitan's water deliveries in any given year often do not translate into actual municipal deliveries by the local water utility. Metropolitan reports total deliveries to each member agency by fiscal year and separately reports total aggregate agricultural deliveries.

The Imperial Irrigation District (IID) delivers raw Colorado River water to several municipal water agencies in the Imperial Valley. Five different water agencies deliver water to cities in the fast-growing Coachella Valley; almost all of these municipal deliveries come from groundwater extracted from the northern portion of the Salton Sea basin (a part of the Colorado River delta and therefore considered part of the Colorado River basin generally). There are extensive groundwater recharge projects in the Coachella Valley, fed by Colorado River water delivered as exchange water from Metropolitan's Colorado River Aqueduct and, in the lower valley, from the Coachella Canal. The City of Blythe extracts groundwater from the Colorado River basin, near the mainstem.

Table 8 lists California water agencies that deliver Colorado River basin water and their service area populations. Note that some water wholesalers deliver water to many cities, while in other cases, several different utilities may deliver water to one city. Metropolitan delivers water to its 26 member agencies, many of which are themselves municipal water districts (MWD) delivering water to individual districts. For example, the San Diego County Water Authority, a Metropolitan member agency, delivers Metropolitan water to the Authority's 24 member agencies[45] (not listed below), some of which are themselves municipal water districts. The 2008 populations listed for Metropolitan agencies are from Metropolitan's member agency web pages, except for the agencies that also list 1990 population, in which case the population data is from the agencies themselves. For ease of identification, in Table 8 Metropolitan and its member agencies are shaded blue, and the Coachella Valley water agencies are shaded red. Metropolitan did not produce an annual report for the year 2000.

Table 8. California Service Area Populations[46]

Water Agency	Service Area Population	
	1990	2008
Metropolitan[47]	14,400,000	18,000,000
City of Los Angeles		4,002,071
San Diego County Water Authority	2,435,903	3,146,274
MWD of Orange County	1,711,455	2,225,192
Central Basin MWD		2,000,000
Upper San Gabriel Valley MWD		900,000
West Basin MWD		900,000
Western MWD of Riverside County		853,000
Inland Empire Utilities Agency		850,000
Eastern MWD		660,000
Three Valleys MWD	468,570	559,900
City of Long Beach		487,000
City of Santa Ana		355,000
City of Anaheim		347,000
City of Glendale		207,000
City of Pasadena		160,000
City of Fullerton		134,000
City of Torrance		112,295
City of Burbank		106,879
City of Compton		93,493
City of Santa Monica		90,000
Foothill MWD	80,000	88,000
City of Beverly Hills		42,000
City of San Marino		13,250
Coachella Valley Water Agencies*	235,722	462,386
Coachella Valley Water District	139,620	282,426
Indio Water Authority	36,793	83,475
Desert Water Agency		71,000
City of Coachella	20,775**	40,515
Mission Springs Water District		30,000
Other Water Agencies		
Imperial Irrigation District†	86,290	137,449
City of Blythe	8,125	13,467
TOTAL (rounded)	**14,700,000**	**18,600,000**

Metropolitan and its member agencies are shaded blue and the Coachella Valley water agencies are shaded red. "MWD" = Municipal Water District. *Census estimates for Coachella Valley as a whole, including unincorporated areas; note that the individual agencies' reported populations exceed this number. **1994 population (earliest available) †IID supplies raw Colorado River water to Imperial Valley cities, including El Centro, Calexico, Brawley, and others.[48]

Table 9 shows California water agency total water deliveries for the years 1990 and 2008, and the change between these years. Note that total reported water deliveries for these agencies in 2008 was almost 15,000 acre-feet less than total deliveries in 1990, despite a population increase of almost four million people. However, not all of the California water agencies experienced reduced demand. Several inland areas experiencing rapid growth, such as the Coachella Valley, Eastern MWD, and the Inland Empire Utilities Agency, reported large increases in total water deliveries (including local supplies and imports from other parts of the state), but these were offset by declines in older urban areas such as Los Angeles and Long Beach. Due to Metropolitan's reduced diversions through the Colorado River Aqueduct (see Figure 3) as a result of the 2003 Quantification Settlement Agreement, total Colorado River basin water deliveries decreased from 1990 to 2008, offsetting the increasing volume of deliveries in the Coachella and Imperial valleys. While Imperial Valley municipal water deliveries came from surface water diversions, almost all Coachella Valley water deliveries came from basin groundwater. For most of the Coachella Valley agencies, total reported groundwater production is used as a proxy for total municipal water deliveries, since most of the agencies did not report total volumes delivered. Metropolitan member agencies are listed in decreasing order of 2008 delivery volumes.

Table 9. Water Deliveries in California Water Agency Service Areas

Water Agency	Total Deliveries (acre-feet)		
	1990	2008	Change
Metropolitan	3,747,546	3,592,625	(154,921)
San Diego County Water Authority	717,017	653,543	(63,474)
City of Los Angeles	685,875	648,675	(37,200)
MWD of Orange County	462,020	515,105	53,085
Western MWD of Riverside County	263,748	276,357	12,609
Central Basin MWD	274,979	260,873	(14,106)
Inland Empire Utilities Agency	219,264	239,799	20,535
Eastern MWD	157,405	219,362	61,957
Upper San Gabriel Valley MWD	191,088	175,969	(15,119)
West Basin MWD	203,205	171,341	(31,864)
Three Valleys MWD	138,235	117,606	(20,629)
City of Anaheim	73,164	67,698	(5,466)
City of Long Beach	80,399	53,103	(27,296)
City of Pasadena	38,969	34,467	(4,502)
City of Glendale	32,153	31,279	(874)
City of Santa Ana	51,647	31,249	(20,398)
City of Fullerton	33,933	29,305	(4,628)
City of Torrance	31,286	25,227	(6,059)
City of Burbank	23,588	23,879	291
Foothill MWD	17,115	19,525	2,410
City of Santa Monica	17,061	14,054	(3,007)
City of Beverly Hills	14,867	12,653	(2,214)
City of Compton	11,659	8,373	(3,286)
City of San Marino	6,824	5,247	(1,577)
Coachella Valley Water Agencies	*140,662*	*208,250*	*80,434*
Coachella Valley Water District	75,801	125,283	49,482
Indio Water Authority	12,847	22,160	9,313
Desert Water Agency	42,000	42,957	957
City of Coachella	4,085	7,892	3,807
Mission Springs Water District	5,929	9,957	4,028
Other Water Agencies			
Imperial Valley	26,223	54,219	27,996
City of Blythe	3,018	3,735	717
Total	**3,915,404**	**3,900,892**	**(14,512)**
Total Colorado River Basin Water	**1,384,814**	**1,291,167**	**(93,647)**

Note: Color coding per Table 3.

Figure 3. Metropolitan's Whitsett Intake Plant. The plant pumps water from Lake Havasu to the Colorado River Aqueduct,[49] for distribution to 23 of Metropolitan's 26 member agencies.[50] Source: The Metropolitan Water District of Southern California

Table 10 shows the significant declines in per capita water deliveries for the Metropolitan service area as a whole and in the Coachella Valley, and shows the calculated per capita delivery rates for the Metropolitan member agencies and the Coachella Valley agencies for which population data was also available. Metropolitan member agencies are listed in decreasing order of 2008 delivery volumes. Note that such volumes have no correlation with the calculated per capita delivery rates: the two providers delivering the lowest volumes of water had the highest and lowest per capita delivery rates.

Note that the Coachella Valley agencies report total water "production" (from groundwater extraction), which exceeds total water deliveries. However, the other available dataset – "metered deliveries" – does not reflect deliveries to unmetered accounts, such as municipal landscape irrigation and other institutional uses, and also excludes system losses, volumes included in most providers' delivery data. IID's reported municipal and industrial deliveries more than doubled from 1990 to 2008, perhaps reflecting increased deliveries to commercial and industrial users; this dramatic increase in total municipal and industrial deliveries drives the calculated increase in per capita deliveries by IID. With the exception of IID, the California water agencies showed an annualized decrease in per capita water use of about 1.5 percent per year from 1990 to 2008.

Table 10. Metropolitan's Whitsett Intake Plant

Water Agency/Area	Gallons per Capita per Day		Change	
	1990	2008	GPCD	%
Metropolitan	232	178	-54	-24%
San Diego County Water	263	185	-77	-29%
City of Los Angeles		145		
MWD of Orange County	241	200	-41	-17%
Western MWD of Riverside		289		
Central Basin MWD		116		
Inland Empire Utilities Agency		257		
Eastern MWD		297		
Upper San Gabriel Valley		175		
West Basin MWD		170		
Three Valleys MWD	263	175	-88	-34%
City of Anaheim		174		
City of Long Beach		97		
City of Pasadena		192		
City of Glendale		135		
City of Santa Ana		79		
City of Fullerton		195		
City of Torrance		201		
City of Burbank		199		
Foothill MWD	191	198	+7	+4%
City of Santa Monica		139		
City of Beverly Hills		269		
City of Compton		80		
City of San Marino		354		
Coachella Valley Agencies	533	402	-131	-25%
Coachella Valley Water District	485	396	-89	-18%
Indio Water Authority	312	237	-75	-24%
Desert Water Agency		540		
City of Coachella	176	174	-2	-1%
Mission Springs Water District		296		
Other Water Agencies				
IID	269	352	+83	31%
Blythe	332	248	-84	-25%
California total	**246**	**195**	**-51**	**-21%**

Note: Color coding per Table 3.

Colorado

The majority of Colorado River mainstem flows originate in the state of Colorado, but the majority of the state's population lives outside the basin, in the Denver metropolitan area and in other cities along the "Front Range" of the Rocky Mountains. Through the Grand Ditch, the Colorado-Big Thompson project, and other trans-basin diversions, Colorado has delivered water from the Colorado River basin to its eastern cities and irrigators for more than 120 years. Front Range utilities such as Denver Water import water from the Colorado River basin into their own storage facilities for delivery in the current or in future years, so total volumes of trans-basin diversions do not reflect total municipal deliveries of such water in any given year. Several Front Range cities, such as Thornton and Westminster, rely predominantly on surface and groundwater supplies from outside the Colorado River basin, but share interconnections with Denver Water's treated water system[51] and so have some physical link to Colorado River basin water, though their actual use of such water in any given year may be negligible. Figure 4 shows Denver Water's collection system, including the tunnels exporting water from the Colorado River basin. The City of Lakewood, Colorado, with an estimated 2008 population of 141,000 people, lists 21 different water service providers[52] and was not included in the study.

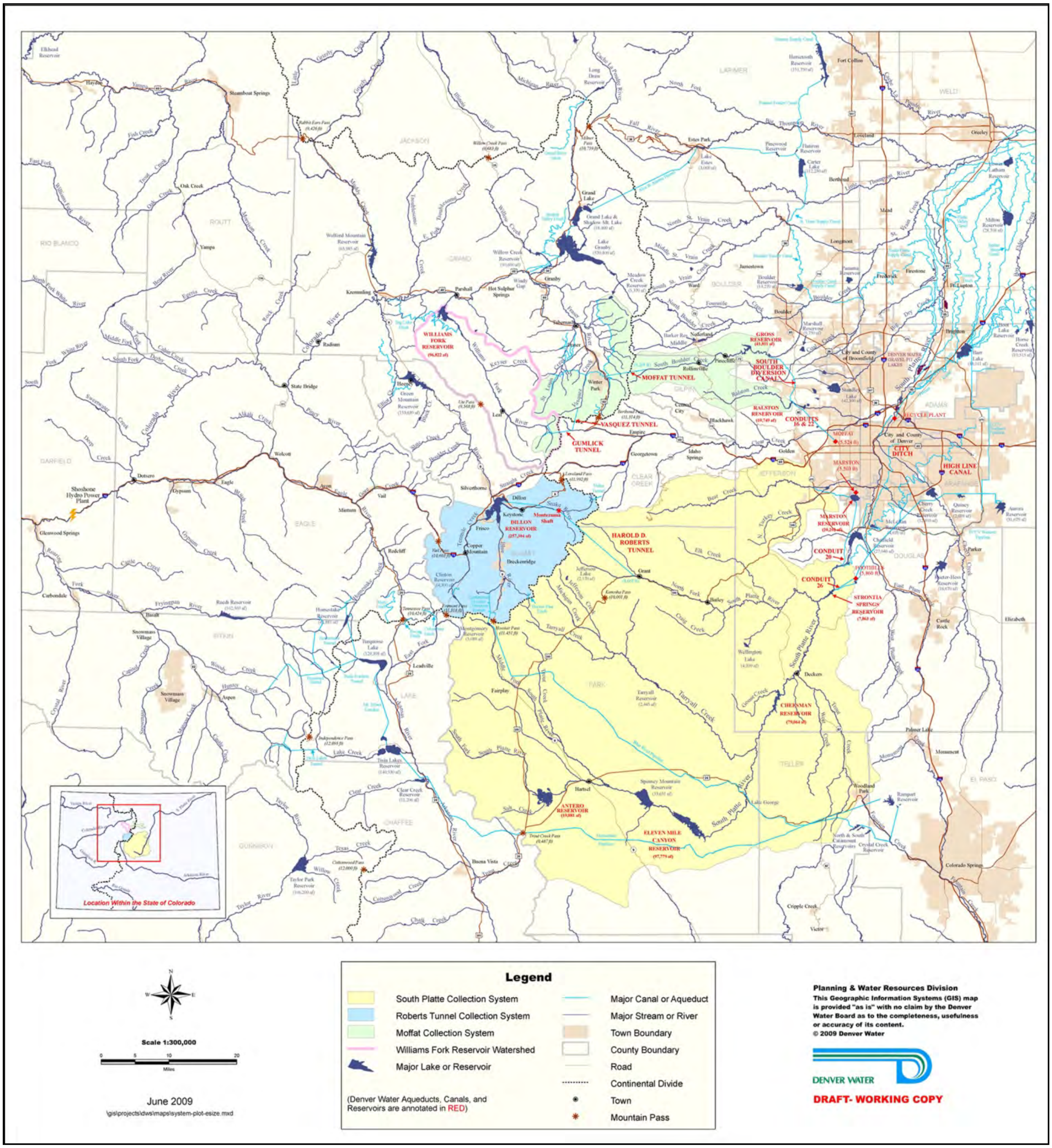

Figure 4 Denver's Water Collection System.
Source: Courtesy of Denver Water, 4/29/11

Table 11 shows service area populations for agencies delivering Colorado River basin water as at least a portion of their total deliveries. Total population of these service areas increased by more than 800,000 people since 1990. Fewer than 600,000 people in Colorado live in the Colorado River basin itself, predominantly in small communities of less than 10,000 people; most of these small communities are not listed. Grand Junction, Montrose, and Durango are the only Colorado cities actually within the basin that are included in this study. Note that the numbers reported for many of the cities in Table 11 are for the full service area populations and are greater than the populations of the cities themselves. The populations listed for Grand Junction include the Grand Valley as a whole and reflect the service area populations of three separate water providers delivering water to the area.[53]

Table 11. State of Colorado Water Agency Populations

Water Agency or Area	Service Area Population		
	1990	2000	2008
Denver Water	891,000	1,000,000	1,154,000
Colorado Springs	303,522	382,693	424,416
Aurora Water	222,103	276,393	313,144
Pueblo	123,051	141,472	157,224
Grand Junction	93,145	117,985	140,928
Thornton	75,950	99,874	136,510
Fort Collins-Loveland	95,900	118,300	128,700
Greeley	74,706*	95,074	122,944
Boulder	98,065	110,073	114,963
Westminster	90,000	101,052	110,938
Arvada	89,700	103,200	106,400
Longmont	52,372	73,344	86,194
Broomfield	24,638	38,272	53,807
Montrose	27,000	37,000	45,000
Commerce City	16,500	26,000	42,500
Golden	13,116	17,159	17,377
Durango	12,430	14,151	16,787
Totals (rounded)	**2,303,000**	**2,750,000**	**3,144,000**

*estimated

Table 12 shows water deliveries by agency. Total water deliveries increased by more than 12 percent from 1990 to 2008, but deliveries of Colorado River basin water increased by more than a third in that period. Colorado Springs, with a population increase of 40 percent since 1990, drove most of the total increase in water deliveries and, with Denver Water, the majority of the increase in Colorado River basin water deliveries. Fort Collins, Boulder, and Greeley all delivered less water in 2008 than they did in 1990. As shown in Table 13, all Colorado cities except Broomfield saw a decrease in per capita deliveries from 1990 to 2008, with the greatest decrease in Greeley. Fort Collins, Durango, Denver, and Boulder all decreased per capita delivery rates by more than one percent per year. Note that the year 2000 was unusually hot and dry in much of the Front Range, increasing water demand in these cities. Across the state as a whole, total per capita use declined by almost one percent a year on average.

Table 12. State of Colorado Agency Water Deliveries

Water Agency	Non-agricultural water deliveries (Acre-feet)							
	1990		2000		2008		Change 1990-2008	
	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin
Denver Water	246,908	101,528	294,808	132,520	250,965	126,161	4,057	24,633
Colorado Springs	68,834	45,666	94,247	61,822	85,533	72,416	16,699	26,750
Aurora Water	39,228	9,123	58,260	5,491	48,201	10,887	8,973	1,764
Pueblo	32,883	-	43,203	5,593	40,933	5,063	8,050	5,063
Grand Junction[54]			19,379	19,379	19,285	19,285		
Thornton	13,566	*	19,974	*	23,514	*	9,948	*
Fort Collins-Loveland	28,507	14,538	31,594	18,956	25,631	11,534	(2,876)	(3,004)
Greeley	22,017	? [55]	22,989	8,004	21,059	13,499	(958)	?
Boulder	20,326	2,542	24,233	16,953	18,953	5,609	(1,373)	3,067
Westminster	15,768	*	22,519	*	21,070	*	5,302	*
Arvada	15,657	11,430	20,972	16,148	18,413	13,810	2,756	2,380
Longmont	12,862	3,087	17,686	7,428	17,210	6,884	4,349	3,797
Broomfield	4,897	*	9,654	*	10,776	*	5,879	*
Montrose	6,518	6,518	8,390	8,390	9,446	9,446	2,928	2,928
Commerce City	4,472	*	5,953	*	9804	*	5,332	*
Golden[56]			4,143		3,526			
Durango	3,840	3,840	4,140	4,140	3,940	3,940	100	100
Total	**>536,283**	**>198,272**	**702,144**	**304,824**	**628,259**	**298,534**	**>72,000**	**~67,000**

Note: Color coding per Table 3. ? = Unknown *Share interconnections with the Denver Water's treated water system and so have some physical link to Colorado River basin water, though actual delivery volumes of such water were not reported.

Table 13. State of Colorado Water Agency Per Capita Deliveries

Water Agency or Area	Gallons per Capita per Day			Change 1990-2008	
	1990	2000	2008	GPCD	%
Denver Water	247	263	194	-53	-22%
Colorado Springs	202	220	180	-23	-11%
Aurora Water	158	188	137	-20	-13%
Pueblo	239	273	232	-6	-3%
Grand Junction		238	178		
Thornton	159	179	154	-6	-4%
Fort Collins-Loveland	265	238	178	-88	-33%
Greeley	263	216	153	-110	-42%
Boulder	185	197	147	-38	-20%
Westminster	188	199	170	-18	-10%
Arvada	156	181	154	-1	-1%
Longmont	219	215	178	-41	-19%
Broomfield	177	225	179	+1	+1%
Montrose	216	202	187	-28	-13%
Commerce City	242	204	206	-36	-15%
Golden		216	181		
Durango	276	261	210	-66	-24%
Colorado Average*	**218**	**225**	**176**	**-42**	**-19%**

Note: Color coding per Table 3. *Average only reflects cities with data for that year.

Nevada

Roughly 90 percent of southern Nevada's water supply comes directly from the Colorado River; the remaining 10 percent comes from groundwater within the Colorado River basin. Historically, artesian springs in the Las Vegas area provided water that periodically flowed to the Colorado River. The Southern Nevada Water Authority, a seven-member agency formed in 1991, delivers Colorado River water to its member agencies in the greater Las Vegas metropolitan area and to Laughlin.[57] Table 14 shows the Authority's estimated service population; note that these populations do not reflect the very large numbers of tourists visiting the area. In 2008, an estimated 37.5 million tourists visited Las Vegas, distorting water demand from what would be expected solely by looking at permanent residents. The Virgin Valley Water District provides basin groundwater to Mesquite and Bunkerville; a casino in Mesquite reportedly accounted for 20 percent of the district's total water deliveries in 2005, and a golf course accounted for another 11 percent.[58] Note the very rapid population growth rate in both service areas.

Table 14. Nevada Water Agency Populations

Water Agency	Service Area Population			Annual Growth Rate 1990-2008
	1990	2000	2008	
Southern Nevada Water Authority	750,621	1,364,248	1,922,069	5.4%
Virgin Valley Water District	2,930	10,403	20,512	11.4%
Total	**753,551**	**1,374,651**	**1,942,581**	**5.4%**

Table 15 shows Colorado River basin water deliveries for these two water agencies. Note that total deliveries increased by 77 percent from 1990 to 2008, over a period when total population increased by almost 160 percent. As shown in Table 16, this translates into a 31 percent reduction in per capita deliveries in southern Nevada. The sharp increase in water deliveries in the Virgin Valley Water District is likely driven by new casinos and tourism; note that per capita deliveries in the district were higher in 2000 than in 2007. Had per capita deliveries in both districts continued at the 1990 rate, total water deliveries in 2008 would have been some 795,000 acre-feet – 269,000 more than was actually delivered in 2008 and likely more than would have been physically available for diversion.

Table 15. Nevada Agency Water Deliveries

Water Agency	Colorado River Basin water deliveries (Acre-feet)			
	1990	2000	2008	Increase 1990-2008
Southern Nevada Water Authority	292,900	477,900	519,200	226,300
Virgin Valley Water District	700*	4,000*	6,775**	6,075*
Total	**293,600***	**477,900**	**525,975**	**232,500**

Note: Color coding per Table 3. *estimated **2007 deliveries

Table 16. Nevada Water Agency Per Capita Deliveries

Water Agency	Gallons per Capita per Day			Change 1990-2008	
	1990	2000	2008	GPCD	%
Southern Nevada Water Authority	348	313	241	-107	-31%
Virgin Valley Water District	200*	340*	295**	~95	+38%
Nevada	348	313	242	106	-31%

Note: Color coding per Table 3. *estimated **2007

New Mexico

New Mexico includes portions of the San Juan River in the Upper Colorado River basin and tributaries of the Little Colorado and Gila rivers in the lower Colorado River basin. Farmington, New Mexico, diverts water from the San Juan River, but municipal deliveries in New Mexico's portion of the Lower Colorado River basin, to meet demand in Silver City and other small communities, come almost entirely from groundwater extracted from the basin. New Mexico exports about 92,000 acre-feet of Colorado River water out of the upper basin each year through the San Juan-Chama Project. In 2008, a small fraction of this water supplemented deliveries to the City of Albuquerque, but most went toward augmenting the flow of the Rio Grande and to agricultural uses in the Middle Rio Grande basin.[59] Population and water delivery data for the San Juan and lower Colorado River basins come from the New Mexico Office of the State Engineer and reflect deliveries for each basin as a whole, including rural areas. Table 17 shows the populations of Albuquerque and the two basins. Albuquerque's population grew more than 27 percent from 1990 to 2008, roughly the same rate as New Mexico's Lower Colorado River basin, while the population of Farmington and the San Juan River basin grew by more than 36 percent over this period.

Table 17. New Mexico Populations

Water Agency/Basin	Agency-reported populations		
	1990	2000	2008
Albuquerque	423,371	497,916	538,586
Farmington (San Juan River Basin)	107,381	133,287	146,597
Silver City (Lower Colorado River Basin)	56,874	70,270	72,659
Totals	**587,626**	**701,473**	**757,842**

Table 18 shows water deliveries by New Mexico utilities. All deliveries in the Farmington and Silver City regions came from Colorado River basin water; Albuquerque relied entirely on local groundwater before 2008, so had no Colorado River basin water use prior to 2008. Because of its new San Juan-Chama Drinking Water Project,[60] Albuquerque represents a new user of Colorado River water and as of 2010, a net increase of some 48,000 acre-feet annually in new municipal demands for Colorado River basin water. Despite its 27 percent population increase, Albuquerque reported a 16 percent reduction in total water deliveries from 1990 to 2008. As shown in Table 19, per capita water deliveries in the two regions within the Colorado River basin remained essentially unchanged from 1990 to 2008, unlike the dramatic decline witnessed in Albuquerque.

Table 18. New Mexico Water Deliveries

Water Agency/Basin	Non-agricultural water deliveries (Acre-feet)							
	1990		2000		2008		Change	
	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin
Albuquerque	117,014	-	113,860	-	98,225	367*	(18,789)	367*
Farmington (San Juan River Basin)	21,230	1,230	24,615	24,615	29,416	29,416	8,186	8,186
Silver City (Lower CO River Basin)	8,626	8,626	11,025	11,025	10,919	10,919	2,293	2,293
Total	**146,870**	**9,856**	**149,501**	**35,641**	**138,560**	**40,702**	**(8,310)**	**10,846***

Note: Color coding per Table 3. *Albuquerque's surface water diversion project began in December 2008 and is now diverting approximately 48,000 acre-feet of Colorado River basin water annually.

Table 19. New Mexico Per Capita Deliveries

Water Agency/Basin	Gallons per Capita per Day			Change	
	1990	2000	2008	1990-2008	%
Albuquerque	247	204	163	-84	-34%
Farmington (San Juan River Basin)	177	165	179	+3	+1%
Silver City (Lower CO R Basin)	135	140	134	-1	-1%
New Mexico	**223**	**190**	**163**	**-60**	**-27%**

Note: Color coding per Table 3.

Utah

Like New Mexico, Utah is a state with land in both the upper and lower Colorado River basins. In southwest Utah, the fast-growing City of St. George diverts water directly from the lower basin's Virgin River and pumps basin groundwater, for use within the basin. The population of Washington County (including St. George and other portions of the Virgin River watershed) as a whole almost tripled from 1990 to 2008, rising from 48,560 to an estimated 135,678. However, most of Utah's population lives outside of the Colorado River basin, along the "Wasatch Front." According to provisional 2007 Reclamation data,[61] Utah exported more than 130,000 acre-feet of water from the Duchesne watershed in the Colorado River basin to the Wasatch Front, primarily for agricultural uses. The Central Utah Water Conservancy District and the Provo River Water Users Association both export water from the Duchesne basin into the Diamond Fork and Provo River systems for agricultural and municipal deliveries. Each of these agencies delivers water to municipal water wholesalers and directly to municipal water agencies, supplementing local supplies. Deliveries in any given year tend to be a mixture of same-year diversions and holdover deliveries from previous-year diversions stored in reservoirs, so total trans-basin diversions from the Duchesne basin do not equate to total deliveries in any given year. Figure 5 shows the Bonneville Unit System, importing water from the Colorado River basin to the Wasatch Front, as well as local sources and infrastructure. The Jordan Valley Water Conservancy District reports a service area population, but is not the sole provider delivering water to people in its service area.

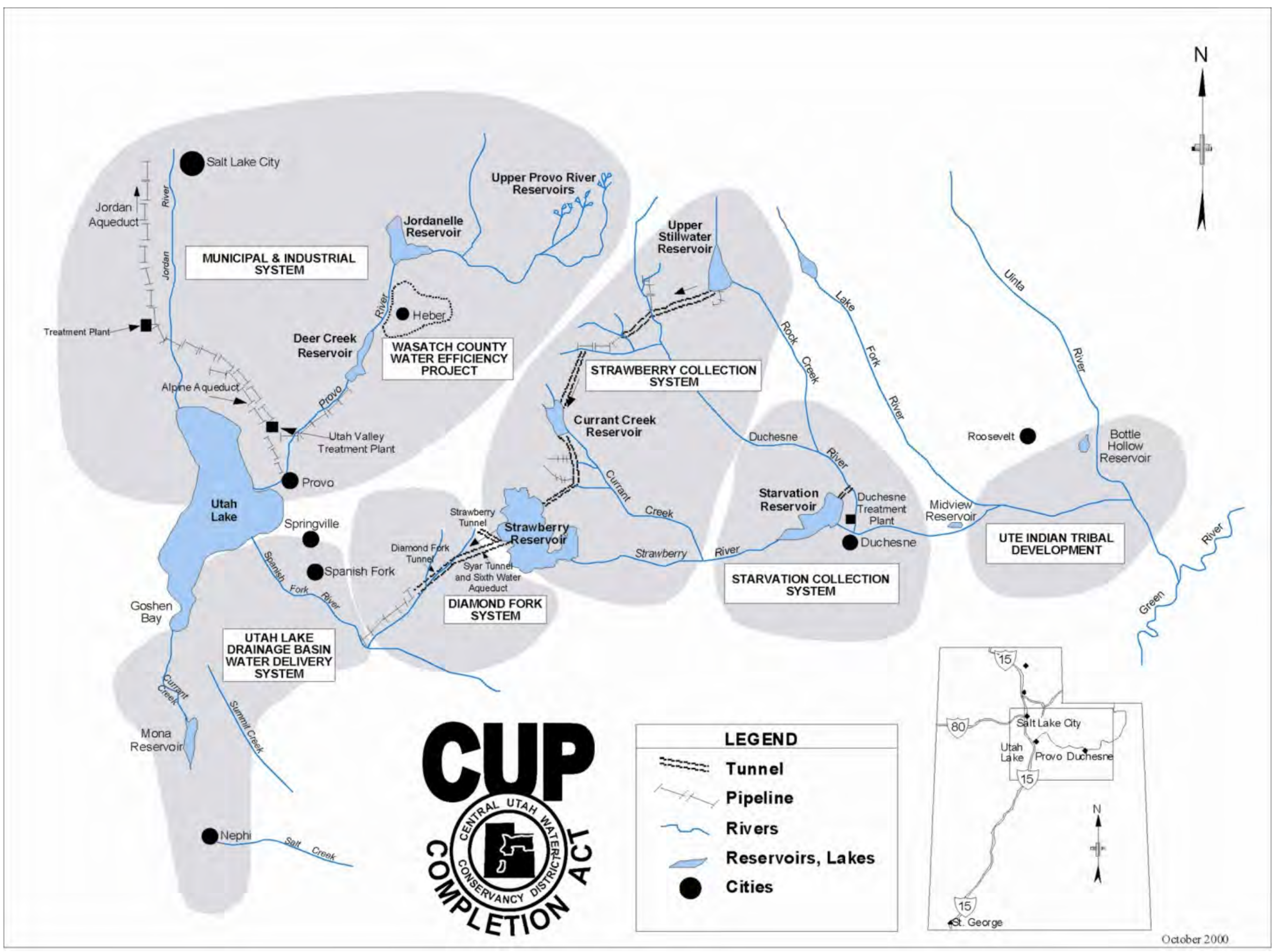

Figure 5. The Bonneville Unit System.
Source: Image courtesy of the Central Utah Water Conservancy District.

Table 20 shows the populations served by several of these water districts. Note that the population of St. George more than doubled between 1990 and 2000, and continued to grow at a slower rate through 2008, while Salt Lake City grew by about 13 percent between 1990 and 2008. The population of Lehi City reportedly grew by almost 500 percent over this same period, though as shown in Table 21, the city's reported water deliveries only doubled.[62] Several other Utah cities also reported extraordinary population growth between 1990 and 2008, including South Jordan (329 percent); Riverton (213 percent); and West Jordan (138 percent). Note also that Sandy's service area population reportedly declined by more than 18,000 people between 2000 and 2008.

Table 20. Utah Water Agency Populations

City	Water Agency	Agency-reported populations		
		1990	2000	2008
various	*Jordan Valley Water Conservancy D.*[63]	*440,544*	*464,763*	*567,299*
Salt Lake City	Salt Lake City Corp. Culinary Water	285,000	312,192	322,215
Salt Lake City (part)	Taylorsville-Bennion Improvement District	48,000	60,000	69,300
Provo	Provo City Water Resources Division	83,000	112,000	116,000
West Valley	Granger-Hunter Improvement District	86,976	98,000	110,000
West Jordan	West Jordan City Utilities	42,892	65,000	102,000
Sandy	Sandy City Corporation Water	87,304	118,107	99,750
Orem	Orem Municipal Water System	68,000	90,000	93,202
St. George	City of St. George	31,000	75,000	83,364
South Jordan	South Jordan Municipal Water	12,419	33,010	53,281
Lehi City	Lehi City Public Works Dept.	8,400	21,148	48,624
Riverton	Riverton Culinary Water	12,000	26,500	37,500
Springville	Springville Water Department	14,000	24,500	30,000
Pleasant Grove	Pleasant Grove City	13,000	24,300	29,104
American Fork	American Fork Municipal Water System	15,000	23,000	27,000
South Salt Lake	South Salt Lake Culinary Water	13,025	10,275	18,000
Total*		**820,016**	**1,093,032**	**1,239,340**

*Total does not include Jordan Valley Water Conservancy District, which wholesales water to some of the other agencies listed.

As shown in Table 21, total water deliveries increased for 11 of the 16 Utah water providers included in this study. St. George witnessed the highest rates of change in terms of the absolute volumes of deliveries,[64] while Riverton and South Jordan both roughly quadrupled their total deliveries from 1990 to 2008. St. George is the only municipality listed that directly uses Colorado River basin water; the Wasatch Front cities receive Colorado River basin water mixed with water from other sources, including local surface and groundwater. Total exports from the

Duchesne River system, in the Colorado River basin, exceed 100,000 acre-feet per year, but agriculture uses most of this water. The total municipal use of such Colorado River basin water, which typically passes through several water agencies that blend it with water from other sources before delivery to end users, could not be determined.

Note that total deliveries in Salt Lake City and Sandy were both much higher in 2000 than in 2008, likely due to the unusually hot and dry conditions that summer; Sandy's service area population in 2000 reportedly was also much higher than it was in 2008. With the exception of the 2008 volume for South Salt Lake, all delivery data shown in Table 21 come from the Utah Division of Water Rights website. As shown in the two full examples given in Appendix A, reported annual populations and deliveries can vary dramatically from year to year and therefore may reflect changing accounting procedures or simply may reflect errors in reporting or transcription. As shown by the calculated per capita delivery volumes for 2000 and 2008 in Table 22, Lehi City's reported deliveries in 2000 and 2008 (or reported populations in those years, or a combination of the two) are much lower than expected. With the exceptions of Salt Lake City, Provo, and South Salt Lake, total water deliveries increased from 1990 to 2008 in the Utah service areas. However, total water deliveries for the listed cities decreased from 2000 to 2008 by about 4,000 acre-feet, likely reflecting the relatively cooler conditions in 2008.

Table 21. Utah Agency Water Deliveries

Water Agency or City	Total Water Deliveries (Acre-feet)			Change	
	1990	**2000**	**2008**	**1990-2008**	**%**
Jordan Valley Water	58,324	85,259	83,042	+24,718	42%
Salt Lake City	110,042	89,138	75,843	-34,199	-31%
Salt Lake City (part)	13,802	16,445	13,989	+187	1.4%
Provo	36,075	29,958	28,135	-7,941	-22%
West Valley	18,934	26,293	25,481	+6,547	35%
West Jordan	11,173	18,080	19,449	+8,276	74%
Sandy	22,007	31,519	25,194	+3,187	15%
Orem	21,094	22,805	22,579	+1,485	7%
St. George	12,909	23,130	32,626	+19,718	153%
South Jordan	3,288	8,994	12,484	+9,196	280%
Lehi City	1,946	1,523	3,930	+1,984	102%
Riverton	2,833	6,467	12,024	+9,191	320%
Springville	7,723	7,845	8,053	+330	4.3%
Pleasant Grove	3,727	5,520	5,264	+1,537	41%
American Fork	5,128	9,358	9,599	+4,471	87%
South Salt Lake	3,362	4,110	2,602*	-760	-23%
Total**	274,042	301,185	297,251	+23,210	8.5%

Note: Color coding per Table 3. *Obtained from city staff. **Total does not include Jordan Valley Water Conservancy District, which wholesales water to some of the other agencies listed.

Table 22 shows per capita deliveries for municipal water providers in Utah; nine of the cities listed experienced average declines of greater than one percent per year. Per capita water deliveries in Riverton, West Valley, and American Fork increased from 1990 to 2008.

Table 22. Utah Water Agency Per Capita Deliveries

Water Agency	Gallons per Capita per Day			Change 1990-2008	
	1990	2000	2008	GPCD	%
Salt Lake City	345	255	210	-135	-39%
Salt Lake City (part)	257	245	180	-76	-30%
Provo	388	239	217	-171	-44%
West Valley	194	240	207	+12	+6%
West Jordan	233	248	170	-62	-27%
Sandy	225	238	225	0	0%
Orem	296	226	202	-94	-32%
St. George	372	275	349	-22	-6%
South Jordan	236	243	209	-27	-11%
Lehi City	207	64*	72*	-135*	-65%*
Riverton	211	218	286	+76	+36%
Springville	492	286	240	-253	-51%
Pleasant Grove	256	203	161	-94	-37%
American Fork	305	363	317	+12	+4%
South Salt Lake	230	357	129	-101	-44%
UTAH	**298**	**246**	**214**	**-84**	**-28%**

Note: Color coding per Table 3. *The exceptionally low GPCD rates for Lehi City calculated for 2000 and 2008 suggest the reported data may be incorrect.

Wyoming

Wyoming, source of the Green River, the Colorado River's northernmost tributary, is the least populated of the basin states.[65] Within the Colorado River basin, the Joint Powers Water Board delivers water to the cities of Rock Springs (2008 population approximately 19,000) and Green River (2008 population approximately 13,000) and unincorporated areas of Sweetwater County. Outside the basin, the City of Cheyenne imports Colorado River basin water to supplement local surface and groundwater supplies. As shown in Table 23, population growth within the Green River basin was minimal from 1990 to 2008; Cheyenne grew about 13% over that period.

Table 23. Wyoming Water Agency Populations

Water Agency	Agency-reported populations		
	1990	**2000**	**2008**
Cheyenne	50,197	53,011	56,951
Joint Powers Water Bd (Green River Basin)	38,823	36,500	39,944
Total	89,020	89,511	96,895

Table 24 shows non-agricultural water deliveries by agency for the two areas receiving Colorado River basin water. Cheyenne imports Little Snake River water from the Colorado River basin, but stores this water in reservoirs for use through the next water year. Total Little Snake exports in the years 1990, 2000, and 2008 were 13,986; 15,438; and 18,519 acre-feet, respectively; in 2008, the Wyoming Water Development Commission diverted 5,500 acre-feet of Little Snake water.[66] The volumes of Colorado River basin water deliveries shown for Cheyenne in Table 24 were calculated as total deliveries less total reported local supplies. In 2008, local surface and groundwater sources generated more than double the volume of water for Cheyenne as they had in 1990, leading to the much lower calculated value for Colorado River supplies. Unusually warm and dry conditions likely contributed to Cheyenne's peak use in 2000.

Table 24. Wyoming Agency Water Deliveries

Water Agency	Non-agricultural water deliveries (Acre-feet)							
	1990		**2000**		**2008**		**Change**	
	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin	Total	CO R Basin
Cheyenne	11,918	6,143	16,959	10,651	12,958	686	1,040	(5,457)
Joint Powers Water Bd	7,700	7,700	9,700	9,700	10,600	10,600	2,900	2,900
Total	**19,618**	**13,843**	**26,659**	**20,351**	**23,558**	**11,286**	**3,940**	**(2,557)**

Note: Color coding per Table 3.

Table 25 shows per capita water deliveries for the two areas receiving Colorado River water. Total deliveries by the Joint Powers Water Board, serving Rock Springs, Green River, and Sweetwater County, grew more rapidly than did the number of people served, unlike most other areas of the basin, despite relatively cooler and wetter temperatures in 2008 than in 1990.

Table 25. Wyoming Water Agency Per Capita Deliveries

Water Agency	Gallons per Capita per Day			Change	
	1990	**2000**	**2008**	**1990-2008**	**%**
Cheyenne	212	286	203	-9	-4%
Joint Powers Water Bd	177	237	237	60	34%
Wyoming	**197**	**266**	**217**	**20**	**10%**

Note: Color coding per Table 3.

Mexico

Roughly two thousand square miles of the Colorado River basin – less than one percent of the basin – lie within the states of Baja California and Sonora in the Republic of Mexico. The cities of Mexicali, San Luís Río Colorado, and Nogales lie within the basin. Mexico also exports Colorado River water, via the Colorado River-Tijuana Aqueduct,[67] to the cities of Tecate, Tijuana, and Rosarito. In 2001, almost 95 percent of Tijuana's and Rosarito's water supply came from the Colorado River, with less than six percent from local groundwater and surface supplies.[68] Tecate supplements local groundwater sources with imported Colorado River water, while San Luís Río Colorado, Nogales, and many of the communities surrounding Mexicali rely exclusively on groundwater.

Like many areas in the Navajo Nation but unlike U.S. cities, direct water service for some Mexican households is intermittent or nonexistent. For example, Sonora's state water agency reports that 87 percent of Nogales households are connected to the municipal water service, though reportedly only between 5 and 39 percent of these households receive water 24 hours a day. Some 30 percent of the Nogales households with water connections receive water only 4-5 hours per day, and sometimes only three days per week.[69] To accommodate this intermittent water service, many households fill their own water tanks or reservoirs, and often supplement their intermittent direct service with water purchased from delivery trucks. Limited water availability means that total and per capita water use in these communities is dramatically lower than in similarly sized cities in the U.S.

Table 26 shows both census-reported populations and state-agency-reported populations with water service connections for the six cities in Mexico using Colorado River basin water. Unlike the U.S. census, the Mexican census does not post annual population estimates at the municipality level, so 2010 populations are listed as a proxy for the 2008 data used for the U.S. providers. Census populations include both the city itself and outlying towns within the broader *municipio*. Note that the census-reported populations for Tijuana in 1990 and 2000 are lower than the service-connected populations reported by the state water agency.

Table 26. Populations of Municipalities in Mexico Using Colorado River Basin Water

Municipio	Census			Agency-Reported Population with Service Connections		
	1990	2000	2010	1990	2000	2008
Tijuana	747,381	1,210,820	1,559,683	829,233	1,260,501	1,550,170
Mexicali	601,938	764,602	936,826	320,224	496,932	705,505
*Mexicali - non-city**				42,925	72,051	185,427
Nogales	105,873	159,787	220,292	?	130,816	189,759
San Luís Río Colorado	110,530	145,006	178,380	95,461	126,645	138,796
Tecate	51,557	77,795	101,079	?	71,113	81,586
Playas de Rosarito**		63,420	90,668	--	62,713	82,338
TOTAL	1,617,279	2,421,430	3,086,928	>1,300,000	2,220,000	2,934,000

? – Unknown *Population outside city limits that received water from Mexicali's municipal water provider.
**Rosarito was part of the Tijuana *municipio* until 1995.

The Tijuana-Rosarito metropolitan area is the most densely populated metropolitan area on the U.S.-Mexico border and among the fastest-growing. The population of the area grew from 65,364 in 1950 to 1,650,351 in 2010, an annual growth rate of more than 5.5 percent for sixty years. The populations of Tijuana/Rosarito, Nogales, and Tecate each roughly doubled from 1990 to 2010. Assuming that the 1990 service area populations of Nogales and Tecate were roughly proportional to the census-reported populations in those years suggests that the combined total populations of the Mexican cities depending at least in part on Colorado River basin water more than doubled from 1990 to 2008, with an increase of more than 1.4 million.

Table 27 shows water deliveries by Mexican agencies in the years 1990, 2000, and 2008, with estimated volumes of Colorado River basin water. Total municipal water deliveries in 2008 came almost entirely from the Colorado River basin, predominantly from the river itself. Sonora's state water agency reports[70] that Nogales' total billed water deliveries in 2003 (the earliest year posted) were 145,000 acre-feet, or almost an acre-foot per person and about nine times the amount billed in 2008. Table 27 adjusts billed amounts by dividing these by reported efficiencies (86.75 percent for Nogales in 2008) to generate the volumes shown, though these still do not account for unbilled deliveries. Information on 1990 deliveries by Tecate was not available. Tijuana/Rosarito's reported deliveries increased by 68 percent from 1990 to 2008, while San Luís Río Colorado's deliveries increased by more than 40 percent over that same period. Total deliveries of Colorado River basin water increased by at least 45,000 acre-feet over that period, and possibly by substantially more if Tijuana/Rosarito's 1990 deliveries included a lower percentage of Colorado River water.

Table 27. Mexico Water Agency Deliveries

Municipio	1990		2000		2008		Change 1990-2008	
	Total	**CO R Basin**	**Total**	**CO R Basin**	**Total**	**CO R Basin**	**Total**	**CO R Basin**
Tijuana	53,244	?	65,790	62,200	86,018	82,100	32,774	?
Mexicali	65,559	65,559	70,064	70,064	69,472	69,472	3,913	3,913
Mexicali - non-city	7,925	7,925	9,141	9,141	10,659	10,659	2,734	2,734
Nogales	?		?		20,373	10,800		
San Luís Río Colorado	17,188	17,188	25,953	25,953	24,400	21,199	7,212	7,212
Tecate	?		5,908	4,069	6,591	4,749		
Playas de Rosarito			3,693	3,490	4,179	4,000		
TOTAL (rounded)	**>144,000**	**>90,700**	**>181,000**	**>175,000**	**221,700**	**203,000**		

Note: Given in acre-feet . ? = unknown

Table 28 shows per capita water deliveries for the *municipios*. Note that GPCD rates for most of these cities are substantially lower than those for U.S. cities, reflecting a variety of factors including different landscaping preferences, intermittent access to water for many customers, and different cultural norms. The value shown for Nogales in 2008 is unexpectedly high given the limited access many residents have to potable water; this value may reflect an error in the reported data. Note that Mexicali's and San Luís Río Colorado's calculated per capita water delivery rates were essentially the same in 1990, but Mexicali's calculated per capita delivery rate decreased significantly by 2008 while San Luís Río Colorado's rate remained essentially unchanged. The reason San Luís Río Colorado's 2008 rates are so much higher than those of other cities was not determined.

Table 28. Mexico Water Agency Per Capita Deliveries

Municipio	Gallons Per Capita Per Day			Change 1990-2008	
	1990	2000	2008	GPCD	%
Tijuana	57	47	50	-8	-14%
Mexicali	183	126	88	-95	-52%
Mexicali - non-city	165	113	51	-114	-69%
Nogales			110		
San Luís Río Colorado	161	183	157	-4	-2%
Tecate		74	72		
Playas de Rosarito		53	45		

General Trends

This compilation of records from cities and agencies delivering Colorado River basin water as at least part of their water supply reveals several interesting trends, including very high rates of population growth, increased municipal reliance on water from the Colorado River basin relative to other sources, and an encouraging trend to deliver less water per capita in 2008 than in 1990. This trend means that these water agencies withdrew less water in 2008 than they would have had per capita deliveries remained constant, reducing pressure on the over-allocated Colorado River.

This study includes 68 water agencies[71] with population and water delivery data for both 1990 and 2008, and 32 additional providers with limited data. The total reported service populations for the 68 agencies increased from 23.5 million in 1990 to 33.5 million in 2008, an increase of more than 40 percent. Water delivery data for Mexican water agencies in 1990 were incomplete, but extrapolating from 1990 census data indicates that the populations of *municipios* relying in large part on water from the Colorado River basin increased from about 1.4 million in 1990 to 2.9 million in 2008. Many cities in the basin experienced extraordinary population growth rates: several cities in Arizona and Utah more than tripled in size over this period.

The total water deliveries of these 68 agencies, including both Colorado River basin and non-Colorado River basin water, increased by more than 600,000 acre-feet from 1990 to 2008, from 6.1 million acre-feet to 6.7 million acre-feet, an increase of about 10 percent. The total volume of Colorado River basin water deliveries also increased by more than 600,000 acre-feet over this period, from more than 2.8 million acre-feet to more than 3.4 million acre-feet (an increase of more than 20 percent), though records of basin water deliveries are less accurate than those for total deliveries since many of the retail providers do not report their deliveries by source. The similarity between the total increase in municipal deliveries and the increase in deliveries of Colorado River basin water masks the changes across the basin states. For example, Metropolitan's deliveries of Colorado River water decreased by 190,000 acre-feet from 1990 to 2008, while most of the increase occurred in Arizona and Nevada (where all the deliveries by these agencies come from the Colorado River basin), and in Colorado (where much of the increase came from increased basin exports to Front Range cities). The total volume of Colorado River basin water delivered to municipalities in Utah could not be determined, because this water passes through multiple systems and is mixed with water from other sources.

The general increase in U.S. agencies' total water deliveries masks dramatic variability in the volume of annual deliveries by agencies across the basin states, and even within the service areas of some wholesale water providers. For example, total water deliveries in The Metropolitan Water District of Southern California's service area actually fell by more than 150,000 acre-feet from 1990 to 2008, as large decreases by some member agencies exceeded increases in fast-growing areas such as Eastern MWD (62,000 AF) and MWD of Orange County (53,100 AF). Restrictions on imports from California's Bay-Delta likely contributed to Metropolitan's decreased deliveries in 2008, and the signing of the Quantification Settlement Agreement in 2003 diminished Metropolitan's access to Colorado River water, though Metropolitan's total Colorado River water imports in 2008 were still more than a million acre-feet, or more than 83 percent of their 1990 volume.

Total water deliveries increased in the Southern Nevada Water Authority's service area by more than 226,000 AF from 1990 to 2008.[72] Over that same period, total municipal water deliveries by the five water providers in California's Coachella Valley increased by almost 68,000 acre-feet. Except for Tempe and Flagstaff, municipal water deliveries increased for every Arizona water agency included in this study. For the 19 Arizona water providers with delivery data for both 1990 and 2008, total water deliveries increased by more than 278,000 acre-feet.

Population growth accounts for most of these increased deliveries, though other factors, such as commercial development and climatic variability, also contribute. For the 19 Arizona water providers noted above, service area populations increased by more than three million people from 1990 to 2008. In Southern Nevada, the service area population increased by more than 1.2 million people. But water deliveries are not strictly a function of population, even within the same water provider's service area, as shown by California's net decrease in total deliveries despite adding almost as many people as Arizona and Nevada combined.

Section 4 notes the very wide range of per capita delivery rates by agency. Figure 6 displays this range for 66 providers[73] with both 1990 and 2008 data, indicating the number of providers with per capita rates within the bins shown. Over this period, median GPCD for these providers declined from 229 to 180. This histogram reflects the general trend toward lower per capita delivery rates from 1990 to 2008. Three of the four cities with per capita delivery rates of less than 100 GPCD are in Mexico; the other is Lehi City, Utah, which reported a 65 percent reduction in per capita delivery rates and so may reflect inaccurate data.

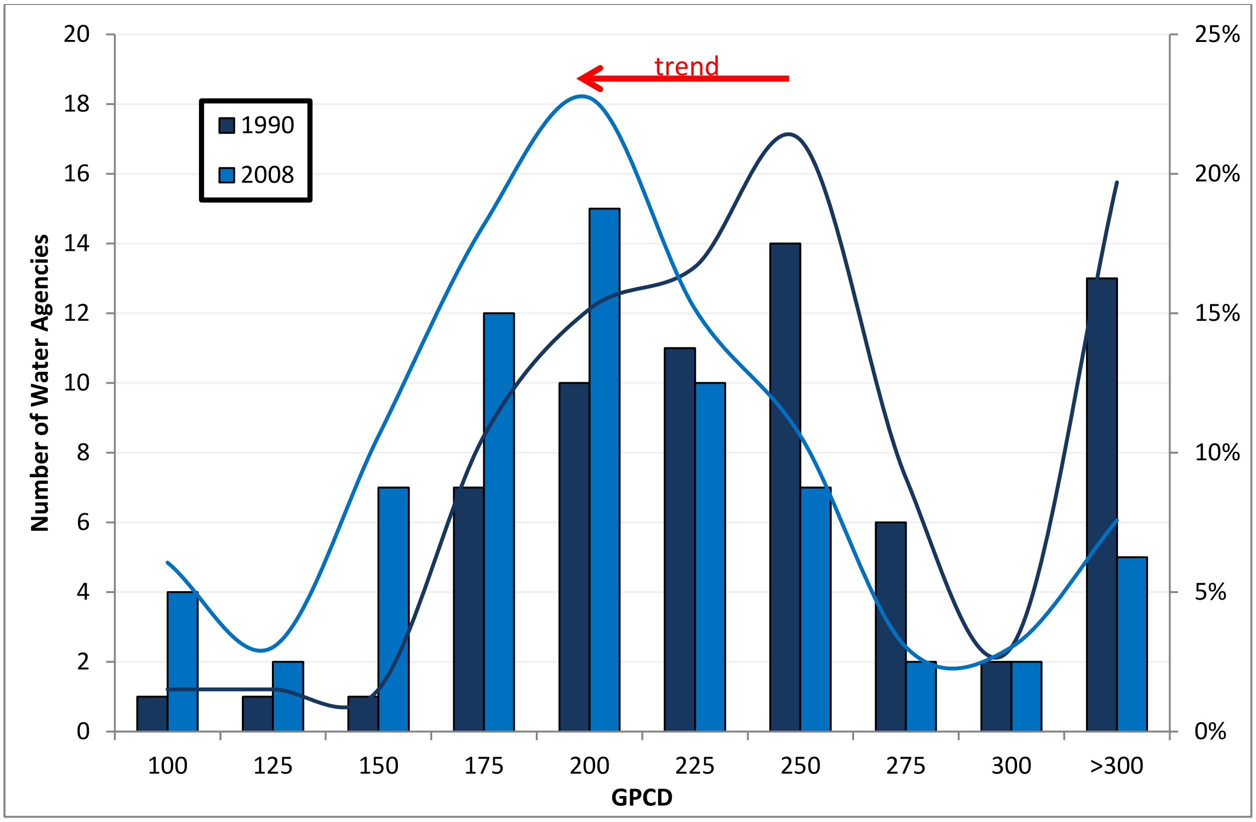

Figure 6. Per Capita Delivery Rates by Numbers of Water Agencies, 1990 and 2008

Figure 7 shows per capita delivery rates for 98 water agencies, but only shows 2008 data (36 of these agencies did not have 1990 data and so were not included in Figure 6). Coincidentally, the median rate for this larger group is also 180 GPCD. Most of the agencies with the lowest GPCD are in Mexico, but several are in southern California. Water agencies with 2008 per capita delivery rates of less than 150 GPCD are found in Arizona, California, Colorado, Mexico, New Mexico, and Utah. Interestingly, the four cities with the highest GPCD are all in southern California, including one small, very affluent residential city in Metropolitan's service area, showing the very broad range of delivery rates even within a limited area.

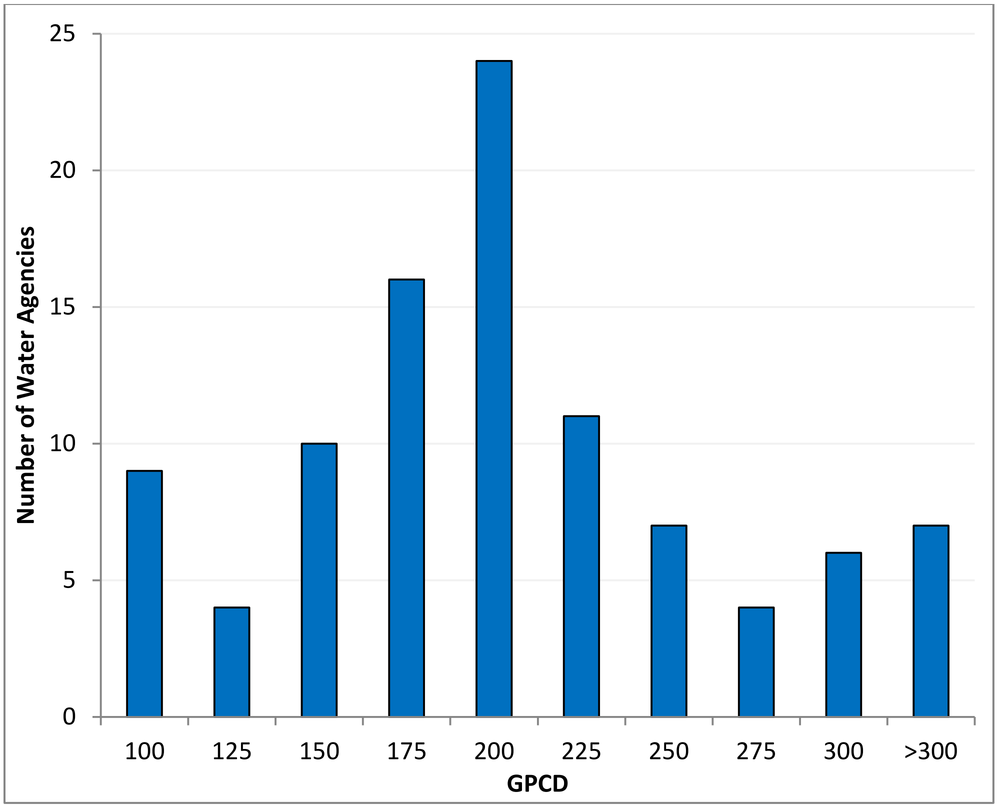

Figure 7. Per Capita Delivery Rates by Numbers of Water Agencies, 2008

Changes in per capita deliveries varied markedly across the water agencies included in the study, indicating that water deliveries do not simply track population, even within the same city. Figure 8 shows the number of water agencies experiencing reductions in per capita deliveries and the numbers of people served by these agencies, expressed as a percentage of the total number of people served by all of these agencies. Five water agencies experienced greater than five percent increases in per capita deliveries over this period, while 29 experienced reductions of greater than 20 percent, equivalent to an average annual decline of at least one percent. Median change for the group was a reduction of 16 percent, equivalent to a reduction of 36 gallons per capita per day. More than 20 percent of the agencies experienced an average annual reduction of at least 1.5 percent per year (equivalent to a 30.7 percent total reduction in GPCD). Note that several of the providers with relatively low per capita deliveries in 1990, such as Flagstaff, Arizona and Boulder, Colorado, achieved greater than one percent annual reductions in deliveries, implying that such reductions are also attainable for those with higher baseline per capita deliveries.

Figure 8 shows that more than 80 percent of the people receiving Colorado River basin water lived in service areas where per capita delivery rates decreased by an annual average of at least one percent. The vast majority of these people lived in Metropolitan's service area, where the *average* decline for the population as a whole was -21.5%. Unfortunately, we could not obtain sufficient information to break down this down for all of Metropolitan's individual member agencies. Although nine water agencies experienced increased per capita deliveries from 1990 to 2008, they delivered water to only 2.1 percent of the total population shown below.

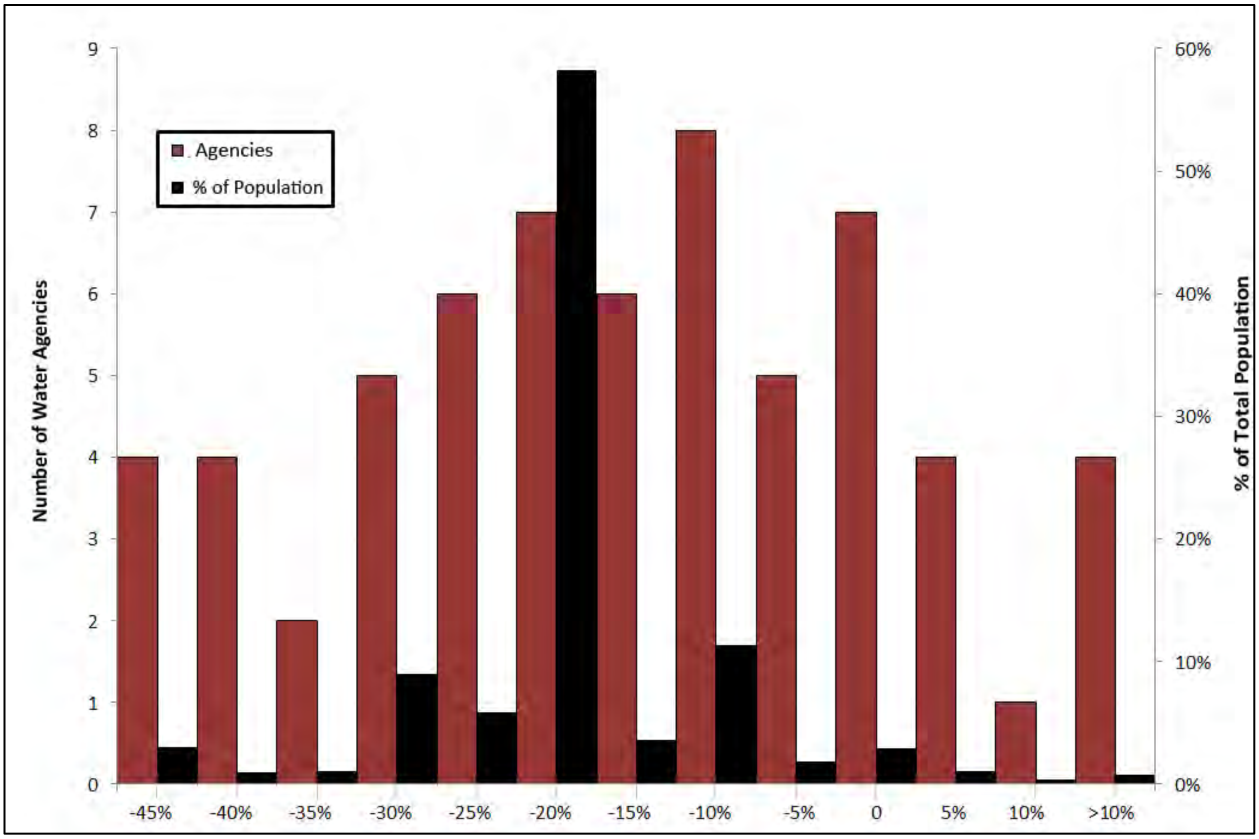

Figure 8. Change in per capita deliveries from 1990 to 2008, by number of water agencies and their 2008 service area populations

Note that the changes shown in Figure 8 are relative. Some of the highest declines in per capita delivery rates, such as those for Provo and Springville, Utah, came from areas with very high initial rates. Others with high rates of decline, such as Flagstaff, had relatively low per capita delivery rates in 1990 and enjoyed marked reductions even from that low baseline. This study tracks system-wide municipal deliveries, rather than just residential deliveries, so several factors influence total deliveries. For example, total per capita deliveries by the Virgin Valley Water District in Nevada reportedly increased by almost 40 percent from 1990 to 2008. New casinos and associated commercial development explain much of this increase. Figure 8 also does not account for climatic impacts. Several water agencies, such as those in southern Nevada and in the Coachella Valley, experienced markedly higher temperatures and/or lower precipitation in 2008 than they had in 1990, likely increasing water deliveries, though such impacts were likely offset by the economic recession and decline in housing starts in the area.

Twenty-eight water agencies in this study (including 17 Metropolitan member agencies) delivered less water in 2008 than they had in 1990, despite significant increases in population served. Table 29 lists these water agencies and the magnitude of their delivery reductions, as well as their population increases and changes in GPCD. Although most of these agencies are in southern California, there are agencies with net declines in deliveries in most of the basin states, suggesting opportunities for other cities throughout the basin to achieve similar results.

Table 29. Water Agencies Delivering Less Water in 2008 than in 1990

Agency	1990-2008 Change In		
	Deliveries (Acre-Feet)	Population	GPCD
Metropolitan	(154,921)	3,594,000	-23%
San Diego County Water Authority	(63,474)	710,371	-29%
City of Los Angeles	(37,200)		
West Basin MWD	(31,864)		
City of Long Beach	(27,296)		
Three Valleys MWD	(20,629)	131,430	-34%
City of Santa Ana	(20,398)		
Upper San Gabriel Valley MWD	(15,119)		
Central Basin MWD	(14,106)		
City of Torrance	(6,059)		
City of Anaheim	(5,466)		
City of Fullerton	(4,628)		
City of Pasadena	(4,502)		
City of Compton	(3,286)		
City of Santa Monica	(3,007)		
City of Beverly Hills	(2,214)		
City of San Marino	(1,577)		
City of Glendale	(874)		
Salt Lake City, UT	(34,199)	37,215	-39%
Albuquerque, NM	(18,789)	115,215	-34%
Provo, UT	(7,941)	33,000	-44%
Fort Collins-Loveland, CO	(2,876)	32,800	-33%
Orem, UT	(1,485)	25,202	-32%
Boulder, CO	(1,373)	16,898	-20%
Greeley, CO	(958)	48,238	-42%
Tempe, AZ	(840)	31,000	-19%
South Salt Lake, UT	(760)	4,975	-44%
Flagstaff, AZ	(56)	18,343	-29%

If the water agencies in this study had continued to deliver water in 2008 at 1990 per capita rates, total water deliveries would have been almost 8.5 million acre-feet (assuming that much water would have been physically available) instead of 6.5 million acre-feet, some two million acre-feet more than actually delivered in 2008. The substantial reduction in per capita deliveries achieved by many of the agencies in this study, representing more than half of the total population receiving Colorado River basin water, can be seen as a net augmentation of existing water sources of some two million acre-feet, water that otherwise would have been withdrawn from surface streams or pumped from the ground. Declining real and per capita deliveries in

Metropolitan's service area account for more than half of this savings. Total 2008 deliveries in the San Diego County Water Authority service area were almost 273,000 acre-feet less than projected by 1990 per capita rates; water deliveries in Phoenix were some 130,000 acre-feet less than they could have been had per capita delivery rates remained constant. Deliveries in SNWA's service area were almost 230,000 acre-feet less than they could have been.

If the 66 water agencies in this study had all experienced GPCD declines of at least one percent (or more, for those with greater declines), total deliveries would have increased by about 300,000 acre-feet, only half as much as the actual increase in municipal deliveries by these agencies. While small in comparison with the two million acre-foot reduction already achieved, this is still a sizeable volume of water that could be realized if the agencies with low per capita reductions had been more efficient.

These projections of reduced deliveries based on declining per capita delivery rates are purely conjectural, an exercise in "paper water" accounting rather than a quantification of actual, physical, "wet water" deliveries. Total municipal water deliveries increased by more than 600,000 acre-feet between 1990 and 2008, taking water from a basin that faces a future challenged by diminished supply and continued population growth. Yet the water delivery trends of many of these water agencies, such as those highlighted in Table 29, offer a route forward, where growth can be accommodated within existing supplies and total demands on the basin actually decline over time. The large number of water agencies from many parts of the Colorado River basin states and Mexico that have already achieved substantial declines in per capita deliveries demonstrate what increased water efficiency and conservation can accomplish and should encourage the less successful agencies to promote conservation and efficiency more aggressively in their own service areas.

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Endnotes

[1] Ray Ahlbrandt patiently created the basin map shown as Figure ES-1, with subsequent revisions by Julie Martinez

[2] Frank Waters, 1946, *The Colorado*, New York: Rinehart & Co, p. 13.

[3] Acre-feet are the conventional unit of measurement of water in the West; an acre-foot is equivalent to 325,851 gallons or 1,233 cubic meters, the volume required to cover an acre of a land to a depth of one foot.

[4] "The fastest-growing U.S. cities," (growth since 2000), posted at http://www.citymayors.com/gratis/uscities_growth.html.

[5] This study uses the phrase "Colorado River basin water" to encompass mainstem Colorado River water, all other surface water in the Colorado River basin, and all groundwater extracted in the basin.

[6] See *Record of Decision – Colorado River Interim Guidelines for Lower Basin Shortage and the Coordinated Operations for Lake Powell and Lake Mead*, available at http://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf, and related implementing agreements posted at Reclamation's website: http://www.usbr.gov/lc/region/programs/strategies/documents.html.

[7] For the years 2000 through 2010, annual runoff was about 75 percent of the Colorado River's historic annual flow, causing shortages in the Upper Basin and decreasing the surface elevation of Lake Mead by more than 130 feet from October, 1999 to October, 2010. In that time, total Colorado River system storage decreased by more than 23 million acre-feet, equivalent to one and a half years of the river's average annual flow as measured at Lees Ferry, the conventional measuring point for Colorado River discharge

[8] See for example Christensen, N.S., and D.P. Lettenmaier, 2007. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin, *Hydrology and Earth Systems Sciences* **11**: 1417-1434; Barnett, T.P., and T.W. Pierce, 2009, Sustainable water deliveries from the Colorado River in a changing climate, *Proceedings of the National Academy of Sciences*, www.pnas.org_cgi_doi_10.1073_pnas.0812762106; and Reclamation, 2011, SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water, Report to Congress. Available at http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf.

[9] Figure and data courtesy of Jim Prairie, Bureau of Reclamation.

[10] For information on Reclamation's Colorado River Basin Study, see http://www.usbr.gov/lc/region/programs/crbstudy.html.

[11] See H. Cooley et al., 2010, *California's Next Million Acre-Feet: Saving Water, Energy, and Money*, Oakland: Pacific Institute, and other publications available at http://www.pacinst.org/publications/.

[12] Source: J.F. Kenny et al., 2009, *Estimated use of water in the United States in 2005*: U.S. Geological Survey Circular 1344, 52 pp. Available at http://pubs.usgs.gov/circ/1344/.

[13] Sources: Kenny et al. 2009 and C.R. Murray and E.B. Reeves, 1977, *Estimated use of water in the United States in 1975*, U.S. Geological Survey Circular 765, 39 pp. Available at http://pubs.er.usgs.gov/publication/cir765.

[14] The Metropolitan Water District of Southern California annual reports.

[15] Southern Nevada Water Authority annual reports, available at http://www.snwa.com/html/about_annual_rpt.html.

[16] For some water agencies, the most recent available data is for the year 2005.

[17] Reclamation's provisional Upper Colorado River Basin Consumptive Uses and Losses Report: 2001-2005, dated June, 2007, p. 7, states:

"Currently, all ground-water pumping is counted as consumptive use charged against the Colorado River Basin. Obviously, this is not necessarily true. Depending on the location and depth of the well and what types of soils are present in the area, it is possible that little or none of the water pumped would have contributed to the Colorado River System for hundreds or even thousands of years. It has recently been proposed that an interagency study team be put together consisting of personnel from various State Engineers Offices, Bureau of Reclamation, and any other pertinent agencies. This study team would establish guidelines for computing what amounts of ground water pumped should be charged against the Colorado River Basin. These guidelines will need to be established on an area by area basis rather than one set percentage for the entire basin. Results of this study will be incorporated in future Consumptive Uses and Losses Reports. However, until these guidelines are established, the Consumptive Uses and Losses Reports will continue to report all ground-water pumping as depletion from the system.

"Although significant ground-water usage occurs in Arizona, and New Mexico, for purposes of this report ground-water overdraft has not been taken into account in the computation of tributary consumptive use."

[18] For example, see SNWA, 2009, *Water Resource Plan 09*, pp. 38-39, available at http://www.snwa.com/html/wr_resource_plan.html.

[19] While municipal providers frequently point out that agricultural demand is a bigger factor than urban demand, agricultural demand for Colorado River basin water is actually decreasing over time due to urban development and agricultural-to-urban water transfers, while urban demand continues to increase, as documented in this report.

[20] Reclamation's annual decree accounting reports, available at http://www.usbr.gov/lc/region/g4000/wtracct.html, include the following text: "COMPILATION OF RECORDS IN ACCORDANCE WITH ARTICLE V OF THE CONSOLIDATED DECREE OF THE UNITED STATES SUPREME COURT IN ARIZONA *V.* CALIFORNIA, 547 U.S. 150 (2006): V. In accordance with Article V of the Consolidated Decree of the United States Supreme Court in Arizona *v*. California, The United States shall prepare and maintain, or provide for the preparation and maintenance of, and shall make available, annually and at such shorter intervals as the Secretary of the Interior shall deem necessary or advisable, for inspection by interested persons at all reasonable times and at a reasonable place or places, complete, detailed and accurate records of: (A) Releases of water through regulatory structures controlled by the United States; (B) Diversions of water from the mainstream, return flow of such water to the stream as is available for consumptive use in the United States or in satisfaction of the Mexican Treaty obligation, and consumptive use of such water. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California and Nevada; (C) Releases of mainstream water pursuant to orders therefor but not diverted by the party ordering the same, and the quantity of such water delivered

to Mexico in satisfaction of the Mexican Treaty or diverted by others in satisfaction of rights decreed herein. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California and Nevada; (D) Deliveries to Mexico of water in satisfaction of the obligations of Part III of the Treaty of February 3, 1944, and, separately stated, water passing to Mexico in excess of treaty requirements; (E) Diversions of water from the mainstream of the Gila and San Francisco Rivers and the consumptive use of such water, for the benefit of the Gila National Forest." Additionally, Title VI, Section 601(b)(1) of Public Law 90-537, the Colorado River Basin Project Act of 1968, directs the Secretary of the Interior to "Make reports as to the annual consumptive uses and losses of water from the Colorado River System after each successive 5-year period, beginning with the 5-year period starting October 1, 1970. Such reports will include a detailed breakdown of the beneficial consumptive use of water on a State-by-State basis. Specific figures on quantities consumptively used from the major tributary streams flowing into the Colorado River shall also be included on a State-by-State basis." These reports, known as the *Colorado River System Uses and Losses Report*, are available at http://www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html.

[21] The "Law of the River" refers to the complex, evolving set of laws, treaties, decrees, regulations, contracts, and other legal decisions determining and guiding the management and allocation of the Colorado River. See D. Getches, 1985, Competing demands for the Colorado River, *University of Colorado Law Review* 56: 413-479, and U.S. Department of the Interior, Bureau of Reclamation, 2010, *Colorado River Documents 2008*, Denver: U.S. Government Printing Office.

[22] This study reports data for 22 cities and municipal water providers in Arizona, 13 of which are in Arizona's Active Management Areas (AMAs). However, Arizona DWR reports that there are 76 municipal providers delivering more than 250 acre-feet per year in the AMAs, and a total of about 293 municipal water providers within the AMAs. Outside the AMAs, 83 providers deliver more than 250 acre-feet per year, and a total of more than 500 municipal water providers deliver water to more than one million people. Compiling population and water delivery data for even the 159 larger municipal water providers was beyond this study's limited budget.

[23] According to the U.S. Census Bureau, "Metropolitan and micropolitan statistical areas (metro and micro areas) are geographic entities defined by the U.S. Office of Management and Budget for use by Federal statistical agencies in collecting, tabulating, and publishing Federal statistics. The term "Core Based Statistical Area" is a collective term for both metro and micro areas. A metro area contains a core urban area of 50,000 or more population, and a micro area contains an urban core of at least 10,000 (but less than 50,000) population. Each metro or micro area consists of one or more counties and includes the counties containing the core urban area, as well as any adjacent counties that have a high degree of social and economic integration (as measured by commuting to work) with the urban core." See http://www.census.gov/population/www/metroareas/metroarea.html.

[24] The "CRWUA Member States" page http://www.crwua.org/coloradoriver/index.cfm?action=memberstates on the CRWUA website links to summaries for each of the basin states, listing facilities delivering Colorado River water and other pertinent information.

[25] This report is available online at no charge at www.pacinst.org/water/coloradoriverbasin. Also posted at this website is the spreadsheet compiling water use and population data and calculating per capita use rates. The spreadsheet also lists the sources for the data used in this report..

[26] The Arizona Water Atlas only reports municipal and industrial use as averages for five-year periods through 2005, but offers a consistent data source for the state as a whole. The atlas is posted at http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/default.htm.

[27] New Mexico State Engineer Office technical reports 47 (1992), 51 (2003), and 52 (2008), available at http://www.ose.state.nm.us/publications_technical_reports_wateruse.html.

[28] For example, see SNWA, 2009, *Water Resource Plan 09*, pp. 38-39, available at http://www.snwa.com/html/wr_resource_plan.html.

[29] For example, see BC Wilson, AA Lucero, JT Romero, and PJ Romero, 2003, *Water Use by Categories in New Mexico Counties and River Basins, and Irrigated Acreage in 2000*, New Mexico State Engineer Office, Technical Report 51. Available at http://www.ose.state.nm.us/publications_technical_reports_wateruse.html.

[30] System-wide calculations typically include all deliveries within a specific service area, including industrial and commercial uses, such as tourism. Such calculations can be useful in comparing changes over time for the same location, but are not appropriate for use in comparisons between different locations. Other methods may specifically compare use in, for example, single-family residences, adjusting for differences in climate, providing a basis for comparison between different locations. See American Water Works Association, "Report calls for standardized water conservation metrics," at http://www.awwa.org/publications/StreamlinesArticle.cfm?itemnumber=54056&showLogin=N.

[31] Some water agencies report total water production rather than total water deliveries. Although these volumes are not equivalent, in the absence of better information this study used total water production data when total delivery data were not available. The assumption was that changes in production volumes could be compared over time for the same city, but that different measures were not appropriate bases for comparison between cities.

[32] Calculated as 1 acre-foot/year = 325,851 gallons/acre-foot divided by 365 days/year = 892.74 gallons per day.

[33] Sources: Reclamation's Colorado River Basin Study Fact Sheet, available at http://www.usbr.gov/WaterSMART/docs/Colorado%20River.pdf; National Geographic Colorado River map, at http://maps.nationalgeographic.com/maps/print-collection/colorado-basin1-map.html; and the Colorado River Water Users Association, at http://www.crwua.org/coloradoriver/riveruses/index.cfm?action=overview (though the population totals for the individual states only sum to slightly more than 25 million, as shown in Table 4).

[34] Source: http://www.crwua.org/.

[35] See AZ DWR, July 2010, "Statewide Cultural Water Demand in 2001-2005 and 2006," available at http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/documents/July2010_statewidedemand.pdf.

[36] The Arizona Water Atlas reports total population in the Douglas Basin – the most populated of the four basins – at 28,911 in 2005, with total reported annual municipal water deliveries at 5,500 acre-feet on average for the period

2001-2005. This is less than 0.5% of total water deliveries reported for the state of Arizona as a whole. See http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/SEArizona/Cultural/DouglasBasin.htm.

[37] See Navajo Nation Department of Water Resources, April 2011, *Draft Water Resource Development Strategy for the Navajo Nation*, 99 pp.

[38] Navajo Nation DWR, April 2011, *Draft Water Resource Development Strategy for the Navajo Nation*.

[39] Data from respective water agencies, except for Sierra Vista, Safford, and Nogales, where the data comes from Arizona Water Atlas reports; these three include the 1991, 2000, and 2005 populations for their basins as a whole, and average annual municipal and turf-related deliveries for the years 1991-1995, 1996-2000, and 2001-2005. Lake Havasu City data are total Colorado River diversions for the given year, from Reclamation's annual decree accounting reports.

[40] Kingman, with an estimated 2008 population of about 27,000, also delivers water outside of city limits. Total service area populations in 1990 and 2000 could not be determined; Kingman populations in those years was 12,722 and 20,069, respectively.

[41] The Arizona Water Company is a private municipal water provider delivering water to 83,000 service connections in 21 communities, including: Ajo Heights, Apache Junction, Bisbee, Casa Grande, Coolidge, Lakeside, Miami, Oracle, Overgaard, Pinewood, Rimrock, San Manuel, Sedona, Sierra Vista, Stanfield, Superior, White Tank, and Winkelman.

[42] The Arizona American Water Company is a private municipal water provider with many subsidiaries that deliver water to a large number of communities in Arizona. On January 24, 2011, the parent company of Arizona American Water, American Water, announced its intention to sell Arizona American Water to EPCOR, USA. American Water subsidiaries deliver water to approximately 174,000 customers in Arizona and New Mexico.

[43] From Arizona Water Atlas website, http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/default.htm.

[44] See Metropolitan's website at http://www.mwdh2o.com/mwdh2o/pages/memberag/member02.html for locations of individual member agencies and links to member agency websites.

[45] For information on San Diego County Water Authority's 24 member agencies, see http://www.sdcwa.org/member-agencies.

[46] Sources: Metropolitan member agency populations from http://www.mwdh2o.com/mwdh2o/pages/memberag/member02.html; CVWD annual reports, personal communications with Coachella Valley water agencies and Imperial Irrigation District.

[47] Three of Metropolitan's western-most member agencies – Calleguas MWD, Las Virgenes MWD, and the City of San Fernando – are not connected to Metropolitan's Colorado River distribution system and therefore do not deliver any Colorado River water to their customers. These three agencies are not included in Table 8 and their service area populations are not included in the total reported for Metropolitan.

[48] IID's "Crop Production and Water Utilization Data Report-1990" to Reclamation lists "M&I Population Served" as 109,303, but this is actually the population for Imperial County as a whole. The population listed for Imperial

Valley in 1990 reflects populations of all Imperial Valley communities with census-reported populations greater than 1,000 that received IID water.

[49] In 1990, Metropolitan delivered 1,214,911 acre-feet of Colorado River water, 1,300,014 acre-feet in 2000, and 1,024,964 acre-feet in 2008.

[50] Metropolitan notes that demands by the three MWD member agencies that do not receive Colorado River water do affect Metropolitan's total Colorado River diversions, as increased demands by these three agencies increase demands on Metropolitan's supplies generally.

[51] Denver Water provides water to customers in the city of Denver and in many surrounding suburbs, as shown in their service area map posted online.

[52] See City of Lakewood website, at http://www.lakewood.org/index.cfm?&include=/F?C/wsdistricts.cfm.

[53] See note 54.

[54] The City of Grand Junction, the Clifton Water District, and the Ute Water Conservancy District all provide potable water to Grand Junction valley residents; these potable water volumes, generally reported as total production of treated water, are included in the table. Some residents also receive raw water for landscape irrigation from one of the six Grand Valley irrigation districts, but these raw water deliveries have not been determined, so total municipal water use in Grand Junction is higher than reported here.

[55] The volume of Colorado River basin water delivered in 1990 was not reported.

[56] Despite multiple requests, City of Golden staff only provided this single datum.

[57] The Southern Nevada Water Agency formed in 1991 through a cooperative agreement among the following seven agencies:

"• Big Bend Water District
• City of Boulder City
• City of Henderson
• City of Las Vegas
• City of North Las Vegas
• Clark County Water Reclamation District
• Las Vegas Valley Water District

The Big Bend Water District provides water service to Laughlin. The cities of Boulder City and Henderson provide water and wastewater service to their respective communities. The City of Las Vegas provides wastewater service to its residents. The City of North Las Vegas provides wastewater service to its residents, and water service to its residents, adjacent portions of Las Vegas and unincorporated Clark County. The City of North Las Vegas will be constructing its own water reclamation facility and currently has contract wastewater treatment services with the City of Las Vegas and the Clark County Water Reclamation District. The Clark County Water Reclamation District provides wastewater service for unincorporated Clark County and Laughlin. The LVVWD provides water service to Las Vegas and portions of unincorporated Clark County." Source: SNWA 2009 Water Resources Plan, pp. 5-6.

[58] Michael Winters, 2008, "Water Resources of the Virgin River Basin," powerpoint presentation to the Legislative Committee on Public Lands, attached as an appendix to Virgin Valley Water District *Water Conservation Plan*, available at https://zdi5.zd-cms.com/cms/res/files/521/Conservation%20Plan2008.pdf.

[59] Albuquerque now diverts about 48,200 acre-feet of Colorado River basin water annually, from the San Juan-Chama transbasin diversion, for municipal use. Santa Fe is developing a project to divert San Juan-Chama water, starting in 2014.

[60] The San Juan-Chama Drinking Water Project first diverted surface water into the Albuquerque Bernalillo County Water Utility Authority water distribution system in December, 2008, for municipal uses. Previously, Albuquerque relied entirely on local groundwater. See http://www.abcwua.org/content/view/31/24/ for more information about the Project.

[61] Provisional 2007 data from Reclamation's *Provisional Upper Colorado River Basin Uses and Losses Report 2006-2010*, available at http://www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html.

[62] According to the records posted on the Utah Division of Water Rights WUSEVIEW Water Records/Use Information Viewer website.

[63] According to its website, the Jordan Valley Water Conservancy District, known until 1999 as the Salt Lake County Water Conservancy District, "has a retail service area primarily in unincorporated areas of [Salt Lake] county, making up about 10 percent of its deliveries; approximately ninety percent of its municipal water is delivered on a wholesale basis to cities and water districts. In addition, Jordan Valley treats and delivers water to Metropolitan Water District of Salt Lake & Sandy on a contractual basis for delivery to Salt Lake City and Sandy City, even though neither city is within Jordan Valley Water's service boundaries. Jordan Valley also delivers untreated water to irrigators in Salt Lake and Utah Counties to meet commitments under irrigation exchanges."

[64] See Appendix A for more information on St. George's population growth and annual water deliveries.

[65] Despite the presence of fast-growing cities such as Las Vegas and Phoenix, most of the Colorado River basin is sparsely populated. According to Reclamation's *Upper Colorado River Basin Consumptive Uses and Losses Report*, in the year 2000 the estimated population within the roughly 110,000 square miles of the upper basin was 804,600 people, or less than 7.4 people per square mile. The estimated population within the roughly 132,000 square miles of the lower basin in 2000 was 6,676,000 people, or more than 50 people per square mile. According to 2000 census figures from Mexico's *Instituto Nacional de Estadística y Geografía*, the estimated population within the roughly 2,000 square miles of the Colorado River basin within Mexico was roughly 1,070,000, or more than 530 people per square mile.

[66] Source: Email from Cary Chapman, Control Systems Supervisor, City of Cheyenne Water Department, October 12, 2010.

[67] Pursuant to Minutes 310 and 314 of the International Boundary and Water Commission, the U.S. delivered 5,482 acre-feet of Colorado River water directly to Tijuana in 2008 as "temporary emergency deliveries" via the Colorado River Aqueduct and Metropolitan's, SDCWA's, and the Otay Water District's delivery systems.

[68] Camp Dresser and McKee, 2003, *Environmental Assessment Tijuana and Playas de Rosarito Potable Water and Wastewater Master Plan,* prepared for the Environmental Protection Agency, available at http://www.scribd.com/doc/1797102/Environmental-Protection-Agency-ea.

[69] Sources: Comisión Estatal de Agua de Sonora, 2008 annual water report for Nogales dated March 28, 2011, posted at http://sgc.ceasonora.gob.mx/FichasTecnicas.aspx. Figure 6 in Wilder et al., 2011, "Urban Water Vulnerability and Institutional Challenges in Ambos Nogales," shows the variable water service schedules for the different neighborhoods in Nogales.

[70] See CEA website at http://sgc.ceasonora.gob.mx/Reporte_Fichas_Tecnicas.aspx.

[71] Several of these 68 providers are member agencies of wholesale providers such as Metropolitan, and are listed in the individual state sections but not in Table 1.

[72] Note that this increase in diversions does not represent an equivalent overall depletion of Colorado River flows, since SNWA returns more than 40% of its diversions to the river.

[73] This does not include two agencies: Jordan Valley Water Conservancy District, which wholesales to some other agencies along the Wasatch Front as well as providing some direct retail deliveries, and Surprise, Arizona, which has multiple water providers.

Appendix A – Longitudinal Data for Provo and St. George, Utah

This study uses three years – 1990, 2000, and 2008 – to determine long-term trends in population, water deliveries, and per capita water use for providers delivering Colorado River basin water as at least a portion of their municipal water deliveries. The study generally uses the years 1990 and 2000, because detailed census records exist for those years, and the year 2008, because this is the most recent year for which many agencies have published water delivery data. Selecting three years for comparison, rather than analyzing trends over multiple years, was simply a function of the limited scope of this study. To demonstrate how population and deliveries change on an annual basis, this appendix shows long-term annual population, water delivery volumes, and per capita rates for two cities in Utah. These Utah cities were selected because Utah's Division of Water Rights (DWR) has an excellent website providing detailed, long-term data.[74]

These data are self-reported by the individual water agencies, and contain some errors or anomalies. Table A-1, taken directly from the DWR website, shows the range of information posted as well as some of these anomalies for the city of Provo, Utah. Not included in Table A-1 is the column labeled "Stock," which does not list any delivery volumes for any year shown. Note that the self-reported population for the year 1984 probably reflects a transcription error. The "Total" volume listed for the year 2004 does not actually reflect the total for that year. Note also the anomalously high volumes reported for 1988-1991 domestic deliveries, as well as the variability in reported commercial, industrial, and institutional deliveries. As shown in Table A-1, both 1990 and 2000 include unusually high domestic deliveries, potentially skewing Provo's long-term trends as reported in this study.

Table A-1. Provo Populations and Water Deliveries. [75]

PROVO	(in acre-feet)								
Year	**Population**	**Domestic**	**Commercial**	**Industrial**	**Institutnl**	**Wholesale**	**Other**	**Unmetered**	**Total**
1982	75,000	-	-	-	-	-	-	-	24,573
1983	80,000	-	-	-	-	-	-	-	22,555
1984	8,100	-	-	-	-	-	-	-	20,127
1985	80,500	9,971	1,008	504	9,497	-	-	-	20,979
1986	82,000	10,199	5,527	514	9,487	-	-	-	25,727
1987	82,000	11,952	1,195	598	10,667	-	-	-	30,610
1988	82,500	24,878	5,748	564	10,236	-	-	-	41,427
1989	82,500	27,128	1,154	577	9,477	-	-	-	38,336
1990	83,000	26,334	1,090	531	8,120	-	-	-	36,075
1991	86,000	16,057	2,880	2,512	9,434	-	3,738	-	34,621
1992	86,000	12,654	3,019	2,469	5,215	-	4,228	-	27,585
1993	90,000	-	-	-	-	-	-	-	24,831
1994	95,000	14,047	8,172	641	-	-	200	-	23,060
1995	98,000	12,954	6,654	500	-	-	200	-	20,308
1996	98,000	46	13	2	10	-	1	-	72
1997	105,000	14,878	4,209	642	3,212	-	200	-	23,141
1998	109,000	14,140	3,030	1,010	5,016	-	100	-	23,296
1999	110,418	14,782	4,415	2,187	2,916	-	161	-	24,461
2000	112,000	21,046	2,660	132	6,021	-	100	-	29,958
2001	108,025	15,589	7,813	378	1,150	-	200	-	25,130
2002	109,645	13,967	7,480	200	3,032	11	200	-	24,890
2003	111,629	13,539	7,101	725	3,369	0	-	-	24,734
2004	113,773	13,707	9,551	91	1,474	-	-	300	23,649
2005	115,000	12,574	11,123	486	527	-	-	300	25,010
2006	115,000	14,100	9,431	117	602	-	-	300	24,550
2007	116,000	15,403	9,958	117	650	-	-	325	26,454
2008	116,000	16,341	11,277	105	86	-	-	325	28,135
2009	118,000	13,384	8,518	93	551	-	-	325	22,872
2010	120,000	13,662	9,387	104	579	-	24	325	24,081

Figure A-1 shows annual population data for the Provo and St. George water agency service areas. Note the large and unlikely annual variations for the St. George service area population: St. George reported its 2008 population as 83,364, but its 2009 population as 72,718. St. George’s reported population for 2000, at 75,000, is 50 percent higher than the reported population in 2001.

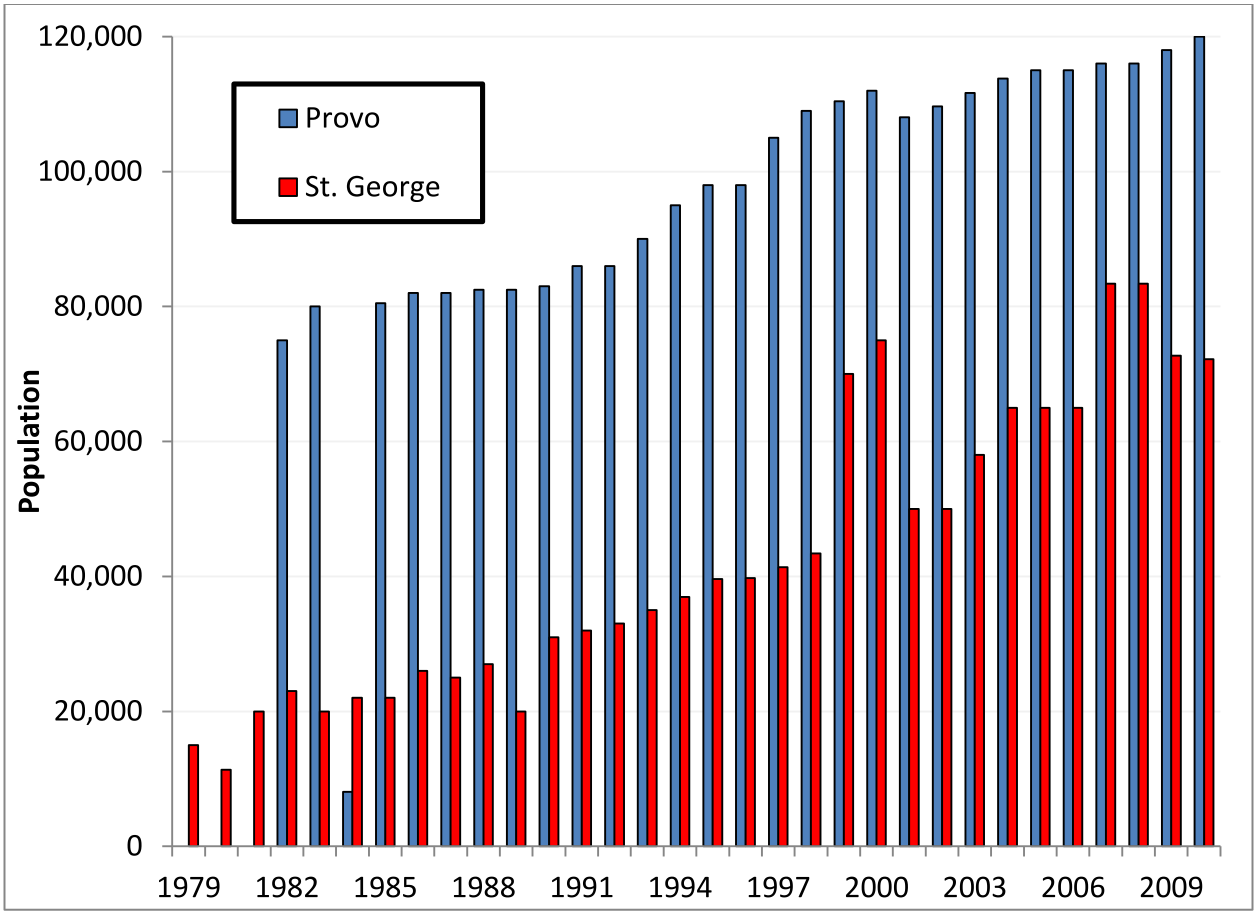

Figure A-1. Provo and St. George Populations, 1979-2010

Figure A-2 shows reported total water deliveries for Provo and for St. George. The 2004 water delivery data for Provo reflects the actual total (25,123 AF) for the rows listed in Table A-1 and not the volume listed under the "Total" column for that year (23,649 AF). Note that the volumes delivered by St. George showed a general increase from 1979 to 1999, while volumes delivered by Provo showed a general declining trend from 1987 to 1995, and then roughly stabilized at about 25,000 acre-feet per year thereafter. However, the volumes delivered in 2000 and 2008 both exceeded this recent average volume. Volumes delivered by St. George from 2006-2010 generally were much higher than volumes delivered during the first part of the decade.

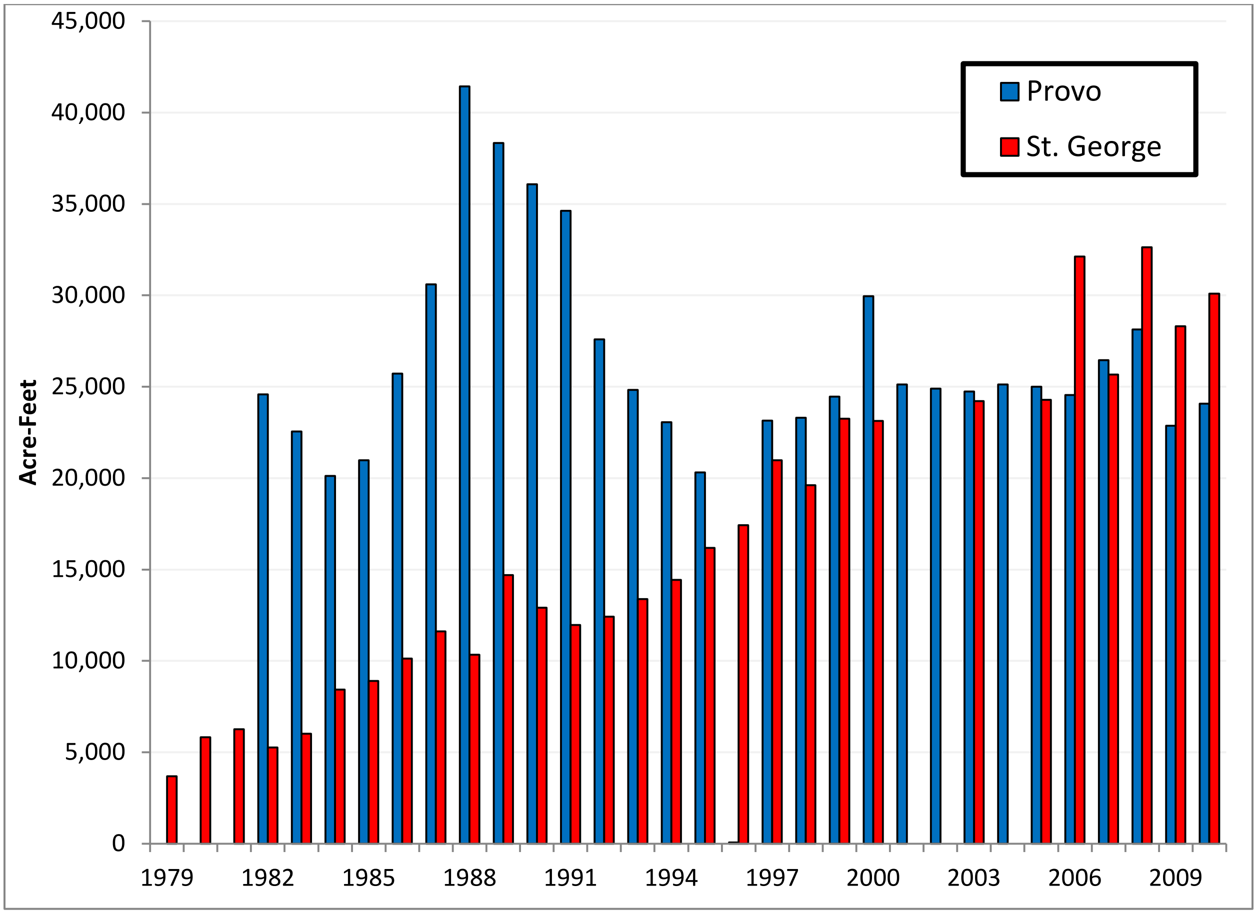

Figure A-2. Provo and St. George Water Deliveries, 1979-2010

Figure A-3 shows calculated per capita consumption (shown as gallons per capita per day – GPCD) for Provo and for St. George. Provo's 1984 population and 2004 delivery volume have been adjusted for this figure, to reflect the total volume noted above and to change the 1984 population to 80,100, more consistent with the reported 1983 and 1985 populations. St. George's anomalously low reported 1989 population of 20,000, combined with a high reported delivery volume of more than 14,000 acre-feet that year, combined to generate the calculated GPCD of 656, a rate almost 50 percent higher than any other year. However, even if the 1989 population were the same as that reported for 1990, GPCD still would have been 423 GPCD, the fourth-highest rate for the period of record, and an extremely high rate under any circumstance. Provo's average GPCD since 1997 has been about 200; both 2000 and 2008 saw higher rates than this recent average, highlighting the difficulty in selecting any particular year for analysis and suggesting that long-term analysis would be appropriate for all of the water providers included in this analysis.

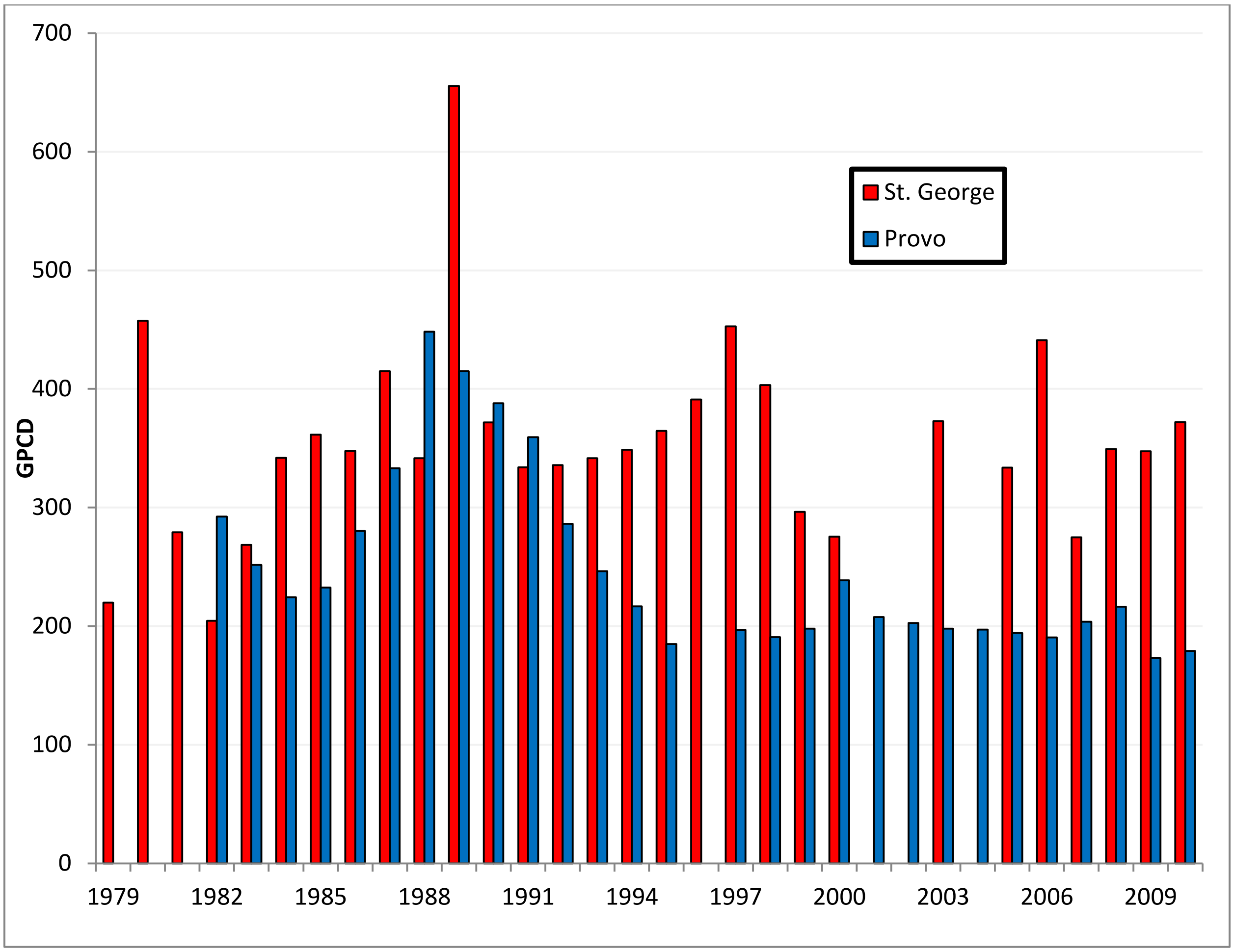

Figure A-3. Provo and St. George Per Capita Water Deliveries, 1979-2010

Appendix B – Impacts of Temperature and Precipitation Changes

Seasonal temperature and precipitation affect municipal water demand. Average monthly temperatures and total precipitation during the typical May-September landscape irrigation season vary tremendously across the cities included in this report. Temperature and precipitation also vary between years in the individual cities. However, no effort was made to adjust or normalize reported water deliveries to reflect annual climatic variations. Instead, this report uses color coding to highlight climatic variations and provide a quick visual clue as to the magnitude such variations likely had on total water deliveries.

Figure B-1 shows how temperature and precipitation influenced water use in the Denver area during the first eleven months of 2010. A forthcoming study modeled the impact of temperature and precipitation on municipal water demands and found that, for California water agencies, a one degree average monthly temperature rise relative to the long-term average increases demand by 1.4 percent during the months April through June, and by 0.7 percent during the months July through October. A one-inch increase in precipitation was found to decrease demand by 3.1 percent during the months April through June, and by 1.6 percent during the months July through October. A one-inch increase in precipitation was found to decrease demand by 3.1 percent during the months April through June, and by 1.6 percent during the months July through October. For this report, we averaged these values for the months of May to September and assume that a one degree average monthly temperature rise relative to the long-term average increases demand by one percent, and assume that a one-inch increase in precipitation decreases demand by two percent over these same months.

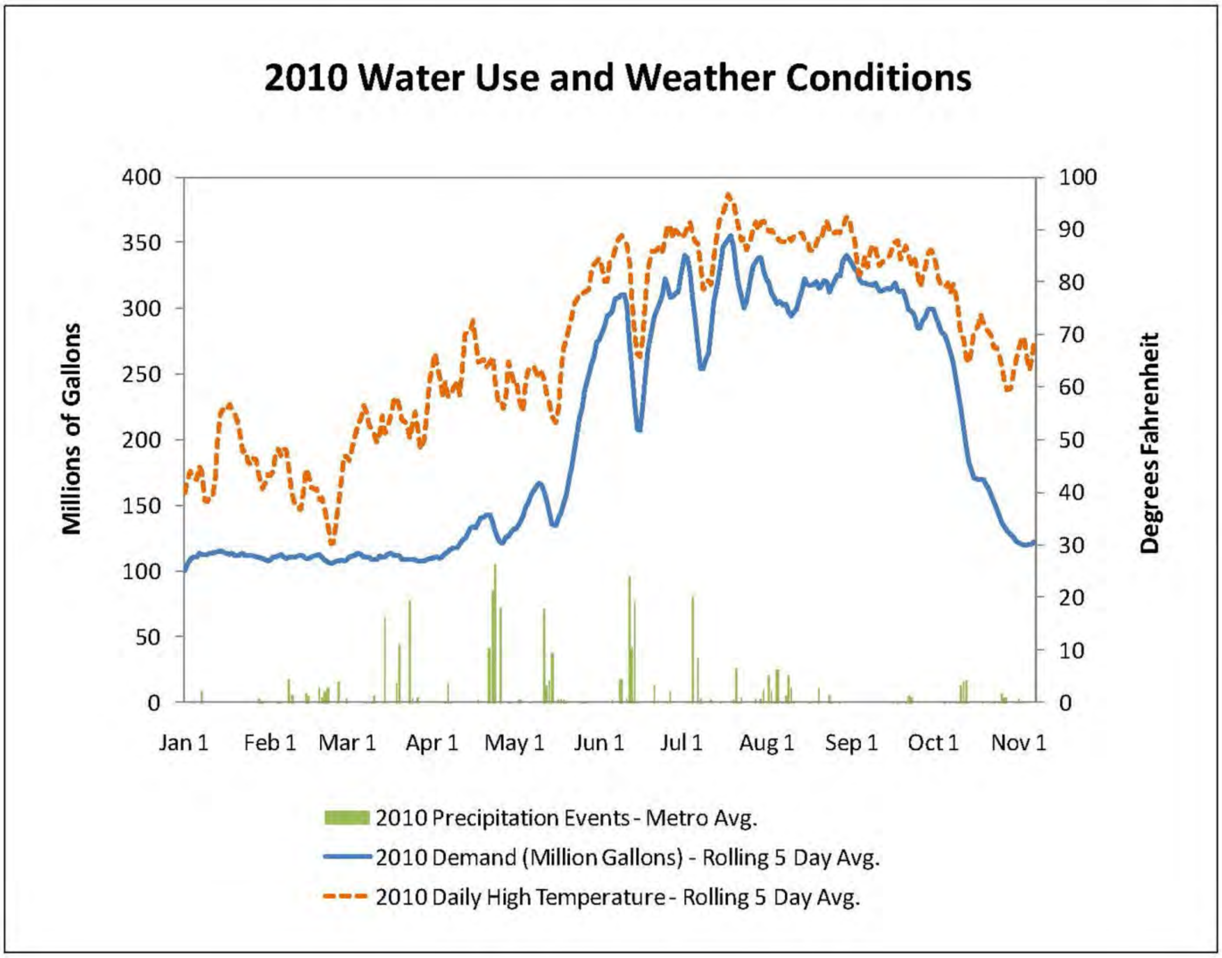

Figure B-1. Water Use and Weather in the Denver Area, 2010.[76]

Table B-1 lists average May-September temperature and precipitation at 25 weather stations[77] and the municipal providers they represent. Several of these weather stations were missing data during this period, as noted below. Figures B-2 and B-3 show cumulative changes from these average values for the three study years, and the relative difference between 1990 and 2008, for temperature and precipitation, respectively. As shown in Table B-1, average May-to-September temperatures range from the mid-to-upper 80s in Las Vegas and Phoenix, to about 60° in Flagstaff and Wyoming. Some areas, such as Colorado's Front Range, parts of Wyoming, and parts of Arizona, receive more than six inches of total precipitation from May to September, while southern California receives less than an inch.

Table B-1 Average May-September Temperature and Precipitation for Utilities' Service Areas[78]

Water Provider or Area	Weather Station Name	Average May-September	
		Temperature (°F)	Precipitation
Albuquerque, NM	Albuquerque Int'l Airport	72.6	5.3
Blythe, CA	Blythe	87.5	1.5
Cheyenne, WY	Cheyenne Municipal Airport	60.6	10.1
Colorado Springs, CO	Colorado Springs Municipal Airport	63.2	12.3
Denver Water, CO	Denver Stapleton	66.4	9.0
Farmington, NM	Farmington Ag Sci Ctr	68.4	3.0
Flagstaff, AZ	Flagstaff Pulliam Airport	59.8	7.8
Fort Collins-Loveland, CO	Ft Collins	66.9	6.6
Grand Junction, CO	Grand Junction Walker Fld	69.7	3.8
Imperial Valley, CA	El Centro 2 SSW	86.3	0.8
Metropolitan – north coastal	Los Angeles Int'l Airport	66.3	0.8
Metropolitan – north inland	Riverside Fire Stn 3	78.1	0.7
Metropolitan – south coastal	San Diego Lindbergh Field	69.4	0.6
Metropolitan – south inland	El Cajon	72.1	0.7
Montrose, CO	Montrose #2	65.5	3.7
Nogales, AZ	Nogales 6 N	74.0	10.9
Payson, AZ	Payson	69.6	8.2
Phoenix, AZ	Phoenix Sky Harbor Int'l Airport	87.6	2.9
Rock Springs, WY	Rock Springs Airport	59.2	4.4
Safford, AZ	Safford Ag Ctr	78.0	4.9
Salt Lake City, UT	Salt Lake City Int'l Airport	69.1	5.7
Sierra Vista-Douglas, AZ	Sierra Vista	75.2	8.8
Silver City, NM	Ft Bayard	69.3	10.1
SNWA, NV	Las Vegas McCarran Airport	84.6	1.2
St. George, UT	St George	79.6	1.5
Tucson, AZ	Tucson Int'l Airport	82.2	6.3

Figure B-2, below, shows the total difference between reported monthly temperatures for the years 1990, 2000, and 2008 and average monthly temperatures, for the weather stations listed in Table B-1, for the months May through September. The values shown in the figure sum the differences for each of the five months – they do not reflect an average difference. That is, if each month were one degree warmer than average, Figure B-2 would show a difference of five degrees for that year, reflecting the projected cumulative impact on demand. Note that this presumes a five-month landscape irrigation season, which is longer than actual for some northern and high altitude areas such as Wyoming, but shorter than actual for much of Arizona and southern California. Figure B-2 also shows – as red bars – the difference in cumulative monthly average temperatures for May-September between 1990 and 2008. When the red bars show negative values, 2008 was cooler than 1990. In the case of Tucson, for example, the cumulative difference between recorded May-September average monthly temperatures for both 1990 and 2008 was 2.8°F. The difference between these two years was zero, so no red bar is shown on Figure B-2. The figure shows that, for these weather stations, most locations experienced warmer than average temperatures during the study years, but that the difference between 1990 and 2008 did not demonstrate a similar trend.

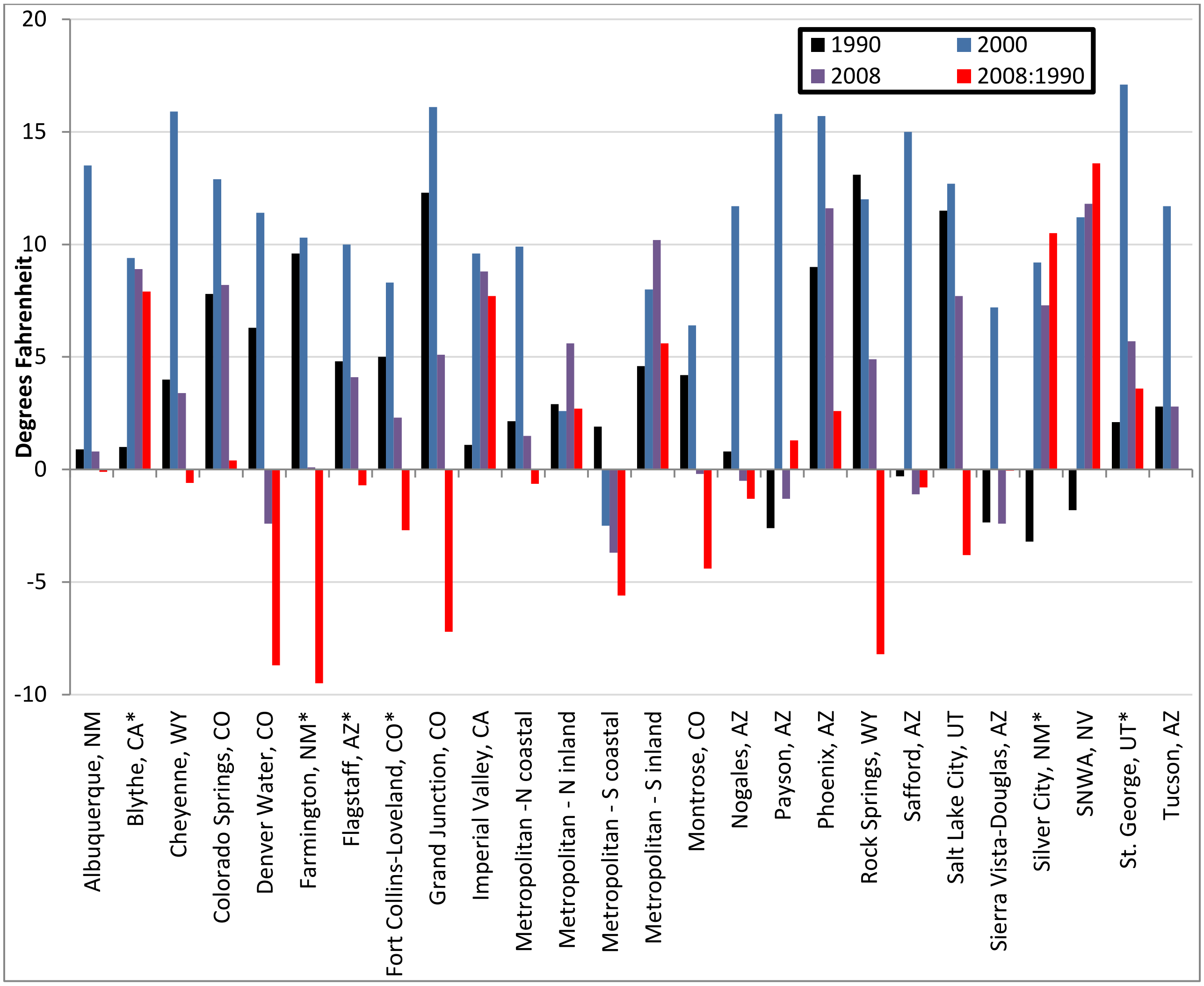

Figure B-2. Combined May-September Deviation From Average Monthly Temperature, for Water Agency Areas. *incomplete monthly data.

Figure B-3, below, shows the difference between total reported precipitation in the months May through September for the years 1990, 2000, and 2008 and the average total precipitation during those months, for the weather stations listed in Table B-1. Note that this presumes a five-month landscape irrigation season, which is longer than actual for some northern and high altitude areas such as Wyoming, but shorter than actual for much of Arizona and southern California. Figure B-3 also shows the difference between 1990 and 2008 in total May-September precipitation. As with Figure B-2, the red bars show the relative difference between 1990 and 2008; where the red bars show negative values, total May-September precipitation for that location was less in 2008 than it was in 1990. Note that several cities in Arizona received markedly less precipitation in 2008 than in 1990, while other areas, especially in California, the difference was negligible. This also reflects normal climate patterns: Southern California receives very little summer precipitation, while Arizona and other parts of the basin can receive significant rainfall in brief summer storms. Not included in this review is relative humidity: dry Santa Ana winds in the fall can significantly increase water demands in Metropolitan's service area even though the temperature variation might not be dramatic.

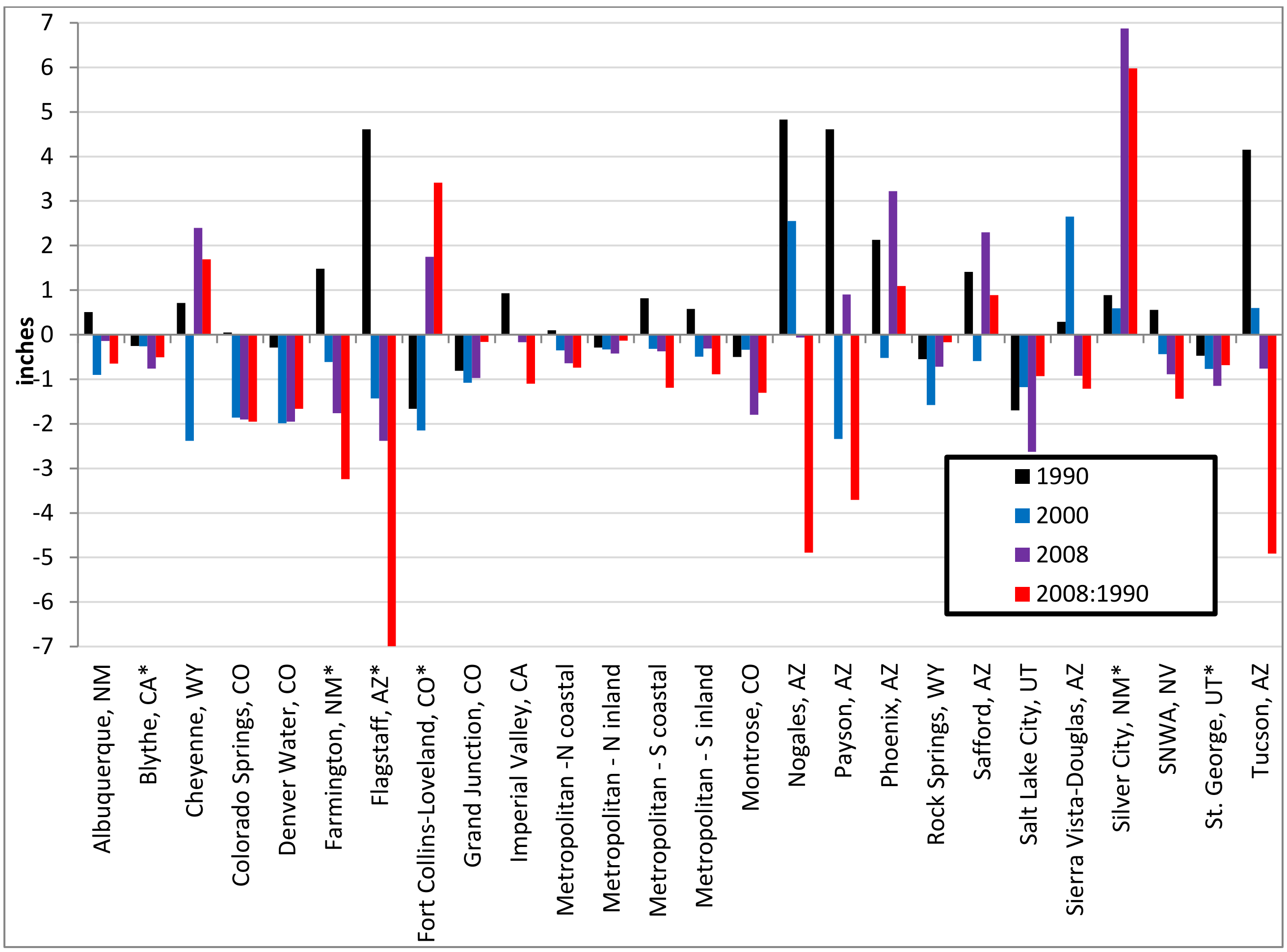

Figure B-3. Combined Deviation from Total May-September Precipitation for Water Agency Areas
*incomplete data

The estimated impacts on water demand from differences in May-September temperature and precipitation are shown in Table 4 (see page 19).

Appendix Endnotes

[74] All data in this Appendix from Utah Division of Water Rights "WUSEVIEW Water Records/Use Information Viewer," at http://www.waterrights.utah.gov/cgi-bin/wuseview.exe. We commend Utah's transparency.

[75] Source: http://www.waterrights.utah.gov/cgi-bin/wuseview.exe?Modinfo=Pwsview&SYSTEM_ID=1010 .

[76] Source: Denver Water, Water Watch Report, 11/15/2010. Available at http://www.denverwater.org/SupplyPlanning/WaterSupply/.

[77] The "summer" irrigation season starts earlier and ends later in lower basin states. Weather station data from U.S. NOAA weather stations, posted at http://www.ncdc.noaa.gov/oa/climate/stationlocator.html. Where stations reported missing values for a given month, this study substitutes partial months values for full month. Some stations reported no data for a given year and were not included.

[78] Source: NOAA's Annual Climatological Summary, posted at http://www.ncdc.noaa.gov/oa/climate/stationlocator.html.