



# Urban and Agricultural Water Use in California, 1960–2015

Heather Cooley



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## Author

Heather Cooley



## Pacific Institute

654 13<sup>th</sup> Street,  
Preservation Park  
Oakland, California 94612  
510.251.1600 | [info@pacinst.org](mailto:info@pacinst.org)  
[www.pacinst.org](http://www.pacinst.org)

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## ABOUT THE AUTHOR

### HEATHER COOLEY

Heather Cooley is Director of Research at the Pacific Institute. Heather holds a B.S. in Molecular Environmental Biology and an M.S. in Energy and Resources and from the University of California at Berkeley. She received the US Environmental Protection Agency's Award for Outstanding Achievement for her work on agricultural water conservation and efficiency and has testified before the US Congress on the impacts of climate change on agriculture and innovative approaches to solving water problems in the Sacramento-San Joaquin Delta. Heather has served on several state task forces and working groups, including the California Commercial, Industrial, and Institutional Task Force and the California Urban Stakeholder Committee, as well as the board of the California Urban Water Conservation Council.

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## INTRODUCTION

**W**ATER IS THE LIFELOOD of California. It provides for the household needs of 40 million people. It generates electricity and cools power plants. It supports one of the most productive agricultural regions in the world and various commercial and industrial activities, ultimately fueling the fifth largest economy in the world. Water is also critical to the health and viability of the state's diverse aquatic and terrestrial ecosystems.

This paper examines statewide urban and agricultural water-use trends from 1960 to 2015 using data from the California Department of Water Resources (DWR). We find that California has experienced a dramatic decoupling between water use and growth. Since 1967, California's population has doubled, and its economic output has increased by a factor of five. Yet statewide water use increased by only 20 percent over this period due to improvements in urban and agricultural efficiency, as well as a shift to higher-value crops and less water-intensive commercial and industrial activities.

Despite positive signs, water use in California remains high. Across the state, rivers and streams are under stress from overuse, and groundwater is over-tapped. Climate change and continued growth are increasing pressure on the state's water resources, including on water supply, demand, and quality. To address these challenges, we must continue and even expand efforts to improve the water-use efficiency of our homes, businesses,

industries, and farms. Moreover, we urge the state to improve data collection and online systems to make data more easily, quickly, and readily available.

## ABOUT THE DATA

Several terms are used to describe water use, including water withdrawals and applied water. Water withdrawals refer to water taken from a source, typically groundwater or surface water, that is used for urban or agricultural purposes. After water is withdrawn from a source, it is subject to seepage or evaporation from reservoirs and canals, i.e., conveyance losses. The term "applied water" is used to describe the water delivered to the intake of a city water system, a factory, or a farm headgate; it is the water withdrawn from a source minus conveyance losses. For the purposes of this paper, the term "water use" refers to "applied water" and is based on estimates developed by DWR and included in the California Water Plan.

DWR develops urban water-use estimates based largely on data submitted annually by operators of public water systems.<sup>1</sup> These data were previously drawn from the Public Water System Statistics survey but are now drawn from Electronic Annual Reports (eARs) submitted annually to

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<sup>1</sup> Public water systems are defined as systems providing water for human consumption to 15 or more connections or regularly serving 25 or more people daily for at least 60 days out of the year.

the State Water Resources Control Board (State Water Board). The eAR dataset, however, does not include water used for energy production, nor does it include water use by self-supplied individuals (typically manufacturing industries, golf courses, and rural residents) that pump groundwater or divert surface water for their own purposes. DWR develops estimates of self-supplied water for rural residents based on per capita use rates in neighboring communities with similar geographic and demographic characteristics. Estimates for energy production are based on reported values for a few counties; however, data are very limited and likely only represent a small fraction of what is being used.

Urban water use estimates are based on measurements of water production, i.e., the amount of water at the intake of the water supplier's system that is put into the water delivery system. Water production is synonymous with the term "applied water." It excludes water losses upstream of the water supplier's system (conveyance losses) but includes water losses that occur within the water supplier's delivery system (distribution losses). Water production is allocated to the major customer classes based on metered water deliveries (for those districts that are metered).<sup>2</sup> Residential water use is typically further divided into indoor and outdoor use based on the assumption that the lowest monthly water production reported for the year (usually during the winter months) represents indoor use because irrigation is not applied during those months. This assumption does not apply to some communities, such as those in desert regions or with significant seasonal tourism, and other corrections are applied.

Agricultural water use, by contrast, is often not based on direct measurement of water at the pump or farm headgate. Rather, it is modeled based on several factors, including crop type and acreage, crop coefficients, weather conditions, and irrigation efficiencies. Additionally, crop acreage is estimated annually based on land-use surveys. These surveys are conducted for select counties every five to eight years such that the values for any given year represent a rolling average across the state. In this paper, agricultural water use represents applied water and includes water for satisfying crop evapotranspiration requirements, leaching fractions, frost protection, pre-irrigation, etc.

Precipitation in California is highly variable from year-to-year, and this variability affects both water demand (especially for agricultural and urban landscape irrigation) and the water available to meet that demand. Thus, while dry conditions may indicate that turfgrass and other plants need more water, insufficient water may be available to meet that need. Because urban estimates are based on measured water use, they adequately capture the effect of precipitation on water availability and demand. Estimates for agricultural water use, by contrast, are based on modeled data and an assumption that all plant water needs are satisfied. They do not, therefore, capture any deficit irrigation that may be occurring.

Finally, water-use estimates reported for years prior to 1989 have been adjusted, i.e., "normalized," to account for dry weather, rationing programs, or other conditions. The goal of this adjustment is to estimate what demand would have been in a "normal" year. With normalization, actual water use in a dry year is higher than the DWR estimate because the additional water used to meet demand in those years would not have occurred had it been a "normal" year and are thus subtracted from the

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<sup>2</sup> Water distribution losses are not captured as a separate customer class. Rather, they are allocated to each of the major customer classes based on water deliveries.

actual values reported. Likewise, actual water use in wet years is less than the DWR estimate because additional water would have been used if it had been a “normal” year and is thus added to the actual values reported. Normalizing was done to help communities prepare for future water needs; however, it makes it difficult to evaluate water use trends and the factors driving those trends. The practice of normalization was discontinued in 1989.

## WATER USE AND GROWTH

California has experienced a dramatic decoupling of water use and growth.

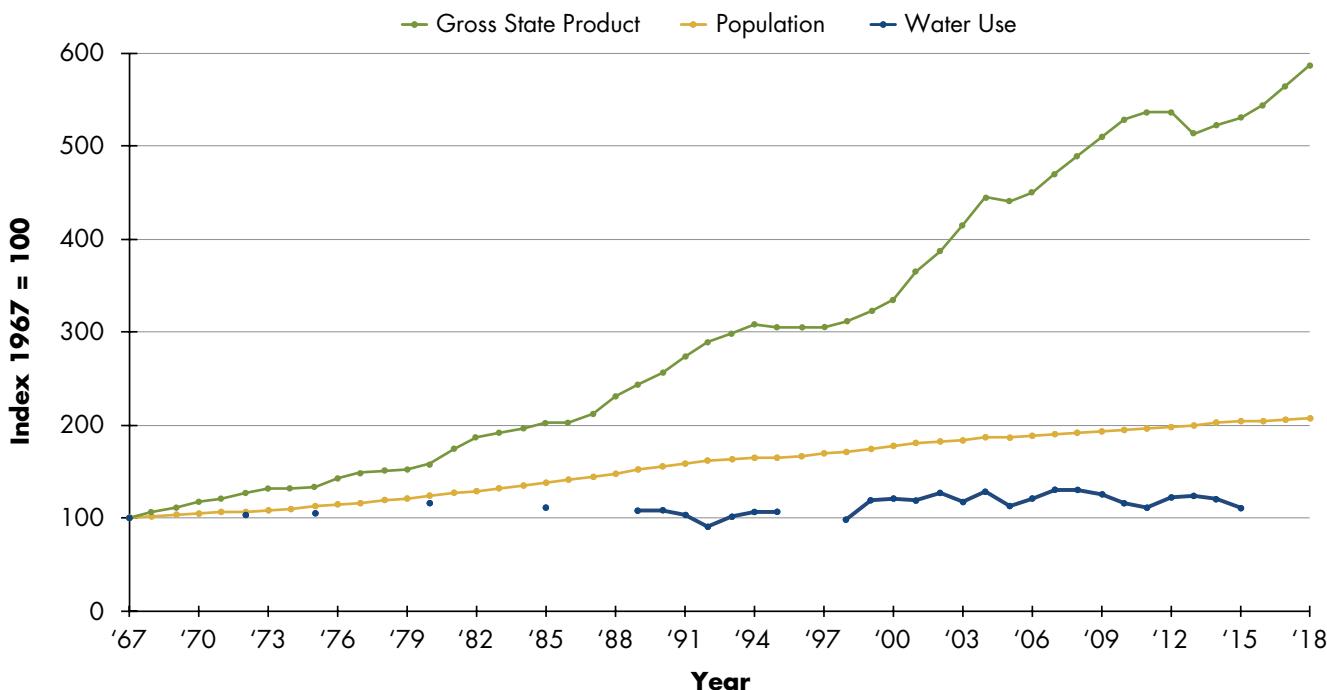
HERE IS A WIDESPREAD perception that population and economic growth inevitably increase water use, but California has experienced a dramatic “decoupling” of water use and growth. Figure 1 shows California’s population, gross state product, and water use between 1967 and 2015. All values are indexed to their 1967 values to allow for comparison among the different datasets. These data indicate that California’s population has doubled and its economic output, as measured by gross state

product, has increased by a factor of five since 1967. Yet statewide water use increased by only 20 percent over this period. This trend was due to improvements in urban and agricultural efficiency, as well as shifts to higher-value crops and less water-intensive economic and industrial activities.<sup>3</sup>

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<sup>3</sup> Given year-to-year variability in water use, these estimates were developed by averaging water use, population, and economic output between 2011 and 2015.

Figure 1. California Population, Gross State Product, and Water Use Indices, 1967 to 2018 



Note: All values are indexed to their 1967 values to allow for comparison. Statewide water use data are not yet available for 2016 through 2018.

Data source: Water use data from DWR ([1964](#), [1970](#), [2018](#), and [2019](#)). Population data from California Department of Finance (2018). Gross state product from US Bureau of Economic Analysis ([2019](#)).

## TOTAL URBAN AND AGRICULTURAL WATER USE

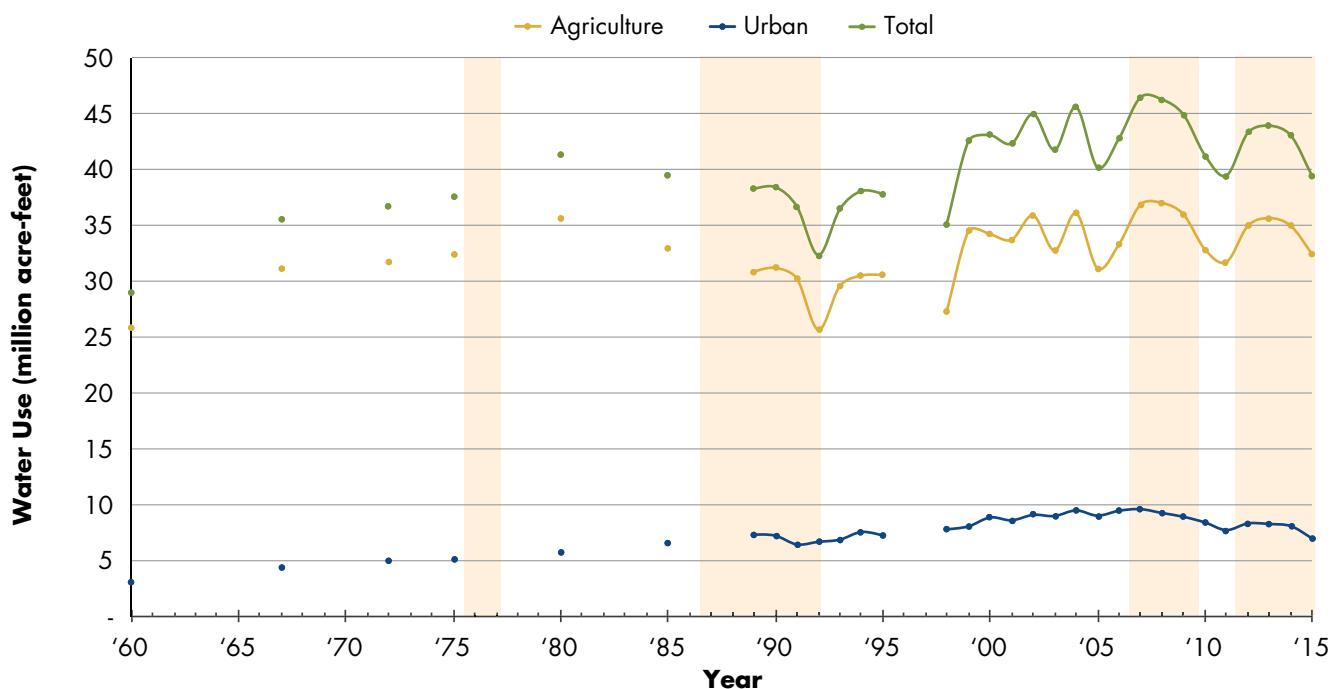
**Total urban and agricultural water use in California has leveled off since the 1980s.**

FIGURE 2 SHOWS the total amount of water used by people and businesses, including on farms, in California between 1960 and 2015. Although data are limited and some trends obscured by the weather normalization that occurred prior to 1989, these data suggest there was a major shift in water use around 1980. Prior to 1980, statewide water use increased at about the same rate as population. Since 1980, however, water use has generally leveled off despite continued population and economic growth. This is consistent with national trends observed by the

US Geological Survey ([Donnelly and Cooley 2015](#), [Dieter et al. 2018](#)). Between 2006 and 2015, the most recent 10-year period for which statewide data are available, total water use in California averaged 43.0 million acre-feet annually.<sup>4</sup> Of that amount, agriculture accounted for 80 percent, or 34.6 million acre-feet per year, while homes and businesses in urbanized areas accounted for the remaining 20 percent, or 8.51 million acre-feet per year.

4 Given interannual variability in water use and mandated reductions during the 2012–2016 drought, we estimate current use by averaging over a 10-year period.

**Figure 2. Total, Agricultural, and Urban Water Use in California, 1960 to 2015** 



Note: Statewide multi-year droughts are shown in shaded orange areas.

Data source: Water use data from DWR ([1964](#), [1970](#), [2018](#), and [2019](#))

## AGRICULTURAL WATER USE

**Agricultural water use in California has remained flat since the 1980s, while the economic value of crop production has grown.**

CALIFORNIA IS ONE of the most productive agricultural regions in the world, supplying both United States and international markets with more than 400 different farm products. In 2018, agricultural production in California was valued at nearly \$54.8 billion, representing 13 percent of the nation's total agricultural production value ([USDA ERS 2020](#)).<sup>5</sup> California is the nation's largest agricultural exporter, with exports totaling \$21.7 billion in 2017 ([CDFA 2019](#)). Despite California's role as a major agricultural producer, farm production and food processing generated less than 2 percent of gross state product ([California Department of Finance 2018](#)).

Water plays a substantial and vital role in California's rich agricultural production. Agricultural water use is highly variable from year to year, ranging from a low of 25.7 million acre-feet in 1992 to a high of 37.0 million acre-feet in 2008 (Figure 3). Weather is a major factor in the year-to-year variability, with cooler, wetter conditions generally reducing agricultural water use and hotter, drier conditions increasing water use. Irrigated crop acreage is also a factor, but as shown in Figure 4, it has varied only modestly since the early 1970s, ranging from 8.8 million to 10.0 million acres and averaging 9.3 million acres.

The most recent five-year period for which statewide data are available (2011–2015) highlights

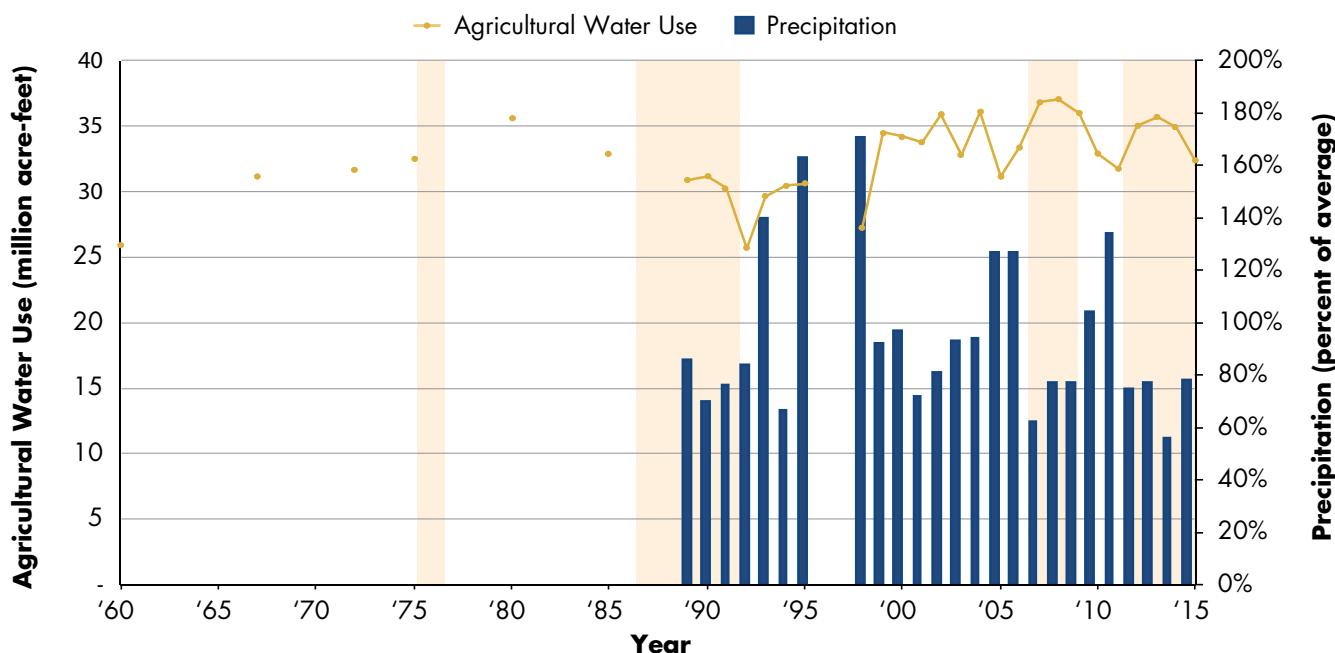
several interesting trends. The year 2011 was wet, with precipitation totaling 134 percent of average. That year, irrigated crop area, at 9.4 million acres, was slightly above average, while agricultural water use was a relatively low 31.7 million acre-feet. Between 2012 and 2016, California experienced the most severe drought on record. While data are not yet available for that entire period, the available data show that irrigated acreage was 9.6 million acres in 2012—the second highest on record—but declined in 2013 and again in 2014. Hot, dry conditions were such that agricultural water use was relatively high during this period, at about 35 million acre-feet, even as irrigated acreage declined. In 2015, irrigated acreage rebounded to more than 9.1 million acres while water use declined to 32.4 million acre-feet, likely a result of shifting to less water-intensive crops.<sup>6</sup> It is noteworthy that the value of agricultural production increased every year between 2011 and 2014, reaching a record \$65.1 billion in 2014. The value of crop production declined to \$57.0 billion in 2015 but remained the fourth highest in state history ([USDA ERS 2020](#)).<sup>7</sup>

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5 All values have been adjusted for inflation and are reported in year 2020 dollars.

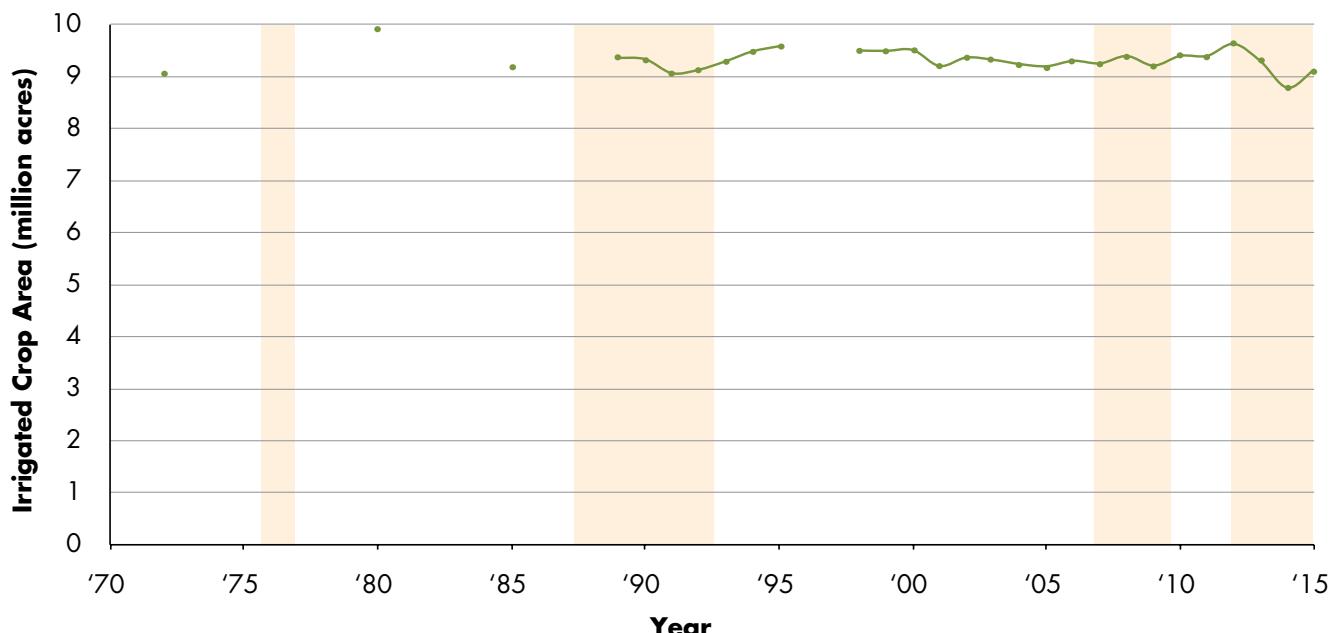
6 Farmers also likely underirrigated fields; however, as discussed previously, these are modeled estimates that do not account for underirrigation.

7 All values have been adjusted for inflation and are reported in year 2020 dollars.

**Figure 3. Agricultural Water Use and Precipitation in California, 1960 to 2015**

Note: Statewide multi-year droughts are shown in shaded orange areas.

Data source: Agricultural water use data from DWR ([1964](#), [1970](#), [2018](#), and [2019](#))

**Figure 4. Irrigated Crop Acreage in California, 1972 to 2015**

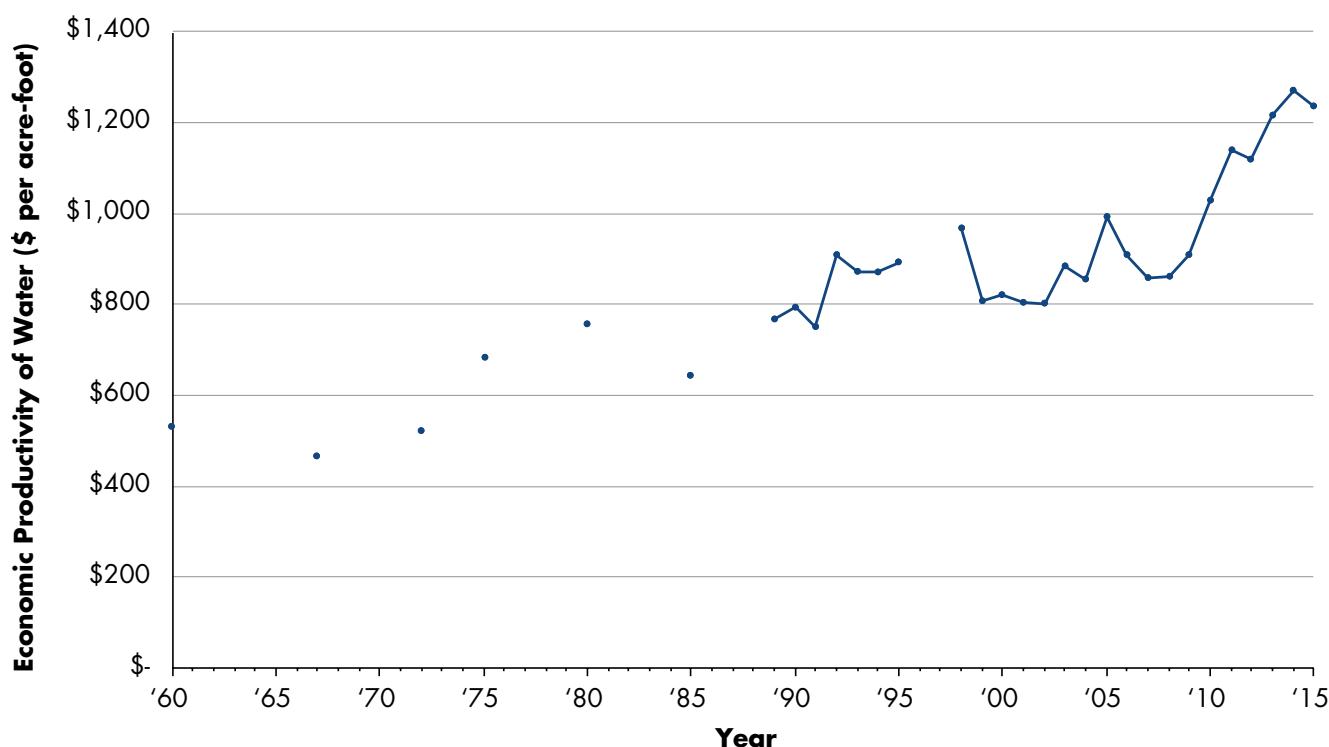
Note: Irrigated crop acreage represents the total irrigated acres of crops produced. Actual acres of lands used may be fewer, due to double cropping. Statewide multi-year droughts are shown in shaded orange areas.

Data source: Data on irrigated crop area from DWR ([2018](#) and [2019](#))

A key measure of agricultural water use is the “economic productivity” of water—the economic value produced per unit of water applied to the crop. Figure 5 shows the gross value added to the United States economy for crop production in California per acre-foot of water applied to crops between 1960 and 2015. All values have been adjusted for inflation and are shown in year 2020 dollars. The economic productivity of water was less than \$600 per acre-foot in the 1960s and early

1970s. Since then, the economic productivity of water increased dramatically, exceeding \$1,200 per acre-foot since 2013. The increase has been driven by several factors, including a shift toward higher-value crops and the increased adoption of more efficient irrigation technologies and practices. For example, the total and percentage of cropland using flood irrigation has steadily declined, replaced by precision drip and micro-sprinkler irrigation systems ([Tindula et al. 2013](#)).

**Figure 5. Economic Productivity of Water in California Agriculture, 1960 to 2015** 



Note: All values are shown in year 2020 dollars.

Data source: Crop production values are based on [USDA ERS \(2020\)](#), while values for agricultural water use are based on DWR ([1964](#), [1970](#), [2018](#), and [2019](#))

## URBAN WATER USE

**Urban water use in California has declined rapidly since the mid-2000s, largely due to reductions in outdoor water use.**

URBAN WATER USE is comprised of various subsectors. Most of the water delivered to urban areas is used in and around homes, with residential water use accounting for 63 percent of total urban use between 2006 and 2015 (Figure 6). Together, institutions (such as schools, prisons, and hospitals) and commercial businesses (such as hotels, restaurants, and office buildings) accounted for 23 percent of California's urban water use. Industry used an additional 5.2 percent to manufacture a wide range of products, from chemicals and electronics to food and beverages, followed by conveyance losses through seepage and evaporation from canals (3.3 percent), groundwater replenishment (4.2 percent), and energy production (1.7 percent).

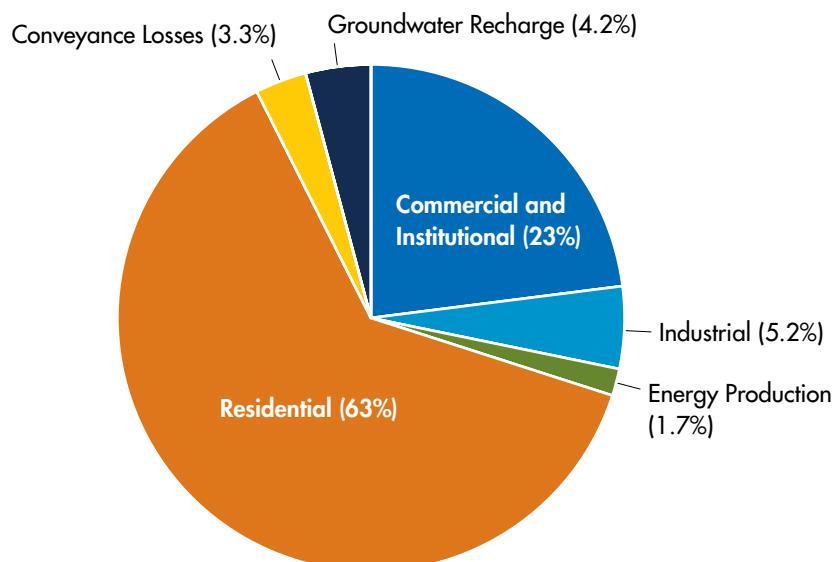
Figure 7 shows total and per capita urban water use in California between 1960 and 2015. In 1960, urban use totaled 3.1 million acre-feet, or 177 gallons per

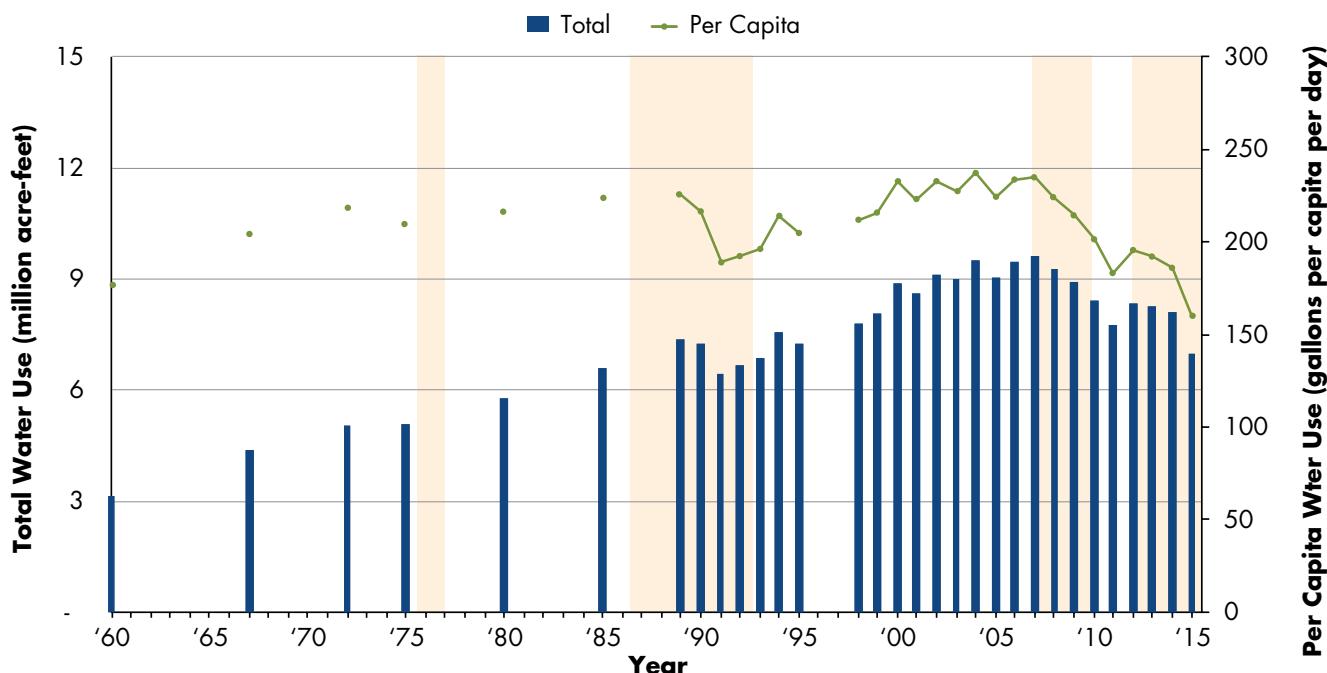
person per day. Both total and per capita water use increased over the subsequent 30 years. California experienced a major statewide drought between 1987 and 1992, resulting in large reductions in total and per capita water use. After the drought ended, total and per capita urban use resumed an upward trend. Per capita use, however, plateaued between 2000 and 2007, averaging 231 gallons per person per day. Total urban water use continued to increase, albeit at a much slower rate, reaching 9.3 million acre-feet in 2007. Since 2007, both total and per capita use have declined dramatically. By 2015, total urban use was 7.0 million acre-feet – levels not seen since 1993. Statewide data are not yet available to evaluate water use since the most recent drought ended. However, monthly reports to the State Water Board suggest that urban water use increased slightly after the drought ended but remains lower than before the drought.

**Figure 6. Urban Water Use in California by Sector, 2006 to 2015** 

Note: Values may not add to 100 percent due to rounding.

Data source: Urban water use data from DWR (2019)



**Figure 7. Total and Per Capita Urban Water Use in California, 1960 to 2015**

Note: Statewide multi-year droughts are shown in shaded orange areas.

Data source: Water use data from DWR ([1964](#), [1970](#), [2018](#), and [2019](#)). Population data from California Department of Finance ([2018](#))

Like agricultural water use, urban water use tends to increase in dry years and decrease in wet years, largely due to water requirements for landscape irrigation. This variability, however, is far less dramatic than for the agricultural sector because landscape irrigation represents less than 50 percent of urban water use statewide. In some hot, dry areas, landscape irrigation is a larger percentage of total use and thus more subject to variable weather conditions.

More detailed data on urban water use are available for 1998 and later. Between 1998 and 2015, water use declined for all major urban subsectors: indoor residential, outdoor residential, and non-residential (Figure 8). Outdoor residential use experienced the largest reductions, followed by non-residential and indoor residential uses. While outdoor residential use represented the largest

use of water among the major urban subsectors in 1998, it represented the least amount of water in 2015.

Reductions in California's residential water use between 1998 and 2015 occurred even as the state's population increased by 19 percent, or 6.2 million people. Residential water use was 139 gallons per capita per day (gpcd) in 1998 and remained above 140 gpcd through 2008 (Figure 9). Since 2007, however, there has been a consistent decline in statewide residential per capita water use. While many communities, including San Francisco ([SFPUC 2011](#)) and Los Angeles ([LADWP 2016](#)), have reported reductions in per capita usage for much longer, these reductions have been offset by growth in hot, dry regions of the state with higher outdoor water use.

In 2015, residential per capita usage fell below 100 gpcd for the first time in the state's history, with indoor and outdoor use totaling 56 gpcd and 43 gpcd, respectively. Some increase in per capita use is likely after the drought ends as, for example, people resume taking longer showers and watering more frequently. However, there is evidence that per capita use stayed below pre-drought levels ([LADWP 2015](#) and [Vorster 2015](#)),

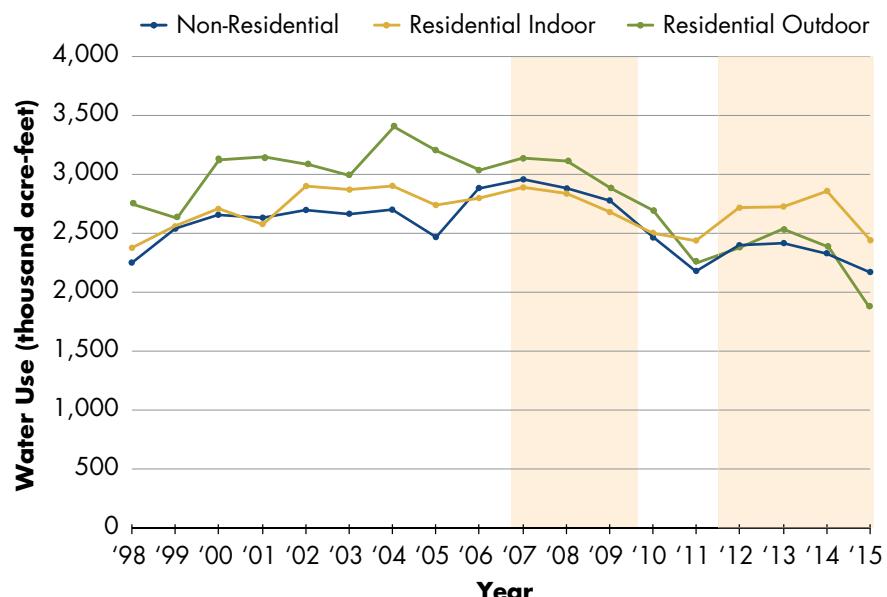
an indication that some of the savings achieved are permanent.

Despite these efficiency gains, international experience indicates that additional savings are possible. Australian households, for example, use an average of 54 gpcd for both indoor and outdoor purposes ([Turner et al. 2016](#)). Israeli households use even less, averaging 36 gpcd ([ICBS 2016](#)).

**Figure 8. Urban Water Use in California by Major Subsector, 1998 to 2015** 

Note: Statewide multi-year droughts are shown in shaded orange areas.

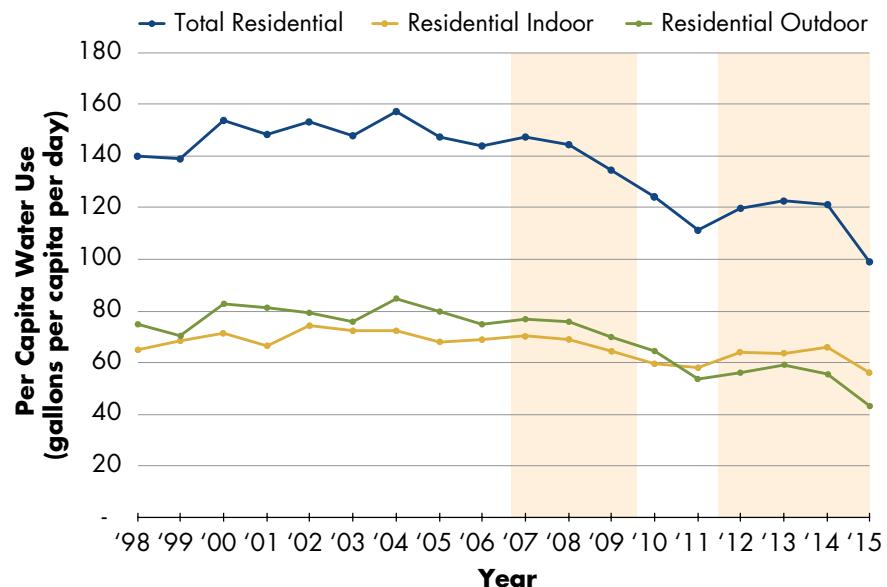
Data source: Water use data from [DWR \(2019\)](#)



**Figure 9. Total, Indoor, and Outdoor Residential Per Capita Water Use in California, 1998 to 2015** 

Note: Statewide multi-year droughts are shown in shaded orange areas.

Data source: Water use data from [DWR \(2019\)](#)



## SUMMARY AND CONCLUSIONS

CALIFORNIA HAS EXPERIENCED a dramatic decoupling between water use and growth, conflicting with widespread assumptions that water use inevitably increases in tandem with population and economic expansion. Between 2006 and 2015—the most recent 10-year period for which statewide estimates are available—total water use in California averaged 43.0 million acre-feet annually, of which agriculture accounted for 80 percent and homes and businesses in urbanized areas accounted for the remaining 20 percent. Since 1967, California’s population has doubled, and its economic output has increased by a factor of five. Yet, statewide water use increased by only 20 percent due to improvements in urban and agricultural efficiency, as well as a shift to higher value crops and less water-intensive commercial and industrial activities. These trends have important implications for planning, policymaking, and investment strategies.

California’s urban and agricultural regions are deriving greater value from the state’s limited water resources. Agricultural water use in California has remained flat since the 1980s, while the economic value of crop production has increased dramatically – from \$530 per acre-foot in 1960 to \$1,250 per acre-feet in 2015.<sup>8</sup>

Urban water use has declined dramatically since the mid-2000s despite continued population and economic growth. In 2015, residential per capita usage fell below 100 gpcd for the first time in the state’s history, with indoor and outdoor use totaling 56 gpcd and 43 gpcd, respectively. That same year, urban water use totaled 7.0 million

acre-feet—levels not seen since 1993. While water-use estimates for 2015 were reduced by drought restrictions, there is evidence that urban water use has rebounded slightly but remains lower than before the drought.

Despite positive signs, water use in California remains high, and international experience suggests that additional savings are possible. Across the state, rivers and streams are under stress from overuse and groundwater is over-tapped. To address these challenges, we must continue and even expand efforts to improve the water-use efficiency of our homes, businesses, industries, and farms.

Finally, more and better data are needed. Measurements of agricultural water use, rather than estimates based on acreages planted and crop type, are essential. A new statewide survey of industrial water use is also needed. The last one is more than 25 years old, and there have been dramatic changes in California’s industrial sector since then. We urge the state to improve data collection and online systems to make data more easily, quickly, and readily available.

<sup>8</sup> All values have been adjusted for inflation and are reported in year 2020 dollars.

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**Pacific Institute**  
654 13<sup>th</sup> Street,  
Preservation Park  
Oakland, California 94612  
510.251.1600 | [info@pacinst.org](mailto:info@pacinst.org)  
[www.pacinst.org](http://www.pacinst.org)

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