Brad Coffey
PPD 631. Graphical Information Systems

Heeding the Call: California's Response to Drought

Introduction

As California suffers through record-breaking drought, water managers and policymakers are trying to constrain water use without damaging the economy or frustrating the public. Governor Jerry Brown established a clear conservation benchmark in January when he declared a drought emergency and called for 20 percent voluntary reduction in all urban areas.[1] As a result of the Governor's declaration, the California State Water Resources Control Board (State Water Board) required water systems to report monthly potable water production and also established a $500 per day fine for wasteful water use. [2]

In June 2014, Californian's averaged 203 gallons per capita per day (gpcd), a decrease of only 4 percent from the same month last year and well below the 20 percent target.[3] The state's overall urban water conservation has since risen to 12 percent in August before falling back to 10 percent in September.

Disclosing water conservation data alone hides the fact that urban water use varies widely across the state. For example in August 2014, urban water use in San Francisco, Los Angeles, and Sacramento averaged 86, 140, and 250 gpcd, respectively. As the state struggled to increase conservation, a *Sacramento Bee* article lamented, "Water consumption varies enormously across California, and the reasons are not easy to pin down. But it is an issue of growing importance as the state struggles to contain water demand."[4]

This project sought to broadly examine factors that influence both short-term water conservation and baseline water use. Factors examined included climate, media coverage, wealth, population density, and water price. Graphical Information Systems (GIS) provides a robust tool to evaluate the relative influence of these factors because GIS facilitates the overlapping analysis of physical, socioeconomic, and political boundaries such as climate zones, census tracts, and public water system service areas.

Data Analysis

Table 1 lists the primary data sources used in this project. The data categories included (1) standard Census Bureau geographic shapefiles and median household income; (2) boundary shapefiles of urban water systems from the California Department of Public Health; (3) climate data from the National Oceanographic and Atmospheric Administration; (4) monthly urban water use reported to the State Water Board; and (5) manually acquired water rates and charges from a manual internet search of water agency websites.

The acquired data needed a high level of quality control and manual manipulation before it could be used and interpreted with GIS. For example, water conservation data from nearly 400 urban water agencies was first downloaded from the State Water Board in a spreadsheet format. Each agency reported their water use in different units (gallons, million gallons, cubic feet, or acre feet) and these units sometimes varied each month. More problematic was that urban water agencies were identified by name but not by their assigned Public Water System Identification number (PWSID). In order to join the water use data with a shapefile of water system boundaries, the PWSID labels needed to be added through a number of manual operations.

A further data processing complication resulted from the presence of multiple boundaries for many urban water systems in the CDHS shapefile database. For some agencies, there were three or more boundaries all which covered a different service area and sometimes overlapped with one or more boundaries of other water agencies. A long, manual process was required to sort out these different geometries and to ensure that the water conservation data was joined to the proper agency.

Another major effort was needed to acquire monthly water rates and charges from the urban water agencies. Typical charges for water include a base fee (often called a meter charge) and usage charges which vary depending on the amount of water consumed. Although some voluntary surveys were available from water industry groups, the surveys tended to be several years old, had low participation rates, and were biased towards more progressive agencies. Instead of relying on voluntary surveys, these data were acquired through a manual search of more than 350 agency websites. Depending on both the agency's water rate transparency and the website's ease of use, determining the rates and charges could require intensive searching. Some agency water rates could not be found on the websites (29 of 361 [8%] of water rates were not available).

Once the individual data sets and shapefiles were acquired, a series of joins, clips, and dissolves were used to condense the data. Water use and conservation data were first calculated in Microsoft Excel and then joined to the water system boundary shapefiles. When processing climate data, the average maximum daily air temperature and the evapotranspiration from two separate types of weather stations were spatially joined to the water system boundary shapefiles. For the larger water system boundaries, the average temperature or evapotranspiration within the boundary was computed. If no station lay within the boundary, the spatial join relied upon the closest station to the shapefile centroid.

Finally, when socioeconomic and population data were examined, the water system boundary shapefiles were used to clip census tract data for median household income and population. A dissolve function was then used to compute the median household income and total population for all of the census tracts within the water agency boundary.

Results and Discussion

Figure 1 shows the August 2014 urban water use for all agencies which serve more than 10,000 people. In total, these 400 retail agencies serve a population of 35 million. Wholesale agencies were not included because their water production is accounted for at the retail level. The fifteen largest retail agencies are labelled on the figure.

Total urban water use in August 2014 varied from less than 110 gallons/capita/day (gpcd) [the 10th percentile of all agencies] to more than 360 gpcd [the 90th percentile]. When including only residential use and excluding commercial and public spaces, per capita use dropped to 70-280 gpcd. On average, 75 percent of urban water use is residential. Water use was highest in the Central Valley and inland areas of Southern California and lowest in coastal urban areas such as San Francisco, Los Angeles, and San Diego.

Figure 2 shows the change in total urban water use following the Governor's emergency declaration. The most noticeable reduction occurred in Southern California. In June 2014, 69 of 202 (34%) of agencies in Southern California were using more water than one year earlier. By August, water use had dropped and only 14 (7%) were still using more water. However, only 7 of 202 (3.5%) agencies were meeting the Governor's goal of 20 percent reduction. During the summer, many water agencies initiated public service announcements and advertising to increase the public's awareness of the drought. The Metropolitan Water District of Southern California (a regional water wholesaler) spent $5 million on advertising to reach all of the major demographic markets in the region.

Several factors were examined to determine their influence on water use and conservation. To simplify the data processing and analysis, only the 15 largest water agencies were further analyzed. Figure 1 shows the location and name of these agencies along with their per capita total water use in August 2014[5]. The total population served by these 15 agencies in 2014 was 12.3 million.

The first factor examined was climate. Figure 3 shows both the mean maximum temperature for August 2014 and the temperature change from the prior August. Small changes in average monthly maximum temperature or evapotranspiration (not shown) likely did not influence water use. Though year-to-year climate change was not a major factor, water use did increase with the average air temperature. Figure 4(a) shows how residential water use and air temperature were correlated for the 15 agencies.[6]

Other water use factors examined include population density and wealth. Figure 4(b) shows how water use varies with population density. Though not as well correlated as air temperature, water use drops as population density rises in urban areas with small plot sizes to irrigate and multifamily residences. Somewhat unexpectedly, rising incomes across water agencies did not lead to increased water use (see Figure 4(c)),

Water cost also influences water use. Figure 5 shows the water rate structure for Fresno, San Francisco, and Irvine Ranch Water District. The three agencies each impose a modest meter charge ranging from $9 - $15. The usage charge varies dramatically. Fresno charges a very low uniform rate of $0.61 per 100 cubic feet (ccf) for all water consumed. San Francisco uses an increasing block rate which charges up to $6.52/ccf—a tenfold increase above Fresno—for most water. Irvine Ranch Water District uses a rate structure which penalizes excessive water use at $12.60/ccf—20 times higher than Fresno. Figure 6 shows how these water pricing models affect consumers at two different monthly usages. The left side of the figure shows the cost for 10 ccf (~7,500 gal, or 60 gpcd for a family of four). This is the typical amount of indoor water use for a family and the cost ranged from $21 in Fresno to $67 in San Francisco. A usage of 40 ccf (~30,000 gal, or 240 gpcd), shown on the right side of Figure 6, would represent a homeowner with a very large plot size or with wasteful water practices. At higher usage, progressive rate structures can provide a powerful signal to the homeowner about their water use. In this example, Fresno charges $39 whereas San Francisco charges $267.

The large difference in water pricing shown in Figure 6 was further explored to examine how water affordability may affect its use. In Figure 4(d), water affordability was computed as a percentage of median household income. In this figure, the monthly water cost was computed from the average residential usage and the utility's rate structure. Across the 15 largest water utilities, water affordability ranged from 0.5 percent of median household income (Irvine Ranch Water District) to 2.2 percent of household income (Golden State Water Company). California policymakers generally consider water affordable if the cost remains below 2 percent of median household income. In this analysis, water affordability did not influence water demand.

After the individual factors of climate, socioeconomics, and water price were examined, a multivariate statistical analysis was conducted. Initial testing with the multivariate approach did not improve the statistical strength of the factors.

Conclusions and Recommendations

This project used GIS techniques to examine water use and conservation in California. In the summer of 2014, monthly weather patterns did not appear to contribute to increased conservation. Rather, increased public awareness through extensive media coverage and targeted public service announcements may have shifted consumer behavior.

Water use varied widely and factors such as climate, population density, water price, and affordability were examined to explain the differences. In general, only weak correlations were observed for these factors either individually or as a multivariate analysis.

Despite these limitations, GIS provided a powerful tool to visualize regions where water usage and conservation were highest. With these types of data, water managers can then guide public affairs investments or modify pricing structures to improve water management.

The dataset for this project was limited by its aggregation to the water utility boundary. For a large agency such as the Los Angeles Department of Water and Power, an analysis of climate, socioeconomic, and water use at the census tract level would have allowed a more refined evaluation. This micro-level analysis is recommended for further work.

Likewise, water use across agencies cannot be viewed as a free market and easily compared. Water agencies are constrained in their pricing structures by California's Proposition 218 to charge only for the cost of service (and not scarcity). Consumers are constrained to purchase water from a governmental or regulated private monopoly. In essence, each agency's water rate structure and demographics creates a supply and demand curve valid only for that agency. A more sophisticated economic model which takes these market forces into account is recommended to further this work.

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[1] Governor Jerry Brown. Drought Statement of Emergency. Jan. 17, 2014.

[2] State Water Resources Control Board. Drought Emergency Water Conservation. Title 23, California Code of Regulations. Jul. 28, 2014.

[3] State Water Resources Control Board. Emergency Conservation Regulation Update. Nov. 4, 2014.

[4] Weiser, Matt. "Conservation conundrum: Water use varies greatly across California." *Sacramento Bee*. August 31, 2014.

[5] Note that both residential and total water use are used throughout this report. Residential use excludes water used by business, government, home-owner associations, and parks. Overall, 75 percent of water use is residential, although the percentage varies from 52 percent (at the 10^{th} percentile) to 98 percent (90^{th} percentile).

[6] Microsoft Excel was used as the graphing tool for data output from ArcGIS because of greater flexibility (and my familiarity) with the program.

Table 1. Data Sources Used for Project

Category	**Source**	**Specific Data and Notes**
Water use	California State Water Resources Control Board	Spreadsheet with monthly potable water use from 414 public water systems
Water price	Individual websites	Individually accessed the water rates and charges for over 300 water utilities from their individual websites
Geography	U.S. Census Bureau (Cartographic boundary shapefiles)	Boundaries for census tract, county, and state
	California Dept. of Public Health (California Environmental Health Tracking Program)	Boundaries for 8,177 public water systems in California
Socioeconomics	U.S. Census Bureau (TIGER/Line geodatabases)	Median household income for 8,057 California census tracts
Climate	California Dept. of Water Resources (California Irrigation Management Information System)	Calculated evapotranspiration data from 147 monitoring systems throughout the state
	National Oceanographic and Atmospheric Administration	Temperature data from 646 monitoring stations throughout the state

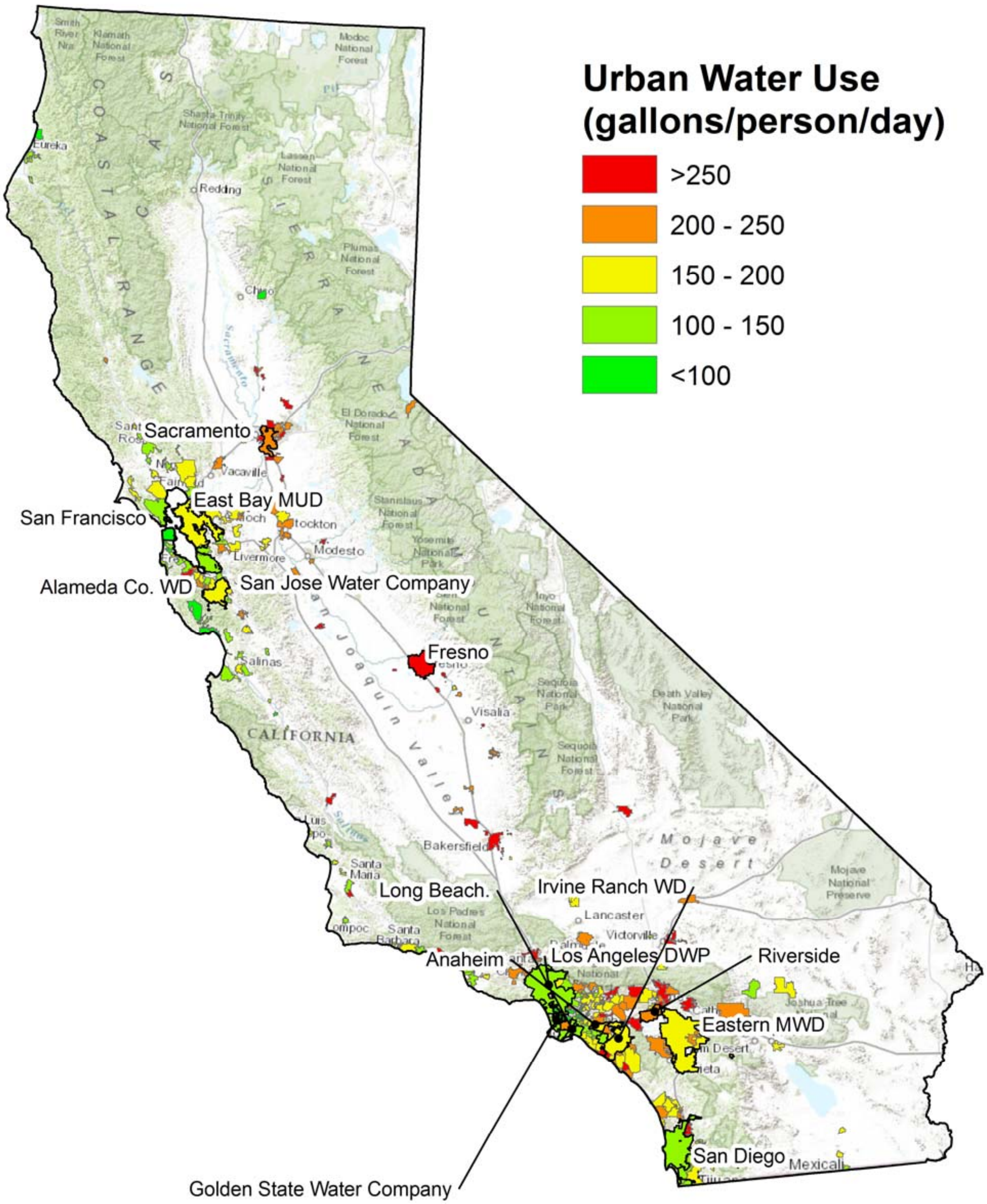


Figure 1. Urban water use in California.
(Figure shows total potable water use for residential and commercial uses in August 2014.)

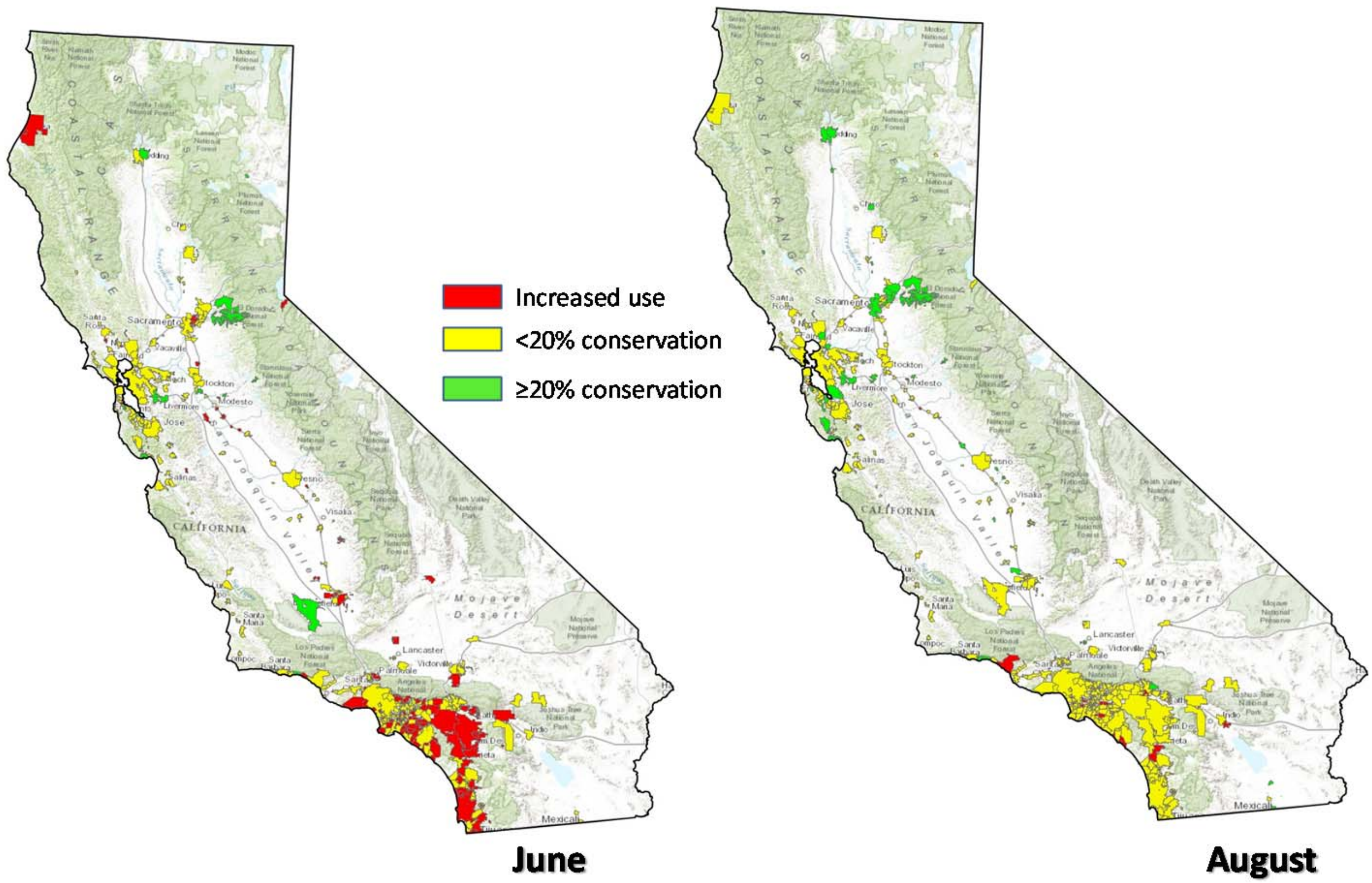
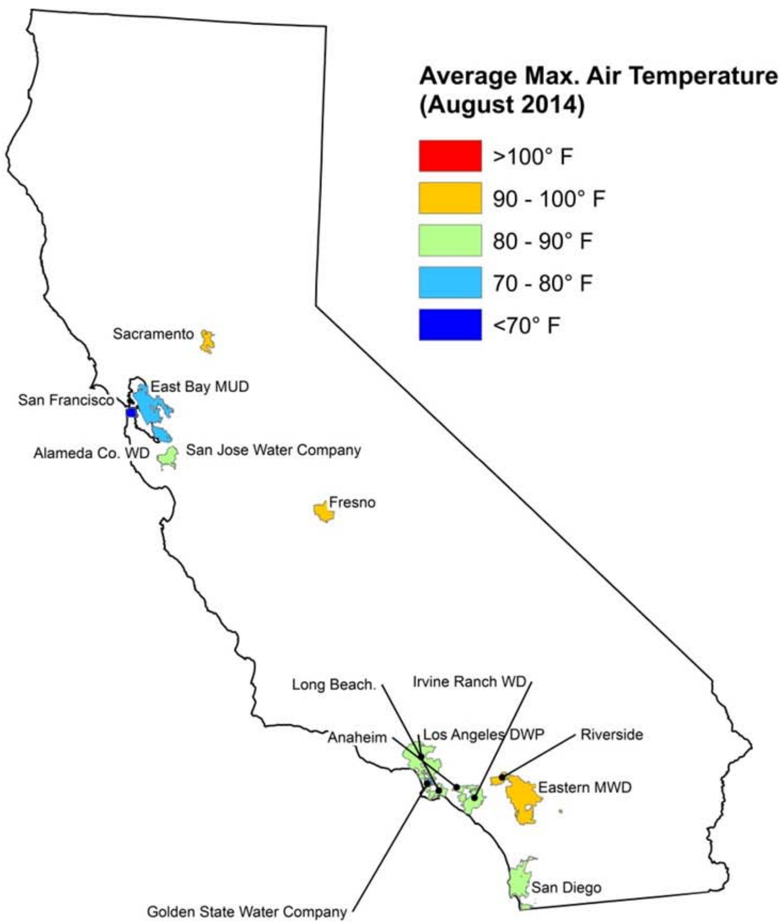


Figure 2. Water conservation in June and August 2014 for 400 water agencies serving at least 10,000 people (Figure shows percent change in water use between the same months in 2013 and 2014.)



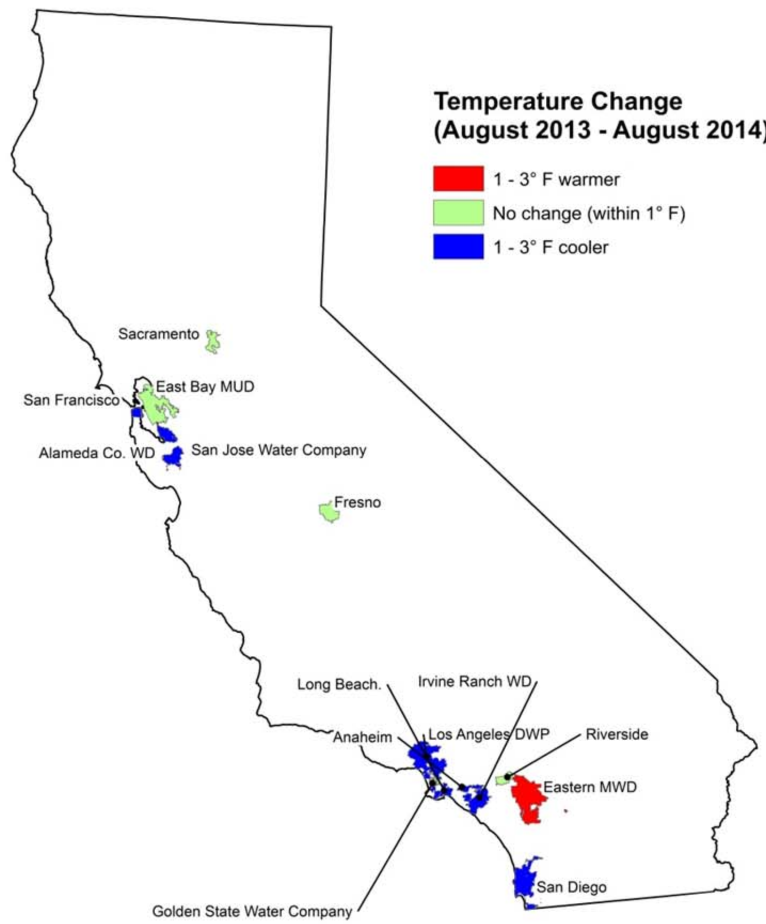
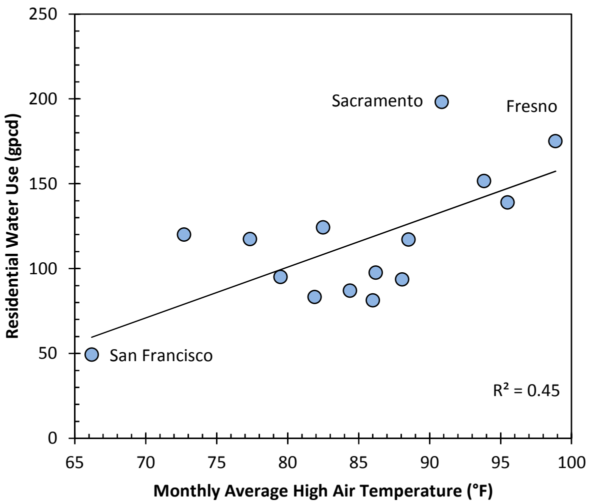
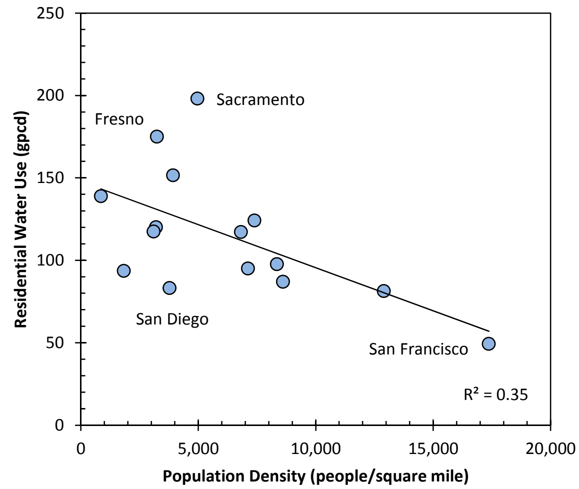


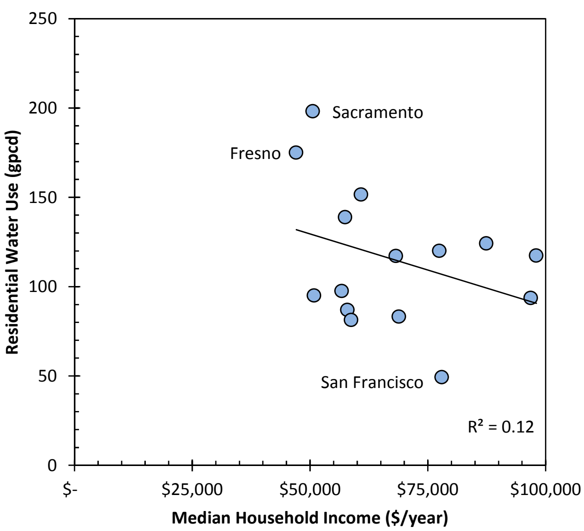
Figure 3. Average air temperatures and change from prior year for August



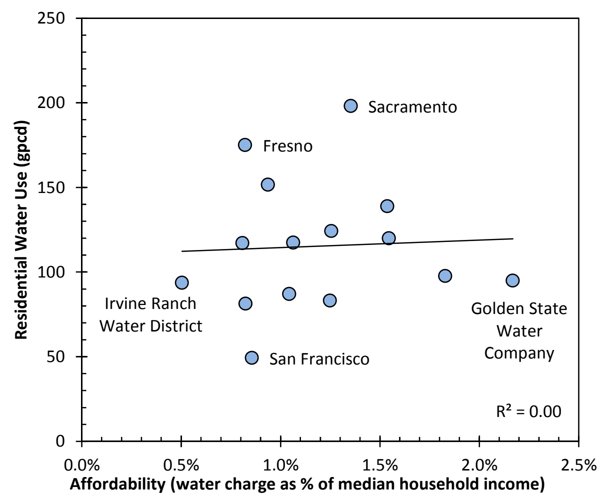
(a). Maximum air temperature



(b) Population density



(c) Median household income



(d) Affordability

Figure 4. Effect of selected inputs on residential water use in August 2014

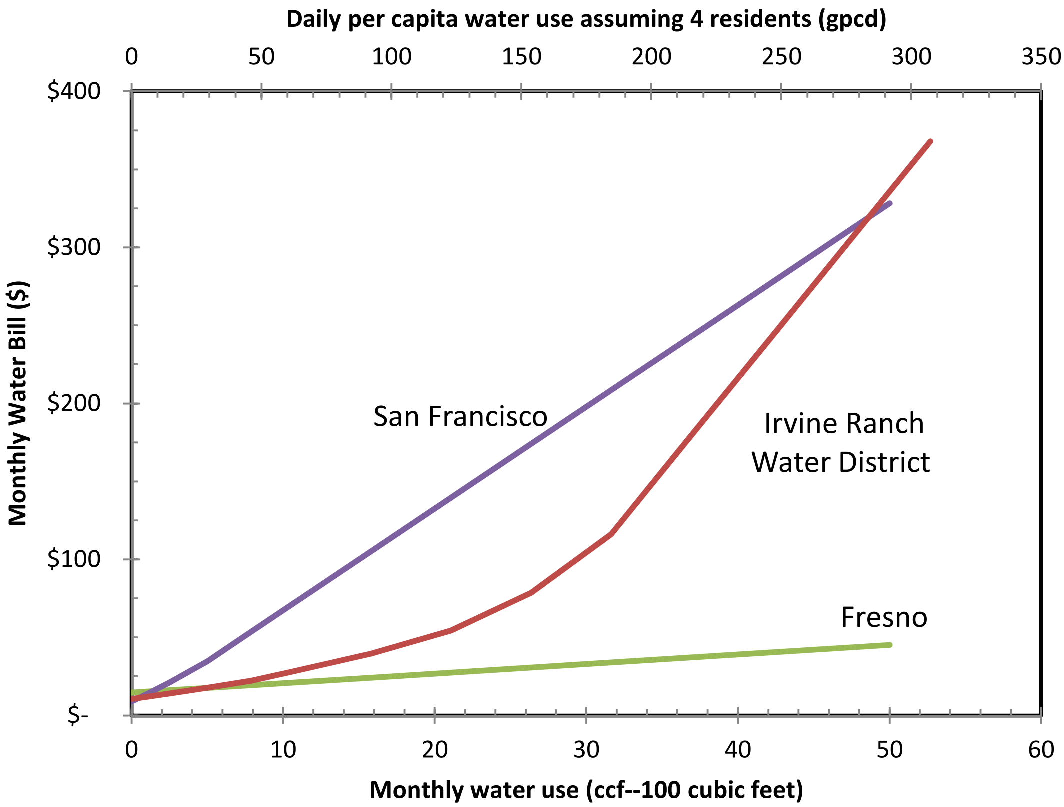


Figure 5. Water cost for three large water agencies

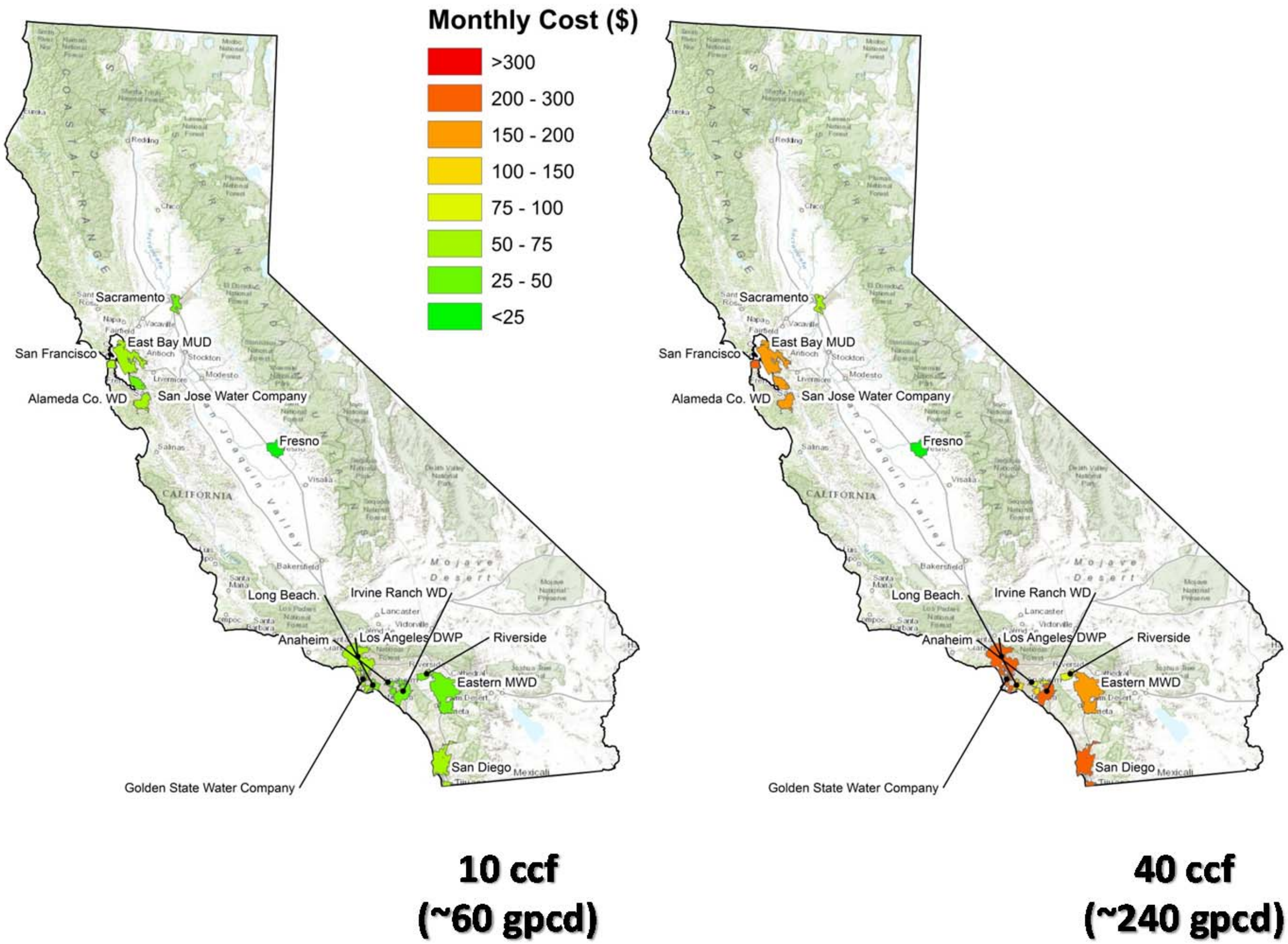


Figure 6. Water pricing for 10 ccf (indoor water use) and 40 ccf (indoor plus wasteful outdoor water use)