CALIFORNIA SINGLE-FAMILY WATER USE EFFICIENCY STUDY

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Disclaimer

All opinions, conclusions and recommendations in this report are those of the principal investigator and research team, and do not necessarily reflect the opinions of any of the sponsors, state officials, participating agencies, reviewers or other persons who may have assisted or participated in this study. The authors apologize and take full responsibility for all mathematical errors, misspellings and grammatical blunders within these pages. Readers are encouraged to point out any of the above to the author by email to bill@aquacraft.com for corrections in later editions of this study or publication of errata.

Author's Preface

This report deals with a simple subject: how water is used in single-family homes in California. Nonetheless, the topic has important consequences for the future of the State of California. The official goal of the State is to reduce per capita water use by 20% by 2020. This report provides useful information and insights as to the technical potential to achieve these goals within the single-family residential water use sector.

The overall period covered by our investigation ranges from 2005 to 2010, and the bulk of the water use data were collected from 2005 through 2008. This study is a bottom-up approach to the subject. Rather than trying to infer customers' water use patterns from gross production data and various other sources such as surveys and census information conducted on whole populations of customers, we have collected highly detailed information at the water meter on random samples of customers chosen from billing databases, with the goal of projecting patterns in the populations from these samples.

We believe that the results of the study shed light both on how California single-family customers are currently using water, how their water use patterns have changed over the ten year period since the Residential End Uses of Water Study, and how future water use patterns might be modified in order to increase the efficiency of use and modify demands to moderate the need for raw water withdrawals from increasingly over-extended supplies. We hope that readers of this report find it of use, and that over time it assists in the common efforts to better manage our natural resources.

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Glossary and Conversion Factors

The following table provides the definitions of terms as they are used in this report. These definitions may vary from common usage based on specific terminology for the study.

A	
actual irrigation application	The volume of water estimated as outdoor or irrigation use. Calculated as total annual billed consumption minus best estimate of indoor use (kgal).
AF	Acre-foot - a volume of water that would cover one acre to a depth of one foot, or 325,850 gallons of water. See conversion table below.
AFY	A unit of volumetric rate: acre-feet per year.
ANOVA, Analysis of variance	A mathematical process for separating the variability of a group of observations into assignable causes and setting up various significance tests.[i]
application ratio	The ratio of the actual irrigation application to the theoretical irrigation requirement. Application ratios are key parameters in assessing irrigation use because they indicate at a glance whether a given site is over- or under-irrigating.
AWC, average winter consumption	Average winter consumption is an estimate of indoor water use. It can be calculated from average winter water usage in the months of December, January, and February where it is assumed that all usage during that period of time is indoors.
AWWA, American Water Works Association	AWWA provides knowledge, information and advocacy on water resource development, water and wastewater treatment technology, water storage and distribution, and utility management and operations. AWWA is an international nonprofit and educational society and the largest and oldest organization of water professionals in the world. Members represent the full spectrum of the water community: treatment plant operators and managers, scientists, environmentalists, manufacturers, academicians, regulators, and others who hold genuine interest in water supply and public health.

AWWARF, American Water Works Research Foundation	Changed to Water Research Foundation in 2008. The Water Research Foundation is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.
B	
BMP, Best Management Practices	A set of water conservation practices identified, supported and in some cases required by the California Urban Water Conservation Council.
C	
CalFed	Members of the California Water Policy Council and the California Federal Ecosystem Directorate (CalFed) signed the Framework Agreement in 1994. By signing this agreement, participants were committed to processes for: setting water quality standards for the Bay-Delta estuary, developing long-term solutions for the Bay-Delta, and coordinating Central Valley Project and State Water Project operations with endangered species, water quality, and CVPIA requirements. CalFed Ops group is charged with coordinating the operation of the water projects with these requirements.
CCF	A measure of volume: one hundred cubic feet or 748 gallons. Also HCF. See conversion table below.
ccf/yr	An annual measure of volume: one hundred cubic feet, or 748 gallons, per year.
CII	Commercial, institutional and industrial customers.
CIMIS, California Irrigation Management Information System	A network of 120 weather stations found throughout California. Managed by DWR.
confidence interval	For a given statistic calculated for a sample of observations (e.g. the mean), the confidence interval is a range of values around that statistic that are believed to contain, with a certain probability (e.g. 95%) the true value of that statistic (i.e. the population value). This report typically uses a confidence interval of 95%.

Coverage Requirements	Requirements detailing level of implementation of CUWCC BMPs. Coverage requirements may be expressed either in terms of activity levels by water suppliers or as water savings achieved.
Current	The word "current" refers to the study period for this project, which was around 2007. All references to "current" demands or "current" data refer to the study period, not the date of reading.
CUWCC, California Urban Water Conservation Council	The California Urban Water Conservation Council was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The Council's goal is to integrate urban water conservation Best Management Practices into the planning and management of California's water resources.
D	
data logging	Collection of flow data from a water meter by use of a portable electronic device that records the number of magnetic pulses generated by the meter on a ten second interval.
DWR, Department of Water Resources	State of California's agency charged with managing water resources and use.
E	
EBMUD, East Bay Municipal Utility District	EBMUD provides drinking water for 1.3 million customers in Alameda and Contra Costa counties. The District's wastewater treatment protects San Francisco Bay and services 640,000 customers.
EnergyStar	EnergyStar is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. The goals of the program are saving money and protecting the environment through energy-efficient products and practices.
EPAct, The Energy Policy Act of 1992	An Act of Congress passed in 1992 with the goal of improving energy efficiency. It also included changes mandating 1.6 gpf toilets.

EPA, Environmental Protection Agency	EPA leads the nation's environmental science, research, education and assessment efforts. The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.
EPA Retrofit homes	A group of 96 homes selected from existing single-family homes in Seattle, East Bay MUD and Tampa. Each home was data-logged and surveyed for baseline use, and then retrofitted with high-efficiency fixtures and appliances. Post-retrofit data were collected so that the impacts of the retrofits could be determined. These homes are used as benchmarks for high-efficiency homes.
ET, Evapotranspiration	Evapotranspiration (ET), as used in this study, is a measurement of the water requirement of plants. According to CIMIS, Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water crops, lawn, garden, and trees need for healthy growth and productivity. See reference ET and net ET.
excess use	When the application ratio is greater than 1 there is excess irrigation occurring. Excess irrigation as used in this report is the difference between the actual volume of water applied to the landscape and the theoretical irrigation requirement, with all values less than one set to zero. This represents the sum of all excess use without netting out the deficit use.
Explanatory variable	A variable used as part of a regression analysis as a parameter to attempt to predict or model another variable. One or more explanatory variables are commonly used in attempts to predict the value of a single dependent or objective variable. For example, household water use was an important dependent variable in this study, which was related to changes in several explanatory variables such as persons per home, size of home, cost of water, presence of high-efficiency fixtures and appliances.
F	
flapper leak	In trace analysis, a periodic leak, often with a flow rate similar to a toilet's flow rate at a given site.
flow trace data analysis	Process of disaggregating end uses of water for a given meter.

FPD	Flushes per day
FS	field study
G	
gal.	Gallon, a measure of volume. See conversion table below.
GIS analysis	Geographic Information System. GIS is a system of capturing, storing, analyzing and presenting geographic data.
gpd	gallons per day
gpcd	gallons per capita per day
gpf	gallons per flush
gph	gallons per hour
gphd	gallons per household per day
gpl	gallons per load
gpm	gallons per minute
gpsf	gallons per square foot
gtd	gallons per toilet per day
H	
HCF, hundred cubic feet	A measure of volume: one hundred cubic feet or 748 gallons. Also CCF. See conversion table.
HET, High Efficiency Toilet	The term refers to toilets designed to flush at 1.28 gpf or less.
High volume, High water use toilet	Toilets designed to flush at volumes greater than 1.6 gpf. Pre-1992 toilets.
I	

irrigated area	Portion of a lot's area that is irrigated. Does not include house footprint, hardscape, etc. Irrigated area is a critical parameter for irrigation analysis. There was a very strong correlation between irrigated area and total lot size demonstrated by the data.
IRWD, Irvine Ranch Water District	Irvine Ranch Water District (IRWD) encompasses approximately 179 square miles and serves the city of Irvine and portions of Costa Mesa, Lake Forest, Newport Beach, Tustin, Santa Ana, Orange and unincorporated Orange County. It is an independent public agency governed by a publicly elected board of directors. Core services include water treatment and delivery, sewer collection and treatment, water recycling and urban runoff treatment.
K	
Kc (crop co-efficient)	The relative amount of water cool-season turf needs at various times of the year.
keycode	The unique code used to identify each study home. The first two digits of the code identified the agency in which the residence was located. The last three digits identified the specific home.
kgal	Unit of volume equal to 1,000 gallons. See conversion table below.
L	
l, liter	A measure of volume, equal to 0.264 gallons.
LA, landscape area	Portion of a lot's area that includes vegetation, ground cover or water surface. May include vegetated areas that are not irrigated. Does not include house footprint, hardscape, etc.
LADWP, Los Angeles Department of Water and Power	Public agency that supplies electricity and water to the City of Los Angeles. Water sources include recycled, imported (MWD) and ground water.
landscape aerial analyses	Utilizing aerial imagery and GIS analysis to identify landscaping features such as likely plant types and corresponding area.

landscape coefficient	The weighted average of crop coefficient for landscape (Kc). Represents the aggregate landscape for a given site. Lower values imply more xeric landscape, while higher values higher water-using landscape.
landscape ratio (LRatio)	This is the ratio of the theoretical irrigation requirement to the reference requirement based on ETo
"leaks"	Whenever the term "leak" is enclosed in quotes this is intended to remind the reader that these events may include uses that are not actually leaks, but which give the appearance of leaks based on the flow rates, durations and timing patterns.
Leaks and continuous events	Events that are identified as leaks during flow trace analysis. These fall into two categories: small and random events that do not appear to be faucet use due to their small volume, timing and often repetitious nature, and long continuous events that appear to be due to broken valves or leaking toilets. Note that some continuous uses may be due to devices like reverse osmosis systems that are being operated on a continuous basis.
LF, Low flow	Describes toilets, faucets and showerheads that meet the 1992 EPAct requirements
logging	Practice of installing data loggers on customer water meters. Same as data logging.
lot size	Lot size is a measure of the total area attributed to a given study site. Often found from parcel data.
lpf	liters per flush
LVMWD, Las Virgenes Municipal Water District	Las Virgenes Municipal Water District provides potable water and wastewater treatment to more than 65,000 residents in the cities of Agoura Hills, Calabasas, Hidden Hills, Westlake Village, and unincorporated areas of western Los Angeles County.
M	
mean	A hypothetical estimate of the typical value. For a set of n numbers, add the numbers in the set and divide the sum by n.

median	The middle number in an ordered set of observations. Less influenced by outliers than the mean.
MG	Unit of volume equal to 1,000,000 gallons. See conversion table below.
mgd	millions of gallons per day
MGY	A unit of volume: million gallons per year.
MOU	Memorandum of Understanding. Especially with respect to the memorandum of understanding that led to the formation of the California Urban Water Conservation Council.
N	
n	number of observations or sample members.
net ET	Equal to Reference ET less effective precipitation. Net ET is a key parameter in analysis and prediction of water use.
NOAA, National Oceanic and Atmospheric Administration	An agency within the Department of Commerce. Focus is on oceans and atmosphere, including weather. Maintains weather stations throughout the United States.
R	
R^2 , coefficient of determination	The proportion of variance in one variable explained by a second variable. It is the square of the correlation coefficient, which is a measure of the strength of association or relationship between two variables.
reference evapo-transpiration (ETo)	ETo measures the moisture lost from a reference crop (normally cool season grass for urban purposes [inches]) and the soil due to temperature, solar radiation, wind speed, and relative humidity. Precipitation is not included in the measurement of Eto, although it does affect several of the parameters in the ET equation such as solar radiation and relative humidity.
Reference requirement	The volume of irrigation water required for a landscape planted exclusively with cool season turf and a 100% efficient irrigation system.

regression	A method for fitting a curve (not necessarily a straight line) through a set of points using some goodness-of-fit criterion.
REUWS homes, Residential End Uses of Water Study homes	This refers to the sample of approximately 1200 single-family homes chosen randomly from the service areas of 12 water providers in 1997. These are considered representative of existing single-family homes from the 1996 time period, prior to widespread implementation of the 1992 Energy Policy Act requirements.
S	
sf	A measure of area, square feet.
single-family home	For purposes of this study, a single-family home refers to a single meter feeding single dwelling unit. Generally detached, but may be attached as in the case of duplexes, triplexes etc., but each unit must be individually metered. Apartments are not included.
standard deviation	An estimate of the average variability (spread) of a set of data measured in the same units of measurement as the original data. It is the square root of the sum of squares divided by the number of values on which the sum of squares is based minus 1. [ii]
standard error	This is the standard deviation of the sampling distribution of a statistic. For a given statistic (e.g. the mean) it tells how much variability there is in this statistic across samples from the same population. Large values, therefore, indicate that a statistic from a given sample may not be an accurate reflection of the population from which the sample came.
T	
Theoretical Irrigation Requirement (TIR)	The volume of water (kgal) needed to meet the calculated requirements of the landscape for a given lot. It is a function of irrigated area, net Eto, landscape ratio, irrigation efficiency.
U	

ULF toilets	Ultra-Low-Flow/ultra-low-flush toilets, which in 1992 represented the best efficiency toilets available. When used in this report, the term ULF refers to toilets designed for flushing at 1.6 gpf. Currently, ULF toilets are the standard, and HET, or High Efficiency Toilets are the best available devices. The term is clearly out of date, but since it is so widely used and understood to represent 1.6 gpf toilets, we continue to use it.
W	
water factor	For clothes washers, this is the ratio of the total average gallons per load to the capacity of the machine in cubic feet. The lower the number the more efficient the machine.
Water Research Foundation	The American Water Works Association research arm. The Water Research Foundation is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.
WaterSense	An EPA Partnership Program created to aid water conservation through labeling of water efficient products, services and buildings.

Table of Unit Conversion multipliers

	GAL	CF	CCF	KGAL	AF	MG
GAL	1	0.1337	1.337 x 10-3	1.0 x 10-3	3.069 x 10-6	1.0 x 10-6
CF	7.48	1	0.01	7.48 x 10-3	2.296 x 10-5	7.48 x 10-6
CCF	748	100	1	0.748	2.296 x 10-3	7.48 x 10-4
KGAL	1000	133.7	1.337	1	3.069 x 10-3	1.00 x 10-3
AF	325,851	43,560	435.6	325.852	1	0.326
MG	1,000,000	13,370	133.7	1000	3.069	1

Note: multiply number of units in column 1 by the number in the body of the table to convert to units shown in row 1, for example: 10 MG x 3.069 = 30.69 AF.

CHAPTER 1 – EXECUTIVE SUMMARY

The California Single-Family Home Water Use Efficiency Study includes data from many traditional sources such as billing data, survey data, weather data and aerial photo information to analyze the water use patterns of a sample of over 700 single-family homes across ten water agencies throughout the State of California. Detailed flow trace data was obtained from portable data loggers, which were attached to the water meters of each of the study homes. These flow traces provided flow readings at ten second intervals from the magnetic pickup, which generate 80-100 pulses per gallon. These highly detailed flow data make it possible to identify individual water use events and to categorize them by their end use. The flow trace data tell not just how many gallons per day the home used, but how many gallons per day were used for individual end uses such as toilet flushing, clothes washing, dishwashers, showers, irrigation, faucets and leaks. Detailed use information can be pulled from the trace, giving for example, a count of toilet flushes and toilet flush volumes during a logging period. Researchers used flow trace data to determine levels of daily use in the homes and the efficiency of that use. Although the flow trace technique contains marginal error, such as from the mis-categorization of some events, it provides information on end uses that is not available from any other source. This report summarizes the results of the study, which began in 2005 and was completed in 2010. Water use patterns found during the 2007 logging period were analyzed to show how much potential remains for conservation savings from both indoor and outdoor efforts.

The executive summary covers the eight key goals as outlined in the 2004 proposal. This provides readers with a review of the most salient information that covers each of the key project goals. Readers wishing to obtain background information and to learn more about the research methods are referred to Chapters 2, 3 and 5.

Goal 1: To provide information on current water use efficiency by single-family customers

Assessing the efficiency of water use in single-family homes implies having a standard upon which to base the comparison. The efficiency of the homes can then be described as a numerical value based on the chosen standard. For the single-family homes it is necessary to have two standards: one for indoor use and one for outdoor use.

Determining Efficiency Standards

The standard used in this study for indoor use was the household water use for a home employing best available technology for all fixtures and appliances and with less than 25 gphd of leakage. In effect, the indoor standard was based on the EPA WaterSense specifications for indoor devices. In the report the data from the 2000 study of a group of 100 homes that had been retrofit with high-efficiency devices, the EPA Post Retrofit Group, was used as the benchmark for what we referred to as efficient homes. For indoor uses it was possible to have a single number that represented the number of gallons per day of use expected for efficient homes.

While indoor uses are relatively consistent from home to home, outdoor uses are much more variable, and it is really not possible to have a single number that tells how many gallons per year should be used for outdoor purposes. What served the purpose for an outdoor standard were two values referred to in the study as the “application ratio” and the volume of excess use. The application ratio is equal to the ratio of the actual outdoor water use to the theoretical requirement for outdoor use based on the size and type of landscape, the local ET and whether there is a swimming pool present. An application ratio of 1.0 indicates that precisely the correct amount of water is being used outdoors at the home. The volume of excess use is the difference between the actual outdoor use and the theoretical requirement (in Kgal). Using these parameters, an efficient home will have an application ratio of 1.0 or less, and will not have any excess outdoor use.

There were ten water agencies that participated in this study, serving a total of 1.3 million single-family households during the study period. There were a total of 735 homes included in the indoor analysis for this study. The weighted average annual total water use of these homes was 132 Kgal per year or 362 gallons per household per day (gphd). Their weighted average indoor water use was 134 Kgal/year (367 gphd). Approximately 53% of the annual use appears to be for outdoor use and 47% for indoor uses, based on billing data analysis. Figure 1 shows the indoor/outdoor split for the homes in the study group.

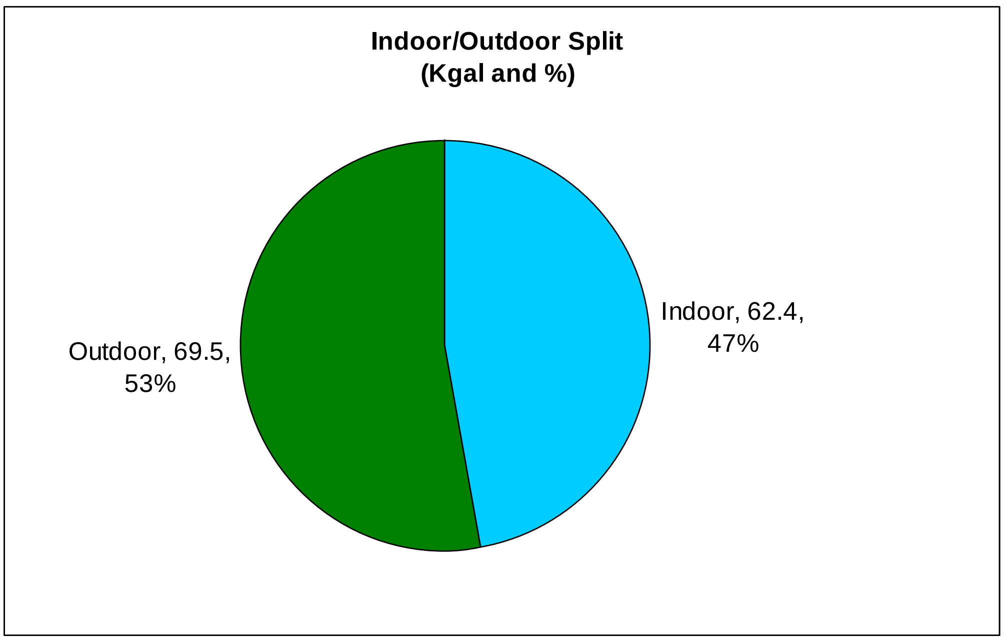


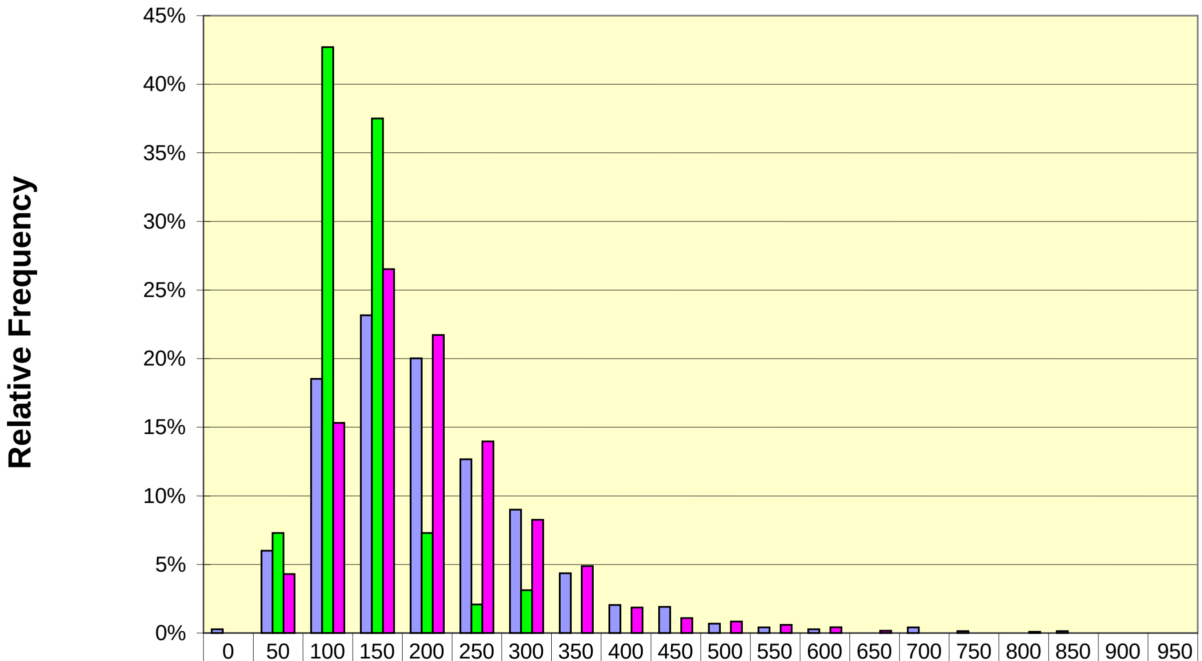
Figure 1: Approximate indoor/outdoor split in logging study group

Indoor Efficiencies

When the indoor use (plus leakage) was analyzed from the flow trace data it showed that the indoor use for the households appears to be declining compared to the data obtained from the RUEWS group from 1997, but it is still significantly greater than the benchmark EPA Retrofit Group. Table 1 shows a comparison of the indoor use of the study group to the two benchmark groups. Figure 1 compares the distribution of indoor use for the three groups. The current California use patterns are much closer to the REUWS benchmark than the EPA Retrofit benchmark.

Table 1: Comparison of average indoor use to benchmarks

Group	Average Indoor Use (gphd)	Percent of REUWS
REUWS (California)	186 ± 10.2	100 %
California SF Home Study	175 ± 8	94%
EPA Post Retrofit Group	107 ± 10.3	57%

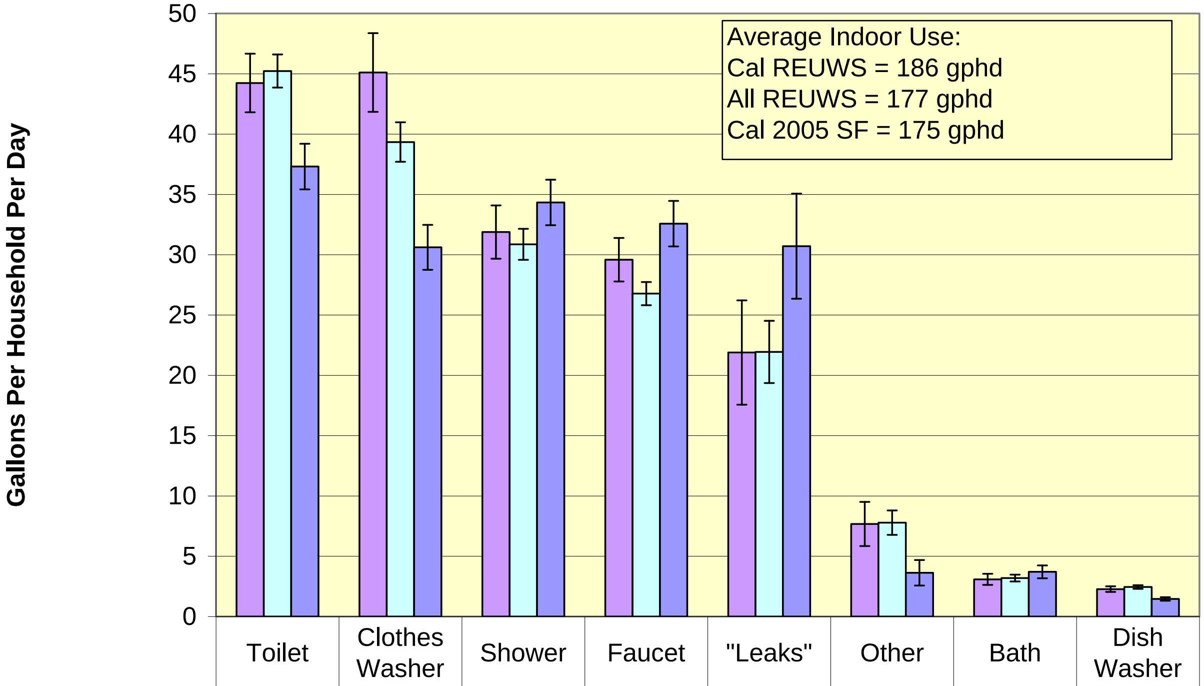


	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950
Cal SF Study	0%	6%	19%	23%	20%	13%	9%	4%	2%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EPA Retrofit	0%	7%	43%	38%	7%	2%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
REUWS	0%	4%	15%	27%	22%	14%	8%	5%	2%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%

Indoor Water Use (GPD) Comparison

Figure 2: Indoor use histogram for California SF Study sites, REUWS, and EPA Retrofit Homes

When the indoor uses are disaggregated the results are more revealing. The disaggregated data, shown in Figure 3, show that, as one would expect, there have been significant reductions in indoor use for toilets and clothes washers in California since 1997. At the same time, the indoor uses attributed to the other categories have stayed the same or increased in a way that has masked the savings from the toilets and clothes washers. This pattern is especially true for events classified as leaks. The analysis showed significantly more long duration or continuous flows that get classified as leaks. These continuous events, which are found in a small number of homes, raise the average volume of water attributed to leaks for the study group from around 22 gphd to 31 gphd. This finding needs further investigation to determine whether these truly are leaks or may be due to devices that actually create a continuous demand for water. This information is important because if the leakage, faucet and shower use were brought down to the levels shown in the REUWS study the average indoor use for the group would have been around 150 gphd, which would have been a significant improvement from the 1997 data.



	Toilet	Clothes Washer	Shower	Faucet	"Leaks"	Other	Bath	Dish Washer
Cal REUWS	44.2	45.1	31.9	29.6	21.9	7.7	3.1	2.3
All REUWS	45.2	39.3	30.9	26.8	21.9	7.8	3.2	2.4
Cal2005SF	37.3	30.6	34.3	32.6	30.7	3.6	3.7	1.5

Figure 3: Comparison of household end uses

The data show a major improvement in the water use efficiency of toilets. There were a total of 122,869 flushes recorded during the data logging period. The average flush volume was 2.76 gallons, and 64% of all flushes were less than 2.75 gallons. The one negative finding on toilets was that apparently many toilets that are designed to meet the ULF standard of 1.6 gpf are flushing at significantly larger volumes. This helps explain why the study found that only 30% of the homes were at average flush volumes of 2 gpf or less, while all of the program data, confirmed by survey data from this study, suggest that over 60% of the toilets in the population are ULF or better models.

Figure 4 shows the comparison of the distribution of toilet flush volumes in the California Single-Family Homes study and the 1997 REUWS study. This shows a dramatic shift in the bins containing the largest percentage of flushes. In the 1997 sample these were between 3.75 and 4.25 gpf, but as of 2007 they were between 1.25 and 2.25 gpf. As more of the toilets on the right side of the distribution are replaced with high-efficiency models the overall demands for toilet flushing will drop well below the current levels, and the percentage of homes meeting the 2.0 gpf efficiency criteria used for this study will increase.

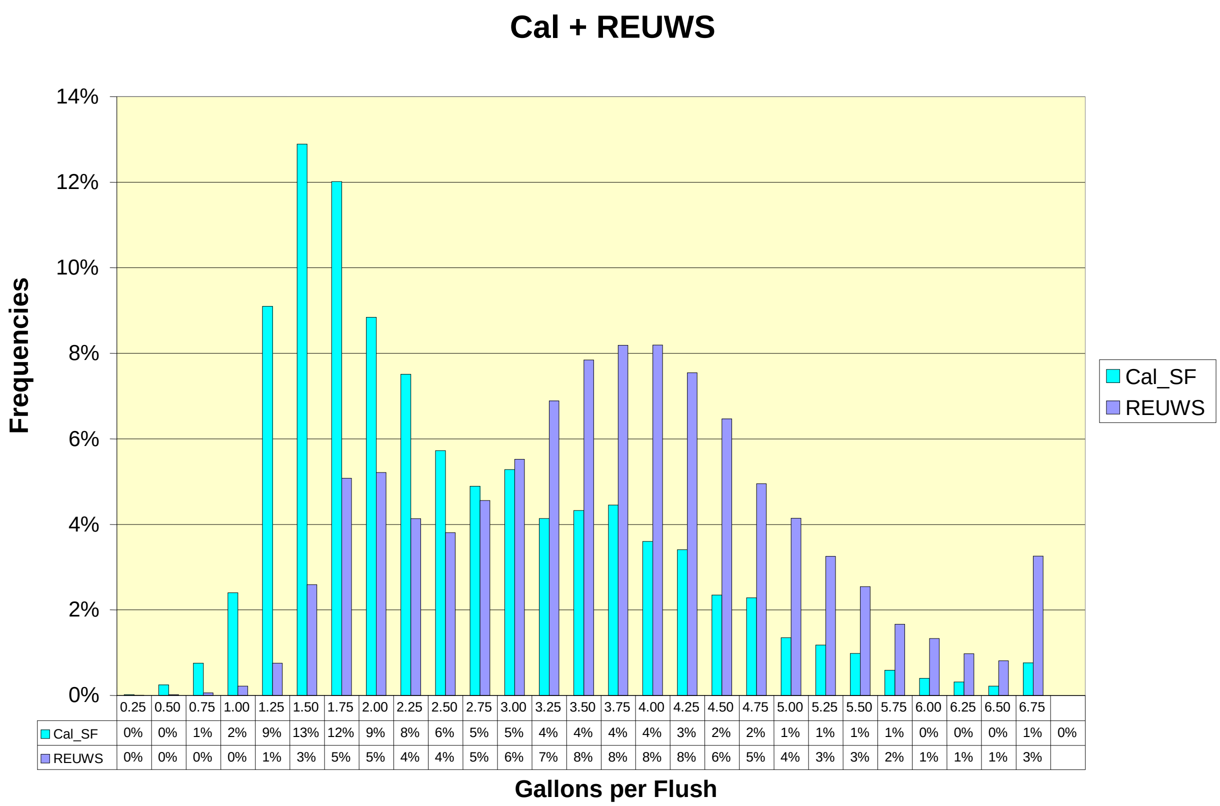


Figure 4: Comparison of toilet flush histograms of California SF Study to REUWS

The distribution of clothes washer load volumes from the data is shown in Figure 5. As of 2007 approximately 30% of homes were using 30 gallons per load or less for clothes washing. At the time of the REUWS only around 1% of the clothes washers used less than 30 gallons per load, so the current data represents a major advance, but the data also show that there is still significant potential for savings in clothes washer use.

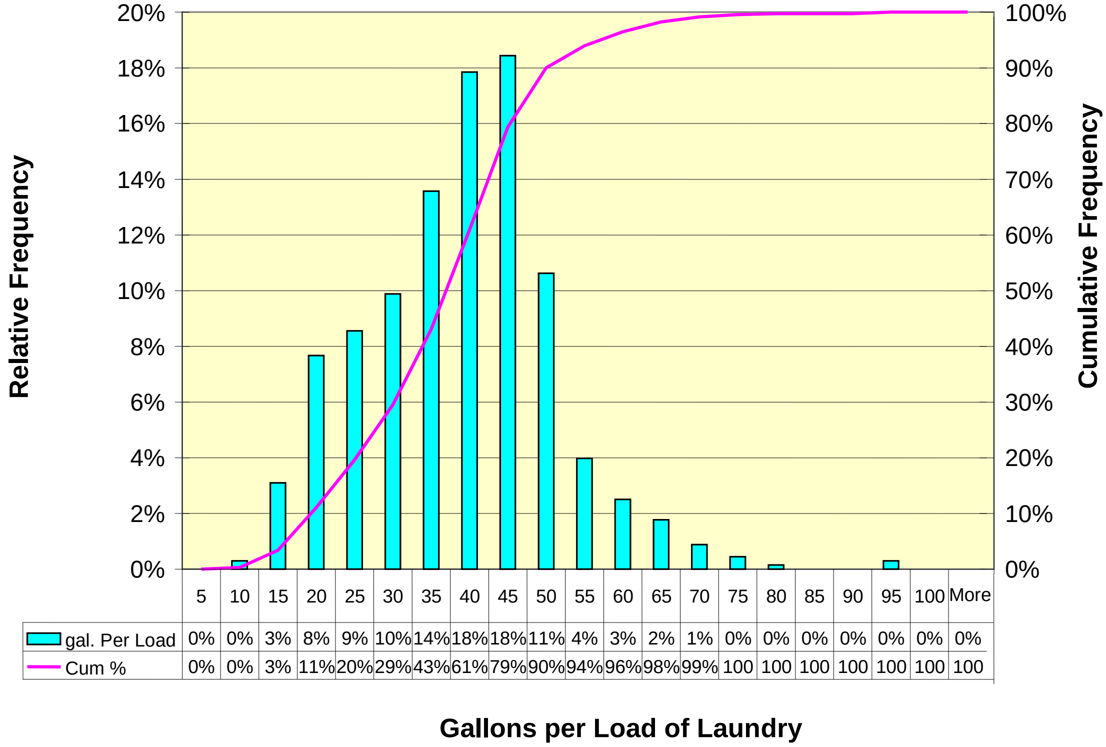


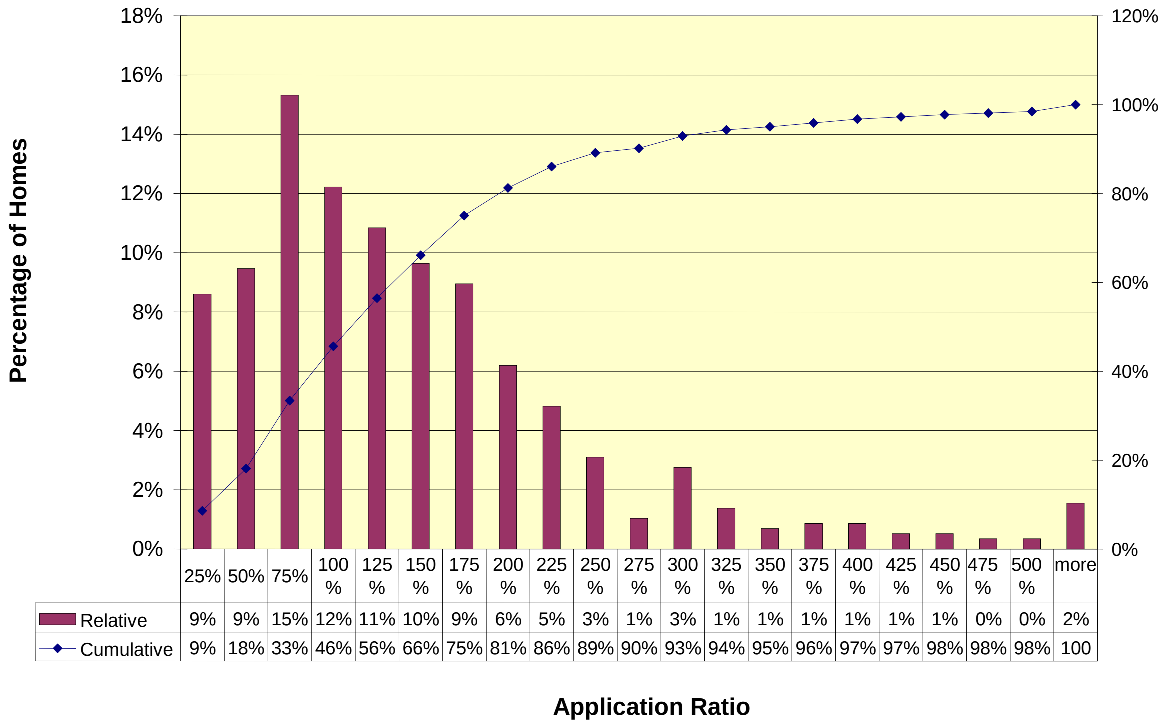
Figure 5: Distribution of clothes washer volumes

There was little change in shower use between 1997 and 2007. The average gallons per shower was just over 18 gallons (around the same volume that is required to fill up an occupied bath tub), and the duration of showers was just under nine minutes. Nearly 80% of all showers were flowing at 2.5 gpm or less. Reducing flow rates and durations of showers remain the methods available for conservation in showers. These are the kinds of things that people can do during drought times to gain savings from behavioral changes.

The average leakage rate in the study homes was 31 gphd, while the median rate was 12 gphd. The wide disparity between these values shows that a small group of homes are leaking at very large rates, and this increases the average for the entire study group. By inspection of Figure 45 and Figure 46, one can see how the small number of homes in the larger leakage bins contributes a disproportionate amount of the total leakage in the group. Leakage is complicated by the fact that some events that Trace Wizard categorizes as leaks may be due to devices such as water treatment systems that create a continuous demand for water. The research team does not believe that this occurs very frequently. Leaks from very short duration events, such as drips or occasional toilet flapper problems usually amount to 10 gpd or less of household demand. The leaks that contribute very large volumes are those that continue for many hours or days. The majority of the long duration events that contribute to the bulk of the leak volumes may be due to continuously running toilets, broken valves or leakage from pools and irrigation systems. These are the continuous events that need to be better understood so that they can be dealt with appropriately. The sample group used 33 gpd of water for miscellaneous faucet use. These uses average less than one gallon per use and have average durations of 37 seconds. The average home recorded over 57 faucet events per day. Faucet use represents a category of growing importance as toilets and clothes washers become more efficient. The key to improving the efficiency of faucet use is to decrease the flow rates and the duration of the events.

Outdoor Use Efficiencies

In the study group, only 87% of the homes appeared to be irrigating. This was based on the fact that some lots had no irrigable area, or that their water use showed little or no seasonal use. Only around 54% of the homes that irrigate are doing so to excess. So, overall, the degree of outdoor use efficiency is fairly good. Figure 6 shows the distribution of application ratios in the study homes.



	25%	50%	75%	100 %	125 %	150 %	175 %	200 %	225 %	250 %	275 %	300 %	325 %	350 %	375 %	400 %	425 %	450 %	475 %	500 %	more
Relative	9%	9%	15%	12%	11%	10%	9%	6%	5%	3%	1%	3%	1%	1%	1%	1%	1%	1%	0%	0%	2%
Cumulative	9%	18%	33%	46%	56%	66%	75%	81%	86%	89%	90%	93%	94%	95%	96%	97%	97%	98%	98%	98%	100

Figure 6: Distribution of application ratios in study homes

If we look all of the irrigating homes and compare their average outdoor use volumes to the average theoretical requirement we see that the two values are close to each other. The average annual outdoor use for the group as a whole is 92.7 kgal. The average theoretical irrigation requirement for the group is 89.9 kgal. So, taken as a whole, there is only 2.8 kgal of excess use per lot occurring in the group. Another way of looking at this is that the under-irrigation in the less-than-TIR group just about balances the over-irrigation in the more-than-TIR group. If all irrigators were brought into compliance with their theoretical requirements, then the data indicate that the net result would be little change in overall use.

The fact that the difference between the average outdoor use and the average TIR is small does not mean that there is no potential for irrigation savings. The savings potential is there, but it exists mainly on the lots of customers who are over-irrigating. From the perspective of water conservation the customers who are deficit irrigating need to be set aside and attention needs to be targeted toward the over-irrigators.

The excess use statistics shown in Table 49, in Chapter 7, shows that the average excess use on the lots that are irrigating is approximately 30 kgal per year. Since only 87% of the lots were irrigators, the average excess use for all single-family accounts is estimated at 26.2 kgal per year. Approximately 62% of this excess use is occurring on 18% of the irrigating lots or 15% of all lots. This is critical for water management because it shows that in a typical system the majority of savings from outdoor use will be found from around 15% of the customers.

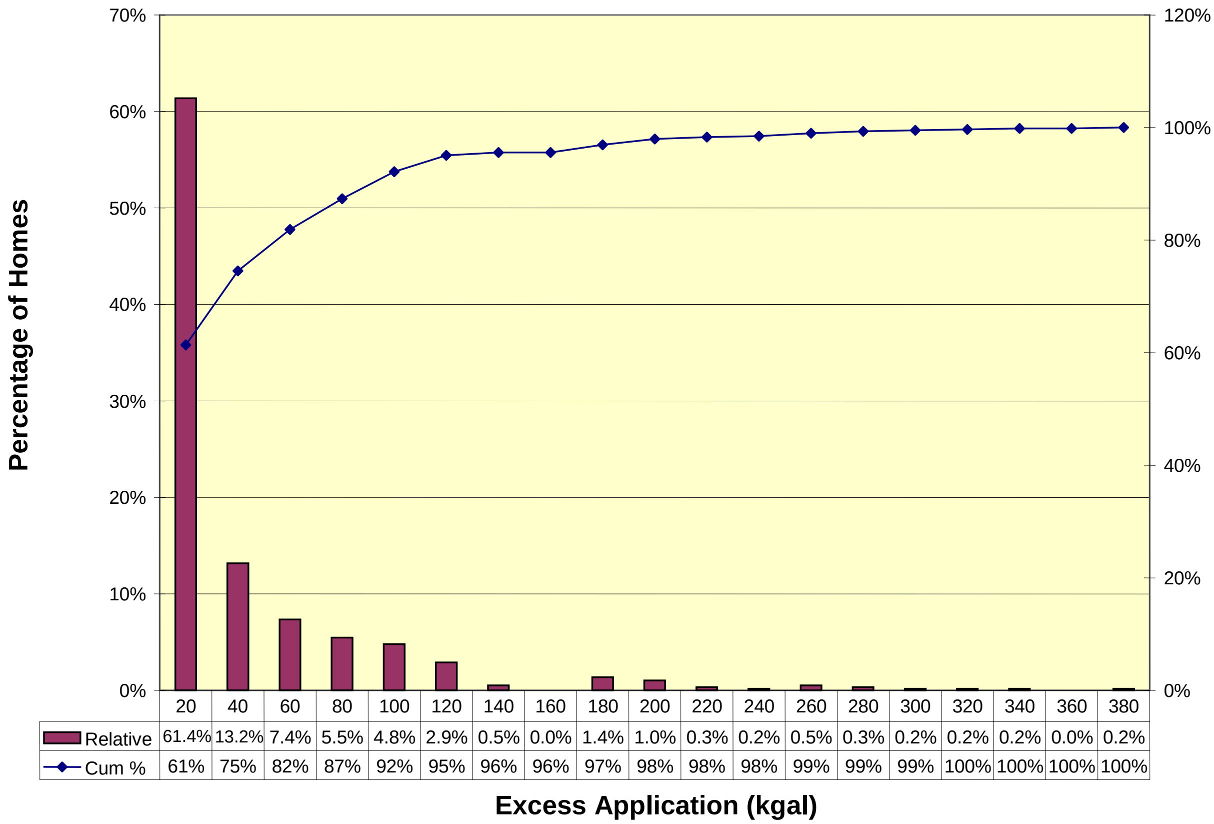


Figure 7: Distribution of excess irrigation by number of accounts

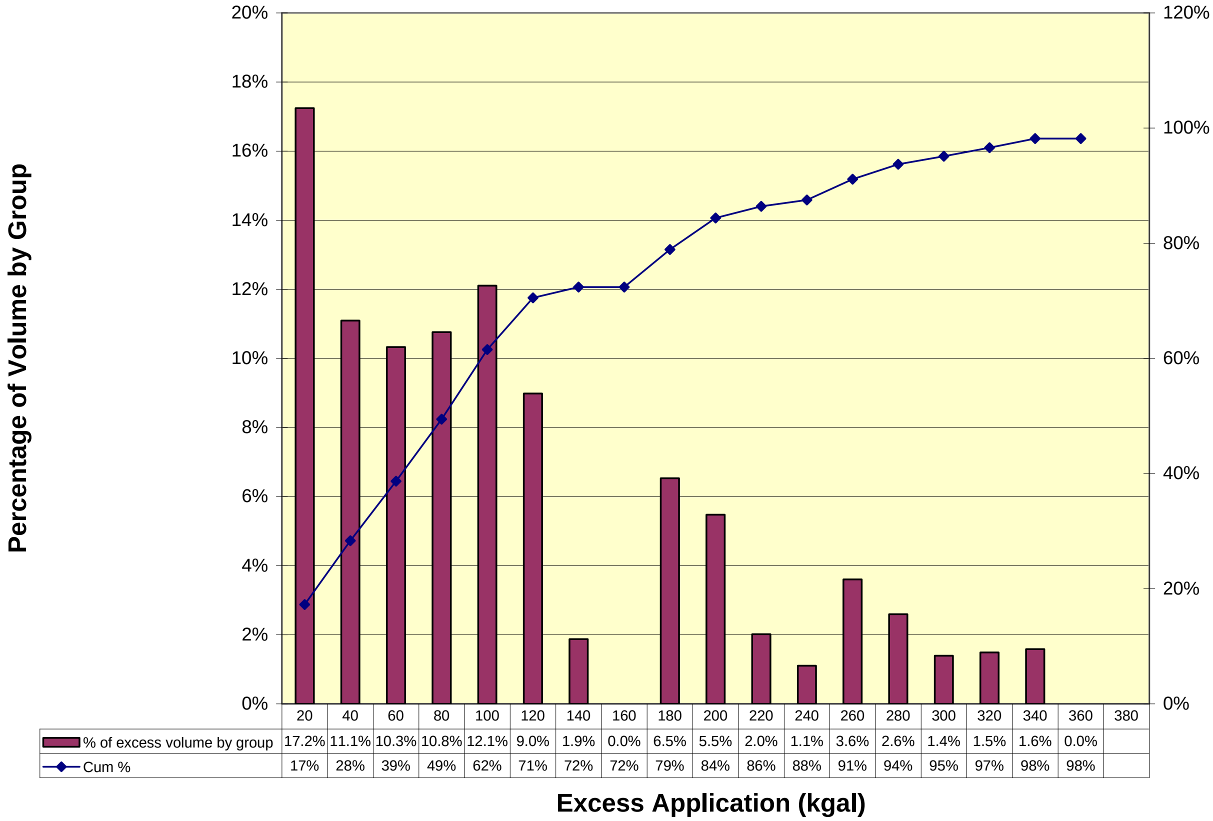


Figure 8: Percent of excess volume attributed to excess use bin

Goal 2: To provide a basis for estimating remaining conservation potential in single-family homes

This question is closely related to determination of the levels of efficiencies. The study used models of indoor and outdoor water use developed from the data collected in the study homes to predict the impact of making specific changes in indoor and outdoor parameters on household water use. These models allow corrections to be made for the variables in the study and present the findings in a normalized manner, and were the chief method for predicting conservation potential in the study homes, and by inference in the state.

For indoor use the data and models (see Table 83, Chapter 9) show that average indoor household water use could be reduced from the 2007 level of 175 gphd to 120 gphd if the following four things could be accomplished:

- The maximum clothes washer volume was 20 gpl
- The volume of water used by miscellaneous faucets could be reduced by 10% (from 2007 levels)
- Leakage could be reduced to a maximum of 25 gphd
- The maximum toilet flush volume could be set at 1.25 gpf

This amounts to a potential of 55 gphd of indoor savings or 20 kgal per year. The report did not discuss precisely how these goals are to be met, and there is no reason that these changes could not be allowed to occur gradually over many years. The key thing is for building codes and regulations to remain in place that require the standards be met in new and remodeled construction. As mentioned elsewhere, the study did not touch on the cost-effectiveness of specific programs aimed at accomplishing these goals.

The study showed that the conservation potential remaining in the system from outdoor uses is significant, and larger than the potential from indoor uses. The data from this study showed that there are three key parameters for modifying outdoor use: the irrigated area, the water demands of plants in the landscape and the percentage of homes in the population that are over-irrigating. Table 87, Chapter 9, shows that according to the outdoor use relationships observed in this study if the average irrigated areas were decreased by 15%, the landscape ratio decreased by 35%, and the percent of over-irrigators reduced from 50% to 20% of the homes it would be possible to reduce outdoor use to an average of 40 kgal per household from its 2007 level of 90 kgal. The low-end estimate is that by simply reducing the rate of over-irrigators and leaving all of the other parameters as is, the outdoor use could be reduced by 28%, saving approximately 0.6 MAF.

In Chapter 10 three levels of potential conservation savings are identified for the single-family sector. The indoor savings potential are based on the end point chosen for indoor household use. In CHAPTER 9, a potential average savings of 20 kgal per home was estimated assuming an indoor use benchmark of 120 gphd. The estimate could be raised to 30 to 40 kgal per household assuming that benchmarks of 105 gphd could be achieved and more aggressive indoor technologies used. Consequently, we can conceive of three levels of indoor water conservation benchmarks: a low, medium and high level at 20, 30 and 40 kgal per year per home. Total indoor estimates statewide are based on the estimate of 9.5 million single-family households in the state.

Outdoor potential conservation savings have been estimated at a low of 0.6, medium of 0.80 and high of 1.0 MAF. The savings in all three ranges are deemed technically achievable, but would require significant and increasing work over time and innovations in preventing over-irrigation and changes to both irrigated areas and plant types. It is encouraging, however, that the low-end savings would more than achieve the desired 20% reduction in use. The practicality of achieving savings in the high range is less clear, and is closely related to the value placed on the saved water (or costs for agencies to develop new supplies as alternatives). Table 2 shows the summary of the estimated potential conservation savings derived from this study. It is worth repeating that what is achievable is a function of the value being placed on the saved water and the costs for program implementation. As water supplies become more constrained, prices typically increase, which may make strategies that are either not or only marginally cost-effective become cost-effective to implement.

Table 2: Summary of projected statewide savings (MAF)

	Baseline	Low	Medium	High
Indoor	2.13	.58	.87	1.16
Outdoor	2.27	.63	.79	1.02
Total	4.4	1.21	1.66	2.18
% of Total		27%	37%	50%

Goal 3: To provide information on the current market penetration of high-efficiency fixtures and appliances in single-family homes

There are two aspects of the penetration rates of efficient fixtures and appliances. The first, which was the primary interest of this study, was to determine what percentage of *households* were operating at levels that are consistent with their being equipped with efficient devices. The second aspect, which was also of interest, was the actual percentage of devices in the market that are *rated* as efficient.

The matter was further complicated by what criteria should be used to classify a fixture as meeting efficiency standards. In the study we looked at the actual performance of the fixtures and appliances in the homes as revealed by their water use on the flow traces. From this perspective a toilet, for example, that flushes at more than a specific level would not be classified as an efficient device irrespective of the actual model installed. For this study we used a cut-off point of 2.0 gpf as the average household flush volume for a home that is totally equipped with 1.6 gpf (ULF) or better design toilets. This represented at 25% margin of error for the toilets. The parameters used for classification of households are shown in Table 3.

Table 3: Metrics used for efficiency determination

Device	Efficiency Criteria
Toilets	Avg. gallons per flush < 2.0 gpf
Showers	Avg. shower flow rate < 2.5 gpm
Clothes washers	Avg. load uses < 30 gal

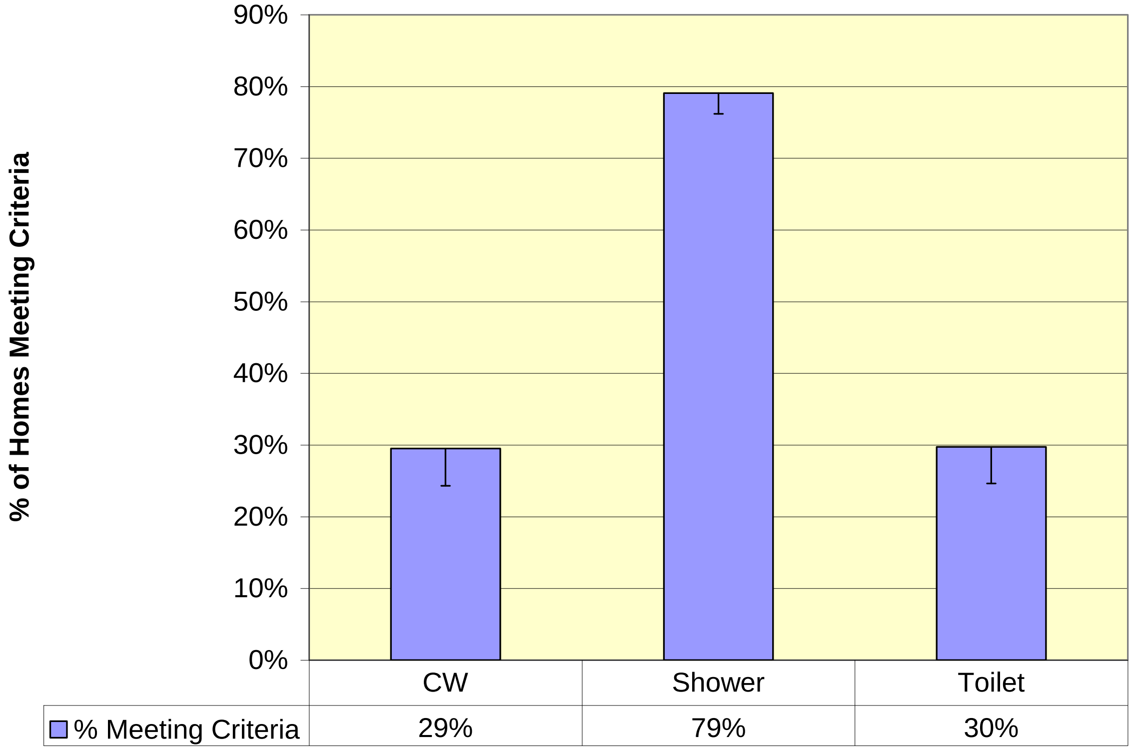


Figure 9: Percentages of homes meeting efficiency criteria for toilets, showers and clothes washers

The results for clothes washers can be interpreted from the perspective of both households and appliances because it is exceedingly rare for a home to have more than one clothes washer. For showers and toilets, however, where there is more than one unit per household the situation is less clear. The efficiency criteria used for the study are set close to the target level for the devices, and therefore a house would need to have exclusively 1.6 gpf toilets or better, and 2.5 gpm showerheads for it to satisfy the criteria. For example, a house with one high volume toilet and one 1.6 gpf toilet would have an average flush volume of more than 2 gpf. There is a considerable amount of discussion of this in Chapter 7 because most agencies believe that they have replaced more than 60% of the toilets in their service areas, yet only 30% of the homes are meeting the efficient toilet criteria. The report concludes that these results are consistent with each other because of two facts: many homes contain mixtures of high volume and ULF or better toilets, and many ULF toilets are flushing at more than 1.6 gallons per flush. The conclusion on toilet penetration was that somewhere between 60% and 70% of the toilets in the single-family residences are probably ULF models or better, and at the same time approximately 30% of the homes have average flush volumes of 2.0 gpf or less.

Goal 4: To provide information on the rate of adoption of high-efficiency fixtures and appliances by California homeowners

In 1997, when the REUWS study was published, approximately 1% of the homes had clothes washer volumes of 30 gallons per load or less, and 10% of the homes had average toilet flushes of 2.0 gpf or less. As of 2007, both devices are showing approximately a 30% household adoption rate. The percent of households with showers at 2.5 gpm was 70% in 1997, and is approximately 80% in 2007.

Device	% of HH in 1997	% of HH in 2007	Change/year
Showers	70	80	1%
Clothes washers	1%	30%	3%
Toilets	10%	30%	2%

The outdoor data from the REUWS study is difficult to compare to that from the California Single-Family study since it was from a much broader geographical area. In the REUWS sample 17% of the homes were applying more than the theoretical irrigation requirement, whereas 54% of the homes in this study were. This is simply an interesting comparison, but does not mean that the rate of over-irrigation is going up. The REUWS areas were based on the estimated irrigable areas on the lots rather than the irrigated areas, and they were not based on comparable aerial photos. As such, we cannot make any statements about rates of change of irrigation application ratios or excess irrigation amounts from the data obtained for this report.

Goal 5: To provide information in how the BMPs have impacted water use

It is clear that the BMPs have been the major driving force behind water conservation efforts in the State of California since they were adopted in 1991. Most of the agencies in this study are approaching their implementation in a similar manner. It was not possible to detect differences in penetration rates of toilets or clothes washers among agencies with more or less aggressive rebate programs. For example, one agency had a program where toilets would be replaced on demand for free with just a phone call from the customer. The percentage of homes meeting the toilet criteria in that agency was not significantly different than in the others. All we are able to say from the data in this study is that whatever changes in single-family water use were identified in this study have been the results of the combined application of the BMPs. It was not possible to single out individual BMP measures and quantify their impacts separately.

The other fact that the study demonstrated was that water savings obtained in individual categories such as toilets and clothes washers, where there has been measurable reductions, do not necessarily show up on the bottom line as overall household savings because changes in other categories may obscure them. In our case, if the analysis was limited to just billing data it would not have been possible to identify any statistically significant change in the household water use of the homes. It was the analysis of the disaggregated data that showed how individual categories of use had changed and showed that there were in fact significant changes occurring.

Goal 6: To provide baseline demand data for future studies

This study provides a wealth of data on single-family water use circa 2007 which can be used as a baseline for future studies provided those studies collect similar data on end uses. The study showed the annual water use for the single-family customers in the ten participating agencies. It showed the seasonal and non-seasonal water use patterns for each and then broke the indoor uses into individual end uses, which were shown on a household basis. Models of indoor water use were developed that showed which factors affected water use and the relationships between total indoor use and indoor use by category, to each of the key variables. Future studies can compare water use as it was reported in this study to water use from their own time period. A good example of this type of comparison is found in Figure 71, Chapter 9, which shows the relationships between indoor use and the number of residents.

The same situation occurs for outdoor use, where information on lot size, irrigated area, landscape coefficient, application rates and volumes of excess irrigation was tabulated. Models of outdoor use, similar to the indoor use models were developed, which can be used to make meaningful comparisons against future samples of customers.

A key assumption for making future comparisons is that the sample of homes used for this analysis is representative of the single-family homes in the agencies and in the State. We know that the samples chosen from each agency match the water use patterns for their respective populations. We also know that the agencies included in this study represent some of the largest in the state. There is no reason that future analyses in these agencies, using new samples of homes chosen in the same manner, cannot provide excellent data on changes in indoor and outdoor use patterns.

Goal 7: To provide information that can be used by California water agencies in updating their Urban Water Management Plans

The degree to which the information presented in this report is useful for preparation of future urban water management plans is a function of how those plans are organized, and how the water use data in them are presented. Water management plans that are based on more disaggregated demand data and which employ estimates of end uses of water will find the information in the report of greatest use. Plans that are based on aggregated demands and overall population estimates will not derive as much benefit.

The types of water management plans that will derive the greatest benefit from the data collected in this report, and from the data collection techniques used for the report, would track at least the following items in their single-family water use accounting:

- Total annual deliveries to single-family accounts
- Winter deliveries (December or January) as a proxy for indoor use
- Number of single-family accounts in system
- Total seasonal and non-seasonal use (derived from annual and winter use)
- Best estimate of population of single-family accounts
- Best estimate of irrigated area in single-family accounts (from samples and GIS data)

These data could be used to generate unit use reports that can be tracked over time and compared to benchmark data. The following unit tracking parameters could be used:

- Annual water use per SF account
- Non-seasonal water use (proxy for indoor use)
    - Annual use

    - Gallons per household per day
    - Per capita use
- Seasonal use (proxy for outdoor use)
    - Annual use
    - Average application rate (gpsf)
    - Average application depth (in)
    - Application ratio (applied inches/f[ET])

These water management plans are based on measurement and tracking of actual water use that has been normalized in a way that allows it to be compared to efficiency benchmarks. For example, by determining single-family winter water use, one can obtain a fairly good proxy for indoor use. Knowing the household indoor use means this can be compared against benchmarks like the EPA retrofit study group, or against the data from this study. This value should decrease over time if the efficiency of the system is improving. What may have started at 170 gphd would drop over time as new and more efficient fixtures and appliances were installed and hopefully as leakage were better controlled. Tracking the household indoor use in this manner would provide the best data for water management plans. Similar tracking of outdoor use would provide information on which to gauge the improvements in outdoor use efficiency. These types of plans could compliment information on BMP activities and conservation expenditures and confirm their effectiveness.

Goal 8: To provide guidance for allocation of resources by identifying areas with the most promising conservation potential

This report pointed out several items that provide insights into where to most effectively allocate resources for water conservation.

Since the signing of the Memorandum of Understanding in 1991, water conservation efforts have been focused on implementation of the Best Management Practices. These are mainly programs that lend themselves to tracking on the basis of activities performed and fixtures replaced. The most convincing argument for the effectiveness of water conservation efforts, however, is one that is backed up by hard data that shows reductions in household water use. This study demonstrated techniques of sampling and data collection that can be used for these approaches. Including detailed analyses of household and per capita water use on representative samples of customers can provide a wealth of information that will compliment the other tracking and evaluation efforts of the agencies. Accounting for toilets and clothes washer rebates provides a primary input on water conservation. It is still somewhat indirect until it can be coupled with demonstrated reductions in household water use for toilet flushing and clothes washing, along with concurrent reductions in the average flush volumes of toilets and load volumes for clothes washers in the homes as of a certain date.

The degree to which both excess use and potential savings are skewed in the population needs to be considered when designing programs. Programs that aim to control leakage or excess irrigation use, for example, should not be targeted to the entire population since most of the leakage and excess irrigation use is associated with a small percentage of the homes. It would be better to design programs that target their efforts to just these customers. Water budgets, smart meters, leak detection devices and better customer information systems are all possible examples of these.

The information on toilets should also be of use for future program design. The data showed two important facts. First, even though a high percentage of toilets appear to have been replaced with ULF models, the percent of homes that are flushing at 2.0 gpf or less is lagging. Second, the data clearly show that the actual flush volumes of ULF type toilets ranges well above the 1.6 gpf level. If future retrofits are focused on newer high-efficiency toilets (those using 1.28 gpf or less), and work continues to replace all of the remaining high volume toilets in the homes upgraded to the high-efficiency toilets, the percentage of complying homes will increase rapidly over time and the household water use devoted to toilet flushing will decrease.

The data show that reducing the percentage of homes that over-irrigate is the single most important factor in reducing outdoor use. The report, however, does not support making weather based irrigation controllers mandatory. The data show that these devices would cause irrigation to rise in about as many homes as they would create reductions. The key to controlling outdoor use is to design programs that discourage excess irrigation use while allowing customers who prefer to under-irrigate to continue to do so. This requires targeting over-irrigators, which requires having some sort of estimate of the irrigated areas and outdoor water use for each customer and comparing this information to their actual seasonal use.

The report highlighted the importance of leaks and other unexplained continuous uses in raising average use for the entire population. Rather than have general programs targeted to all customers, the report suggests it would be better to have systems that can alert customers of the existence of a leak-like use pattern so that it can be remedied immediately. In every group of houses that were logged as part of the study there were several that showed these long duration and high volume leak-like events. Having programs in the billing system that detect increases in use and then send a text message, phone call or email to the customer might be considered. Having in-home monitors that read data from the AMR meters directly is another. Having water rates that seriously penalize excess water use would provide an economic incentive for customers to monitor their use.

The report shows the importance of having more detailed information on customers. It suggests that putting increased resources toward better customer information and water use tracking systems would greatly improve the ability to establish better water management programs. As the old saying goes, “you can’t manage what you don’t measure.” Key information that would assist in water management would include: the number of residents in the home, the annual and winter month water consumption, the size of the lot and size of the irrigated area and the local ET for the lot. Such information would be invaluable for planning and evaluation purposes. Systems that provide customers with real-time information on water use, along with targets for use, enlist the customer as an active partner in water management. Having the customers as partners should greatly enhance the response of the entire system.

CHAPTER 2 – INTRODUCTION

One of the most pressing questions confronting urban water agencies is how much their current water demands can be reduced by conservation. There are various ways of estimating the remaining water conservation potential. This report focuses on an analysis of indoor and outdoor water use in single-family customers derived from detailed measurements of end uses of water. The report shows that while significant and considerable strides have been made in improving single-family water uses there is still potential for additional savings. The report provides insights on how best to tap these increasingly valuable water resources from a technical perspective, but does not deal with the question of cost-effectiveness of particular programs.

Where is water used in California single-family residences? How much water is used for irrigation, toilet flushing, washing clothes and showering? How much water is lost to leaks? What is the current water efficiency level and conservation potential of California homes? What is the average toilet flush volume? How much water does the average clothes washer use? How does water use differ in households equipped with efficient fixtures and appliances? Are there new uses of water that could alter demand patterns? What mathematical relationships best predict single-family water use, and what factors are the best predictors of single-family water use? The California Single-Family Water Use Efficiency Study was conducted to help answer these questions and to provide new and detailed information on the end uses of water in single-family residences in California.

The end uses of water include all places where water is used in the single-family residential setting such as toilets, showers, irrigation, clothes washers, faucets, leaks, dishwashers, baths, evaporative cooling, water treatment systems, water features, swimming pools, hot tubs, etc. Understanding how much, where, and when residential customers use water is fundamental information for utilities, conservation coordinators, planners, system designers, and numerous other water professionals. Updated empirical data on water use and conservation effectiveness are essential for understanding how water efficiency efforts are impacting demands and what can be done to further conservation efforts.

End use research has emerged as an important source of fixture level water use patterns over the past 20 years. Once prohibitively expensive, the advent of compact battery powered flow recorders and signal processing software for disaggregating demands into component water uses has enabled micro-level water use measurements to be made from relatively large samples of residential customers at a reasonable cost. The analytic technique, known as "flow trace analysis," enables disaggregation and quantification of residential end uses from a continuous flow data set recorded from the primary utility water meter at a single-family residence.

Flow trace analysis was the fundamental analytic methodology used to disaggregate water use in the California Single-Family Water Use Efficiency Study. The flow trace analysis technique was developed by Aquacraft in the early 1990s, and was the research approach employed in the landmark 1999 American Water Works Association Research Foundation Residential End Uses of Water study. Since that time, flow trace analysis and the Trace Wizard analytic software have been utilized around the world to quantify residential water uses in research studies in Australia, New Zealand, Cyprus, Singapore, Jordan, England, Spain, Canada, and beyond. These techniques were used to develop the end use data that has been cited in this study for the EPA Retrofit Analysis and the New Home Study. Both studies are described in the literature review.

In the California Single-Family Water Use Efficiency Study, water consumption for various end uses was measured from a sample of 732 single-family homes in 10 water agencies across California. Additionally, annual historic consumption data were obtained from each participating agency allowing for estimation of both indoor and outdoor demands. The irrigated area at each of the 732 study homes was measured using aerial photographs and geographic information system (GIS) technology. Local climate data were obtained in order to estimate irrigation requirements. This allowed for analysis of both theoretical irrigation demands and actual applications at each site. All of this information was collected to provide answers to fundamental questions about the quantity and uses of water in California residential settings, and to examine the potential water savings that might yet be achieved from various conservation measures.

In addition to presenting the findings from the data collection effort, the study also examined the relationships between the end uses of water and household demographics and socioeconomic data. Building from those relationships, predictive models were developed using multiple regression techniques to examine the impact of a range of likely independent variables. These models allow water utilities and planners to input critical variables from their own communities and generate predictions about water use and conservation savings based on actual data. Of equal importance, they allow the impact of changes in single-family household characteristics on water use to be explored, which is a key for estimating the impact of various changes on future demand patterns.

This report describes the methodology and important findings of this study and presents a wide variety of analyses based on the dataset assembled over the course of the study. As with any similar research study, this report represents a time and place snapshot of how water is used in single-family homes in the California study group assembled for the study. Similarities and differences among end uses were tabulated for each location, analyzed, and summarized. Great care was taken to create a statistically representative sample of customers for each of the 10 study locations. However, the precise degree to which these samples are representative of the entire state is unknown. Having the models of water use, however, makes it less critical that that sample be totally representative, since where differences exist in a local population (such as in the number of residents per home) the models can be used to adjust the water use predictions.

A research study of this size and scope must rely on a variety of assumptions. It is recognized that changes in some of these assumptions could impact the results. Wherever possible, the researchers have endeavored to acknowledge key assumptions, and to explain how they may or may not factor into the results.

This study does not include analyses of costs to implement individual conservation programs or benefits from saving water. These topics need to be addressed on a case-by-case basis as part of future work. Costs for implementation of conservation programs vary widely depending on the method chosen and the time allowed for the work to be done. Programs that are highly intrusive and rely on rebates and other hard expenditures for the water agencies can be quite expensive. On the other hand, programs that rely on natural market transformation over time, perhaps encouraged by building codes, can be implemented with less cost. On the other side of the equation, the benefits ascribed to water savings depend on the value that is placed on the saved water, which is another variable that must be considered on a case-by-case basis.

Because this is not a study of cost effectiveness, the reader is cautioned not to assume that any of the water conservation options discussed in the report are feasible to implement. Even the most conservative scenario requires substantial investments, and its implementation needs to be carefully thought out. The study shows what types of changes need to be made in order to reduce single-family water use, and provides estimates of the savings that might be achieved by doing so. It is up to the planners and engineers practicing in the area of water demand management to design programs that can achieve these savings in a cost-effective and customer acceptable manner. Also, many of the outdoor parameters, such as the irrigated areas and plant types are matters of local policy and custom, which may not be easily changed.

Background

This is a study of single-family household water use in California and the factors that affect it. In 1996 the American Water Works Research Foundation (AWWARF) funded what was then the most detailed and comprehensive study of water use patterns in single-family customers in North America. This study was jointly sponsored by 12 water agencies in the U.S. and Canada. The study was called the Residential End Uses of Water Study, or REUWS[1], and it provided unprecedented details on household water use using a random sample of approximately 1200 homes chosen in groups of 100 per study site. The REUWS used a combination of billing data, flow traces from data loggers, and survey data to obtain measurement of daily household and per capita use for each of the major end uses of water. Estimates were obtained for the irrigated areas on each lot in order to also provide estimates of annual irrigation applications. The REUWS study provided a benchmark of water use patterns at a point in time at which few houses had incorporated the more efficient plumbing fixtures mandated by the 1992 Energy Policy Act.

Four of the 12 study sites for the REUWS were located in the State of California. These were: Las Virgenes Municipal Water District, Walnut Valley Water District, the City of Lompoc, and the City of San Diego. All of these were located in Southern California. The results from the California homes showed that their indoor use was very similar to that of the other study homes. The average indoor water use was approximately 177 gallons per household per day and the per capita use of approximately 70 gpcd for indoor uses.

[1] Mayer, P. W., DeOreo, W. B., Opitz, E. M., Kiefer, J. C., Davis, W. Y., Dziegielewski, B., and Nelson, J. O. (1999). "Residential End Uses of Water." American Water Works Association Research Foundation, Denver.

In 2004 a group of California water agencies, led by Irvine Ranch Water District, submitted an application to the California Department of Water Resources to fund an update and expansion of the REUWS study that would be conducted totally within the State of California. This proposal was accepted for full funding by the DWR in the spring of 2005. Data collection began on the project during the fall of 2006 and was completed by the fall of 2008. Analysis continued through 2009 and the project report was published in June of 2010. An extensive review process was undertaken after the draft report was delivered.

For purposes of identifying this study and distinguishing it from the other preceding studies it shall be referred to as the California Single-Family Water Use Efficiency Study, or just the California Single-Family Water Use Study.

Goals of Project

The overall goal of this project was to provide detailed water use data on a new statewide sample of single-family homes in order to provide an updated snapshot of their water use patterns. This would provide an updated benchmark for their water use efficiency, a comparison of their status with respect to the use patterns from both the REUWS and from various studies of high-efficiency homes, such as the EPA Retrofit Study, which yielded a gauge of how much untapped water conservation potential exists in this major category of customers.

Single-family homes represent the largest single category of water users for most water utilities. There is a considerable amount of knowledge about household water use that allows one to establish efficiency benchmarks for single-family homes and compare the water use from a given sample in order to assess where the existing use falls within the efficiency continuum. This project was designed to collect data on the end uses of water in California single-family customers as of ~2007, to assess how efficiently this water is being used, and to determine what potential remains for water savings in homes across the state.

The proposal submitted to the California Department of Water Resources in 2004 identified eight specific goals for the project:

- To provide information on current indoor and outdoor single-family water use efficiencies as a benchmark for current conditions and to evaluate future efficiency programs.
- To provide a basis for estimating remaining conservation potential in single-family homes throughout the State.
- To provide information on the current market penetration of water efficient fixtures and appliances in single-family homes.
- To provide information on the rate of adoption of water efficient fixtures and appliances by California homeowners.
- To provide information in how well the BMPs adopted as part of the 1991 memorandum of understanding have been adopted and how much water savings can be attributed to these efforts.
- To provide baseline demand data for future studies.

- To provide information that can be used by California water agencies in updating their Urban Water Management Plans.
- To provide guidance for allocation of resources by identifying areas with the most promising conservation potential.

Study Methodology

In this study, random samples of single-family residential customers were chosen from water agencies throughout California such that the proportion of the overall sample roughly matched the percent of the state population served by the agencies. These samples were selected so that their mean and median annual water use matched the populations from which they were drawn at the 95% confidence level. Water billing data were obtained for the sample homes and aerial photos were obtained for each. Each home was surveyed and visited so that a data logger could be installed and the landscape could be checked against the aerial photos. Flow trace data were obtained for two-week periods from each home, and these were disaggregated into end uses using the Trace Wizard program. A database of end uses was created which allowed detailed analyses of end use patterns, penetration rates of high-efficiency fixtures and appliances and outdoor uses as both volumes and percentages of theoretical irrigation requirements. Mathematical models were developed for indoor and outdoor water use, which obtained data from the water events database and surveys to search for factors that best explain water use. Conclusions were made and statewide implications were discussed based on the findings of the study. Chapter 5 provides a complete description of the study methodology.

Sources of Error

There are two types of errors to which a study such as this is subject: random errors and systematic errors. Random errors reduce the accuracy of the results, but they do not change the basic conclusions of the study. If random errors are large enough, they make it impossible to detect trends in the data and to develop meaningful relationships, but if they are not too large the underlying relationships in the data are evident. Systematic errors are more malignant, however, in that they create an overall bias in the results that may lead to drawing erroneous conclusions.

Examples of random errors are numerous. One common random error in the flow trace analysis would be for events to get mis-categorized. In a data set containing literally millions of records, one would always expect to have a certain number of events mis-categorized. The program may identify a faucet event that looks like a toilet flush as a toilet, even though the actual event occurred when someone used a bathtub faucet to fill up a 1.5 gallon watering can. On the other hand, toilets may sometimes flush in a manner that appears to be a faucet, so the reverse situation can occur. Small leaks and faucet events can be confusing. Some faucet events may be classified as leaks and vice versa, and there may be some devices, such as evaporative coolers or reverse osmosis systems that can be confused with leaks. In these cases some of the evaporative cooler events may be classified as leaks and some leaks may get classified as evaporative coolers. A situation where all of the events get misclassified is highly unlikely to occur. In this way, random errors tend to cancel each other out.

Another example of random errors is how irrigated areas are identified on aerial photos. Photos for the study were obtained from different sources and taken on different dates. Determining the boundaries and plant types of the landscape sub-area can be influenced by shadows, time of year, condition of the plants, and resolution and spectral bandwidth of the photo. Two analysts working with photos from different dates would never come up with the same results. But if the errors are random in nature the overall variance between the two analyses should be small. An example of this would be the irrigated area analysis of the 12 homes in the Helix Water District system. The agency checked the irrigated area on the lots independently from Aquacraft. While there were some significant variations in results on individual lots, overall the results agreed within 5% of each other. The Helix analysis showed a total irrigated area of 71, 257 sf and the Aquacraft analysis showed a total of 67,603 sf. The difference of 3654 sf amounted to 5% of the original estimate by Aquacraft.

The breakdown of annual water consumption into indoor and outdoor use is another area of random error. In this case we are attempting to estimate total annual indoor water use from a combination of billing and flow trace data so that we can subtract annual indoor water use from total annual use and derive outdoor use. This is a necessary step since the vast majority of single-family homes have a single water meter through which both indoor and outdoor water flows. In many areas of California irrigation occurs on a year-round basis, so use of average winter consumption as a proxy for indoor use is not reliable. In this study we used the estimate derived from projecting the flow trace indoor use to the year as the preferred approach, as long as this yields a reasonable estimate. Sometimes the flow trace data do not appear to be typical of indoor conditions. In those cases we used either the average or minimum month use as a proxy for indoor use, or simply used an allowance of average indoor use to estimate outdoor use. Given the fact that we were dealing with a single water meter, some estimate of this type was needed in order to derive the indoor/outdoor water split. In some cases the approach may result in underestimates of indoor use, and in others it may lead to over-estimation.

The fact that there was a lag between the billing data used for the sample selection and determination of annual indoor use and the flow trace data used to estimate indoor use could be a cause of error. We know that indoor water use tends to be fairly stable, but if there were changes in the occupancy of the homes between the year of the billing data and the period of the logging data then this would cause errors. We tried to minimize the time between these two periods in order to avoid these errors to the degree possible.

There are issues regarding toilets being classified as ULF or non-ULF toilets in the analysis, and whether the flow trace analysis correctly makes this determination. As discussed in more detail in the body of the report, the flow trace analysis merely shows the volume of the toilet flush. The flow trace analysis shows how the toilet is performing, and not the actual model of the device. Many flushes recorded in the dataset may fall outside the 2.2 gallon per flush limit we used as the separation point for individual toilet flushes that are from ULF model toilets. Toilets flushing between 2.2 and 3.3 gpf are in the gray area where we cannot say whether they are poorly functioning ULF models or standard toilets that have been modified. The data point out an important issue with the toilet retrofit program in that if many of the toilets that are installed are technically ULF designs, but they fail to flush at ULF standards then this would be a problem. In our study, these toilets do not get classified as ULF toilets, even though they may be ULF designs.

The report includes data from the EPA New Home Study, which shows a distribution of toilet flush volumes from a group of homes known to contain almost exclusively ULF design toilets. Having a distribution of actual ULF flush volumes made it possible to make a much more accurate estimation of the percent of flushes that are due to malfunctioning ULF toilets versus high volume toilets. This discussion is provided in Chapter 7.

Systematic errors occur when a condition occurs that affects the entire dataset. These types of errors can cause serious distortions in the data and can lead to erroneous conclusions. An example of a systematic error would be a water meter that recorded the wrong volume of water. In a case like this the logged volume would match the register volume, but both would be off from the actual use. If the error was large it would probably make the trace file be discarded as unreasonable, but if it was off by 10 or 20% the data might be accepted and analyzed as correct. In that case, all of the events in that trace file would be either too large or too small. Water meters failing to record very small leaks would be another example of systematic errors. Taking this a step further, if this error only occurred in a single meter, it would not be a serious problem, but if it occurred in all meters the entire study would be distorted.

It is possible that some water treatment systems may give the appearance of leakage, and cause all of the treatment events to be classified as leaks. We know of at least one case where a house may have had a full-time reverse osmosis system in place. If this was operated on a 24-hour, 7 day per week basis, it could have caused that house to be accounted as having a very large leak, when it was actually a very large amount of water flowing down the drain as RO reject water. It is difficult to think of another device that might reasonably cause this type of situation, and also why water being wasted as part of a water treatment process should not be classified along with leaks. Further study of leaks and continuous uses would help clarify this situation.

For aerial photo analyses if there was a scaling error in the photo that affected all of the lots or if the time of year that the photo was taken made it impossible to correctly identify the irrigated areas, then there could be systematic errors in irrigated area determinations. The Irvine Ranch Water District analyzed the irrigated areas of the 102 lots included in the outdoor portion of this study. Their analysis showed irrigated areas averaging 32% more than the Aquacraft analysis. This suggests that there might have been some sort of systematic difference between the two photos. After reviewing and confirming the IRWD results, the IRWD irrigated areas were re-analyzed by Aquacraft using new photos supplied by the District.

An opposite problem occurred in East Bay MUD. The District did an independent analysis of the irrigated areas and determined that Aquacraft had over-estimated the areas by counting parcels of native trees, and dry turf areas as irrigated, when in fact they are not. Aquacraft reassessed the irrigated areas for EBMUD and recalculated the results using the updated areas. Details of these analyses are provided in Appendix E.

CHAPTER 3 –LITERATURE REVIEW

The water demands of the single-family residential sector are of great interest and importance to water providers, planners, and conservation professionals. The scientific study of these demands has been underway for many years, but only in the past 20 years have data sets from large random samples of residential customers in cities across the U.S. been assembled. Since the publication of the Residential End Uses of Water study, interest in residential water use around the world has grown and significant end use studies have now been undertaken in Australia, Great Britain, Spain, New Zealand, Cyprus, Jordan, and many other countries.

Historically there have been a number of research studies that have attempted to measure how much water is devoted to the main residential end uses and to determine the key factors that affect the end use patterns. Billing data analysis, customer interviews, home audits, retrofit studies, and more recently data-logging, are among the tools that have been used by utilities to evaluate customer demands and estimate the effectiveness of conservation measures. As noted by Dr. Thomas Chesnutt, "Conserved water cannot be counted on as a reliable water source if water managers lack a good estimate of potential savings. Hence evaluation is a crucial component of any conservation program. The use of water conservation estimates in regulatory decision-making processes makes accurate evaluations even more important."[2]

In 1940 Roy B. Hunter developed some of the earliest peak demand profiles – known as Hunter curves – used for sizing meters and service lines. Hunter relied on knowledge of the water uses within a given structure, their peak demands, the theoretical estimates of the frequency of use, and the probability of simultaneous use to derive estimates of the peak instantaneous demands for water in buildings. This approach grossly over-estimated the peak demands in most buildings because he lacked accurate information on the probabilities of multiple and simultaneous uses of fixtures within the buildings.[3]

Knowledge of demand patterns is interwoven with an understanding of the end uses of water. According to the American Water Works Association (AWWA) Technical Manual M22: "Demand profiles help to identify service size requirements, clarify meter maintenance requirements, define water use characteristics for conservation programs, assist in leakage management, enhance customer satisfaction and awareness, improve hydraulic models, and establish equitable and justifiable rate structures. Additionally, with increased water scarcity and cost of water, conservation and loss control have become important industry issues. For many utilities water conservation and water loss control have become the most cost-effective means to improve water resource availability."[4]

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[2] Chesnutt, T.W., C.N. McSpadden, 1991. Improving the Evaluation of Water Conservation Programs, Santa Monica, CA.

[3] Hunter, R 1940. "Methods of Estimating Loads in Plumbing Systems." National Bureau of Standards, Washington, D.C.

[4] AWWA, 2004. Sizing Water Service Lines and Meters 2nd Edition, Denver, CO.

The importance of flow profiles (i.e. high resolution time series flow rates that allow individual uses to be identified) was recognized for accurate analysis of end uses of water. By the mid-1970s advances in portable data loggers allowed actual demand data to be collected from the customer water meter using mechanical loggers and circular chart recorders. While cumbersome, these data allowed actual peak demand information to be collected from meters serving specific customers, whose size and other characteristics were known. The 1975 version of the M22 manual used data from these empirical observations to replace the original Hunter curves that were used to estimate peak demands.[5]

Increased attention on demand management created the need to evaluate the effectiveness of various conservation programs and verify savings estimates made at the time of their inception. During the 1980s it was becoming increasingly clear that water conservation offered an economic way to reduce urban water demands, thus reducing the need for continued new water supply projects, which were becoming both more expensive and more difficult to find. In 1981the AWWA published one of the first books on water conservation[6], and in 1984 Brown and Caldwell published one of the first detailed efforts at measuring end uses of water in residential structures by instrumentation[7]. This national study of 200 homes in nine cities provided better estimates of potential savings from conservation efforts on residential demands than had been available previously. "Although testing has established water use for residential plumbing fixtures and water conservation devices under laboratory conditions, estimates of water and energy savings with reduced-flow fixtures and devices have been based upon very different assumptions regarding typical duration of fixture use, flow rate, temperature, and frequency of use. As a result, estimated savings found in the literature for water-saving fixtures and devices span a range of nearly 300 percent."[8]

Although the Brown and Caldwell study measured actual use, which resulted in significant improvement in estimating end use patterns and potential savings, the results were limited by the fact that participation in this study was voluntary. In addition, the equipment required considerable intrusion into the normal operation of the homes. Of significance was the finding that water savings from retrofits did occur, but in many cases the actual savings were less than those predicted from theoretical calculations. The variance of actual water savings from theory can be due to a number of factors: mis-estimation of actual volumes used by the old and new devices, behavior of the occupants may vary from predicted behavior, frequencies of use may vary, modification or removal of conservation devices might also have occurred over the course of the three year study period. In addition, the data in this study suggested some of the savings found initially tended to decrease with time. All of this highlighted the importance of having accurate and unobtrusive ways to measure the actual water use of conservation devices and water savings rather than relying on theoretical predictions.

[5] AWWA, 1975. Sizing Water Service Lines and Meters, Denver, CO.
[6] AWWA, 1981. Water Conservation Management. AWWA, Denver, CO.
[7] Brown & Caldwell, 1984. Residential Water Conservation Projects---Summary Report. HUD-PDR-903, Washington, D.C.
[8] Brown & Caldwell, 1984. Residential Water Conservation Projects---Summary Report. HUD-PDR-903, Washington, D.C.

In 1991 the Stevens Institute of Technology published a study on the water conservation program in East Bay MUD.[9] This study involved a much more extensive data collection effort on residential end uses, but again, one that relied on individual sensors and loggers placed on targeted fixtures and appliances. While the data were useful for evaluation of the conservation program, the process was cumbersome. The Stevens Institute study showed that having residential water use broken down into end uses greatly increased the accuracy of water savings measurements. The disaggregated use data segregated water use by end use. This prevented changes in use in one category during the study from masking the effects of a program for another category. For example, if a toilet retrofit study was being evaluated but unrelated leakage occurred, this could mask the savings associated with the toilet program. Disaggregating data prevented this from happening. Also, having disaggregated data reduced the inherent variability in the water use for each category. This greatly reduced the noise of the measurements and allowed smaller changes to be accurately detected with less data.

A significant step in the process of evaluating the real impact of retrofits on residential water use was the study done by Anderson et al in Tampa.[10] In this study what the authors referred to "an extensive array of electronic water meters, pressure transducers, and event counters" that were installed on 25 homes in Tampa, Florida. Water use data were monitored for 30 days at which point the toilets and showers were replaced, and the process was repeated. The authors pointed out that this type of data was necessary to account for the way the residents behaved. For example, if they flushed their new toilets more, or took longer showers, then the actual water savings would be much reduced from the theoretical savings calculated from product flow and volume data. Using this technique, the authors measured an actual reduction in water use in the homes of 7.9 gpcd, or 15.6% savings. This was less than the predicted savings, which they concluded was due to increases in other water use in the homes.

The development of data loggers provided utilities and researchers with an effective tool for examining and measuring both daily and peak demand. The data loggers could be installed on residential water meters without requiring access to the home and were significantly less intrusive then previous methods.

In 1993 a study of the feasibility of using a single data logger attached to the customer water meter was begun in the Heatherwood neighborhood of Boulder, Colorado. In this study event loggers wired to Hall effect sensors were attached to the customers' water meters. The sensors recorded the passage of the magnets used to couple the meter to the register as water flowed. The design of the meter and magnetic coupling provided approximately 80 magnetic pulses per gallon of flow. At a ten second recording interval the data logger produced a record of water flows (a flow trace) of sufficient accuracy to allow all of the major end uses of water in the home to be identified through visual inspection. The results of this study were published in 1996.[11]

[9] Aher, A., A. Chouthai, L. Chandrasekhar, W. Corpening, L. Russ and B. Vijapur, 1991. East Bay Municipal Utility District Water Conservation Study, Oakland, CA.

[10] Anderson, D. L., D. Mulville-Friel, and W.L. Nero. 1993. "The Impact of Water Conserving Fixtures on Residential Water Use Characteristics in Tampa, Florida." Proceeding of Conserve93.

[11] DeOreo, W. 1996. "Disaggregating Residential Water Use Through Flow Trace Analysis." *Journal American Water Works Association, January 1996*.

This technique was used to disaggregate the water use in a sample of 16 homes for a baseline analysis. These homes were later retrofit with high-efficiency fixtures and appliances and the process was repeated, which provided data on the water savings attributable to residential retrofits. [12]

In 1996 the AWWARF[13] funded a detailed and comprehensive study of water use patterns in single-family customers in North America using data loggers.[14] The study was called the Residential End Uses of Water Study, or REUWS, and was sponsored jointly by 12 water agencies in the U.S. and Canada. It provided detailed information on the end uses of water in residential settings and developed predictive models to forecast residential water demand. Prior to this study, utilities relied largely on theoretical calculations to predict baseline end uses and the water savings of conservation programs. The participants for the REUWS were selected from the residential customer base of 12 utilities across North America and "the predictive models developed as part of this study to forecast indoor demand significantly increase the confidence in explaining the water use variations observed. The major benefit of modeling is to provide a predictive tool with a high transfer value for use by other utilities." (Aquacraft)

The predictive value of any tool is only as good as its ability to provide an accurate assessment of the data. As with any new data measurement technology, questions have been raised as to the accuracy and reliability of data-loggers to measure volumetric end uses[15]. Brainard data-loggers record analog data directly from the customer's water meter which is then evaluated graphically in Trace Wizard©, a proprietary software program developed by Aquacraft. The results from an independent study in 2004 showed that discrete toilet events can be accurately quantified at the 95% confidence level plus or minus 3% of the mean volume[16]. Although extremely accurate for isolated events, early versions of the Trace Wizard program was limited in its ability to disaggregate simultaneous end use events without accessing the original database – a cumbersome and time consuming process. Improvements to the software, however, eliminated the difficulty of disaggregation and provided a powerful tool for analyzing residential end uses.[17]

In 2001 an engineering report was published by the Water Corporation of Western Australia in which data collected from 600 in-home surveys was used to validate end use data collected using flow trace analyses in a separate 120 home study. The study showed that the flow trace analysis was capable of determining the percent of showers, toilets and clothes washers falling into normal and high-efficiency categories, and these results were confirmed by the in-home audits. Studies of this kind, that combine both flow trace analysis and in-home audits, provide excellent

[12] DeOreo, W. (2001). "Retrofit Realities." Journal American Water Works Association, March 2001.

[13] The American Water Works Association Research Foundation, now known as the Water Research Foundation (WRF).

[14] The REUWS was, for its time, the most detailed study of single-familyresidential end uses of water that had been conducted in the U.S.

[15] Koeller, J. & Gauley, W., 2004. Effectiveness of Data Logging Residential Water Meters to Identify and Quantify Toilet Flush Volumes: A Pilot Study, Los Angeles.

[16] Ibid.

[17] Also, it should be kept in mind that Trace Wizard is no more accurate than the water meter used to provide the data.

validation of the flow trace technique for measuring both the volumes used by individual end uses and the efficiency levels of the fixtures and appliance found in the homes.

Three studies in Yarra Valley, Australia showed the benefits of data-logging, when compared to surveys, as a tool for developing predictive models that were both accurate and more cost effective than other data collection methodologies. The first of these studies, the 1999 Residential Forecasting Study[18], involved a telephone survey of 1,000 Yarra Valley Water single-family customers. It provided detailed information on customer water use patterns, end uses, behavior, and penetration rates of conserving fixtures and appliances. One of the limitations of this study was the inability of customers to provide information about fixture efficiency, for example whether or not the home contained standard vs. efficient showerheads or 6/3 or 9/4.5 liter toilets.

The Residential Forecasting Study was followed by the Yarra Valley Water (YVW) 2003 Appliance Stock and Usage Pattern Survey (ASUPS) that was designed to address these issues. In-home surveys were performed by a team of trained technicians who obtained detailed customer information as well as flow data and verification of the penetration of efficient appliances in 840 homes. “These types of surveys are expensive and they are always at risk of yielding non-representative samples due to disproportionate refusal rates by certain segments of the residential population. Furthermore, these surveys provide only limited information about things like the rate at which water-wasting plumbing devices are replaced by their water-conserving alternatives.”[19]

One hundred of the 840 homes in YVW were selected to participate in The Residential End Use Measurement Study in 2004[20]. In this study data loggers were used to disaggregate the indoor use in the home following the same approach as in the Heatherwood and REUWS studies. The results of the 100 home data logged group were compared to the in-home surveys and showed remarkable consistency with data that had been acquired by technicians during the ASUPS. The data logging study also provided information about leakage, fixture replacement, and behavior that was not yielded by a survey. Data-loggers were installed for two two-week periods in each of the homes in order to capture both indoor and irrigation usage. According to the authors, “The findings from REUWS have enabled Yarra Valley Water to establish a robust end use modeling capability. In addition the end use measurement has also enabled more informed design and assessment of various demand management programs and provided a valuable data set from which to provide customers with informative usage data via their quarterly account statement.”[21]

As the value of the data-logging technology became apparent, the EPA funded three residential water conservation studies over a three-year period, from 2000 to 2003. These studies provided important information on the effectiveness of water conserving fixtures and appliances in reducing indoor water use. Baseline water use data were collected from a sample of 96 homes in

[18] Residential Forecasting Study 1999 was a telephone survey of 1000 Yarra Valley Water customers. The survey conducted by AC Nielsen with Peter Roberts, Demand Forecasting Manager for Yarra Valley Water.
[19] Ibid.
[20] Roberts, P., 2005. Yarra Valley Water 2004 Residential End Use Measurement Study, Melbourne.
[21] Ibid.

Seattle, Tampa, and East Bay Municipal Utility District in California that provided information on household and per capita usage of toilets, showers, clothes washers, dishwashers, faucet use, leakage, and other indoor uses. These same homes were then retrofitted with conserving toilets, clothes washers, showerheads, faucet aerators, and hands free faucet controllers; six months later household and per capita use of the various end uses was again examined. The results of the studies clearly showed the ability to achieve significant reduction in household water use with the installation of water conserving fixtures and appliances. Average daily household indoor use was reduced by 39% from 175 gpd to 107 gpd in the homes that were retrofitted with conserving fixtures and appliances. These studies were important in setting benchmarks for water use with best available technology[22] and provided a tool with which utilities could gauge their progress in achieving long-term water savings.

The participants in the EPA residential conservation studies were customers located in three water agencies spread across the United States. Because the participants were volunteers and not selected at random, the study data did not provide information on penetration rates of water using fixtures and appliances that could be generalized to their respective populations. There has also been concern about degradation in savings over time, particularly from toilets. As one of the most consumptive indoor uses, toilets have been the subject of considerable scrutiny.

In 2000, the City of Tucson participated in a data-logging study of residential customers who had received toilet rebates for low-consumption toilets in 1991 and 1992. The data from the 170 study participants "revealed that nearly half of aging low-consumption toilets had problems with high flush volumes, frequent double flushing, and/or flapper leaks. Data logging revealed that the average flush volume for all low-consumption rebate toilets was 1.98 gallons per flush, or about 24 percent higher than 1.6 gallons per flush they were designed to use. In addition, 26.5 percent of households had at least one low-consumption rebate toilet with an average flush volume greater than 2.2 gpf[23]. Other studies have shown that chemical degradation of toilet flappers[24] and poorly fitting after-market toilet flappers[25] have contributed to increased leakage and toilet volume which has contributed to the uncertainty of conservation savings.

These uncertainties led California utilities to recognize the importance of having more specific information for their state. In 2004 a group of California water agencies, led by Irvine Ranch Water District[26], submitted an application to the California Department of Water Resources to fund an update and expansion of the REUWS that would be conducted entirely within the State of California. The work on this study, funded by the California Department of Water Resources and by the participating agencies, began in 2006.

[22] That is best available technology for 2000-2002. As new technologies are implemented the BAT standards will also shift to reflect them. These might include devices like recirculation systems, real time customer feedback devices, "leak" detection devices, and better hands-free faucet controllers.

[23] Henderson, J. & Woodard, G., 2000. Functioning of Aging Low-Consumption Toilets in Tucson A Follow-up with Rebate Program Participants. Issue Paper #22, Phoenix.

[24] Metropolitan Water District of Southern California. Toilet Flapper Materials Integrity Tests, 1998.

[25] Henderson, J. & Woodard, G., 2000. Functioning of Aging Low-Consumption Toilets in Tucson A Follow-up with Rebate Program Participants. Issue Paper #22, Phoenix.

[26] http://www.irwd.com/. Irvine Ranch Water District. Contact: Fiona Sanchez, Conservation Manager.

The overall goal of the California project was to provide detailed water use data on a statewide sample of single-family homes in order to provide a snapshot of their water use patterns updated to the 2006-2008 study period. The study supplied information on the penetration rates of conserving fixtures and appliances that met or exceeded conservation standards as they existed during the study period. In addition it provided an updated benchmark for their water use efficiency, a comparison of their status with respect to the demands from 1996, and a gauge of how much untapped water conservation potential existed in this major customer category.

As a way to encourage and promote conservation, the EPA has developed WaterSense, a partnership program "with interested stakeholders, such as product manufacturers, retailers, and water utilities."[27] The WaterSense program is interested in promoting cost effective products and technologies that are measurably more water efficient than conventional products. Products must be certified by an independent third party and show significant water savings without sacrificing performance.

In order to measure the effectiveness of the WaterSense program, the EPA provided funding for this study, the Efficiency Benchmarking for the New Single-Family Homes, which began in 2005. Working with nine participating utilities[28], some of which participated in the earlier REUWS project, this project was designed to measure both baseline water use in new homes, built after January 1, 2001, and to demonstrate how high-efficiency new homes, using advanced water efficient technologies, can reduce water use below levels sought in the 1992 National Energy Policy Act.

One of the most precise and innovative validation studies of flow trace analysis was done by Magnusson in 2009 as part of a study of hot water use in single-family homes. In this study flow sensors were installed on individual hot water supply lines feeding all of the faucets, showers, dish washers and clothes washer in a test home in Boulder, CO. Data from these monitors was compared to flow trace analysis performed on a single water meter on the feed line to the hot water system. This allowed a comparison to be made between the volumes recorded by the flow trace analysis and those recorded by the supply line meters. Volumetric errors were mainly in the faucet and shower category, with 17.1% and 11.1% errors respectively. The errors for dishwashers and clothes washers were much smaller, at 6.5% and 7.2% respectively.

[27] http://www.epa.gov/WaterSense/docs/program_guidelines508.pdf. February 2009. WaterSense Program Guidelines. Roles and Functions. Accessed May 1, 2009.

[28] The nine participating agencies are: Aurora, Denver, Eugene, Las Vegas, Phoenix, Roseville, Salt Lake City, St John's Regional Water Management District (SJRWM), and Tampa Bay. The purpose of this report is to provide an analysis of the group from which data has already been collected for future comparison and will be referred to as the "standard new home study group."

CHAPTER 4 –DESCRIPTION OF PARTICIPATING AGENCIES

Selection of Study Sites

There were nine sponsoring water agencies that participated in this study. In most cases the sponsoring agencies were retail providers acting on their own behalf and the study homes were selected from their own water customers. In some cases the agency was a wholesale provider that solicited participation from a number of retail providers in its service area. Table 4 shows a list of the agencies and the utilities from which the logging samples were selected. This section provides information about each of the agencies participating in this study and includes the number of customers, customer characteristics, local weather data, the utility's water supply and the customer demands, water and sewer rates, and rate structures.

Table 4: Sponsoring Agencies

Sponsoring Agency	Water Utilities Sampled
Sonoma County Water Agency	City of Petaluma, North Marin Water District, City of Rohnert Park, City of Santa Rosa
Las Virgenes Municipal Water District	LVMWD service area
Redwood City	Redwood City
San Francisco Public Utilities Commission	City of San Francisco
City of Davis	City of Davis service area
East Bay Municipal Utility District (EBMUD)	EBMUD service area
Los Angeles Department of Water and Power	Los Angeles DWP service area
Irvine Ranch Water District	City of Irvine, and portions of the cities of Costa Mesa, Lake Forest, Newport Beach, Orange, Tustin and unincorporated areas of Orange County
San Diego County Water Authority	City of San Diego, Otay Water District, Rincon del Diablo Water District, Sweetwater Water District, Helix Water District

Demographic and Census Information

Previous studies have shown that several demographic factors are strongly correlated with the amount of water used by single-family customers, the most notable being the size of the home and the number of residents in the home. Other factors, while less strongly correlated, will also be presented for their potential use in characterizing the sample in comparison to the state as a whole.

Demographic information was obtained for each municipality from the 2000 U.S. Census. Data include median age, household income and home price, education levels and percentage of residents living below the poverty level. Also included is the median monthly mortgage or rent, the percentage of homes that are rented or owner-occupied, the median age of the homes, the average number of bedrooms, and the percentage of homes that were built after 1995.[29] These results are shown in Table 5 and Table 6.

Table 5: Comparison of Age, Education, and Income Information from U.S. Census by Study Site

	Total Population	Median Age (years)	High School Graduate (or higher) %	College Graduate (or higher) %	Median Household Income $	Percent Families Below Poverty Level %
United States	281,421,906	35.3	80.4	24.4	41,994	12.4
LADWP	3,694,820	31.6	66.6	25.5	36,687	9.2
IRWD[1]	315,000	33.1	95.3	58.4	72,057	5.0
SCWA	458,615	37.5	84.9	28.5	53,076	9.2
Rohnert Park	42,236	31.5	88.0	24.7	51,942	8.0
Petaluma	54,548	37.1	85.9	30.1	61,679	6.0
Santa Rosa	147,595	36.2	84.2	27.6	50,931	5.1
N. Marin[2]	47,630	39.6	90.5	37	63,453	5.6
SFPUC	776,773	36.5	81.2	45.0	55,221	7.8
EBMUD[3]	1,300,000	NA	NA	NA	NA	NA
SDCWA	2,813,833	33.2	82.6	29.5	47,067	8.9

[29] This ensures that the Energy Policy Act of 1992 was in place that requires toilet flush volumes of 1.6 gpf or less, showerheads with flow rates of 2.5 gpm and lavatory faucet aerators that restrict the flow to 1.25 gpm or less

	Total Population	Median Age (years)	High School Graduate (or higher) %	College Graduate (or higher) %	Median Household Income $	Percent Families Below Poverty Level %
City of Davis	60,308	25.2	96.4	68.6	42,457	5.4
Redwood City	75,402	34.8	82.9	35.7	66,748	3.9
LVMWD[4]	20,537	37.6	94.8	48.4	87,008	3.5
City of San Diego	1,223,400	32.5	82.8	35.0	45,733	9.2

1 Statistics for IRWD are based on the City of Irvine, not the entire service area.
2 Statistics are given for the City of Novato.
3 Population given for service area, Econometric statistics are not available for entire service area.
4 Statistics are given for Agoura Hills – Agoura Hills has the largest population of the 4 cities served by Las Virgenes.

Table 6: Comparison of Housing Information from U.S. Census by Study Site

	Median Housing Value	Number of Occupied Housing Units	Percent Owner-Occupied Housing Units	Household Size - Owner Occupied	Household Size - Rental	Number of Bedrooms - Owner Occupied	Number of Bedrooms - Rental	Median Year Structure Built - Owner Occupied	Percent of Homes Built 1995-2000 Owner Occupied	Median Year Structure Built - Renter Occupied	Percent of Homes Built 1995-2000 Renter Occupied	Monthly Average Mortgage	Average Rent
United States	$119,600	55,212,108	68.7%	2.69	2.4	3.0	1.8	1971	11%	1965	6.4	$1,088	$519
LADWP	$221,600	1,275,412	38.6%	2.99	2.73	2.7	1.2	1956	0.4	1964	0.5	$1,598	$612
IRWD[1]	$316,800	53,711	60.0%	2.78	2.46	3.1	1.8	1980	16.1	1985	16.1	$1,897	$1,177
SCWA	$273,200	172,403	64.1%	2.61	2.57	2.9	1.9	1975	8.0	1973	5.5	$1,561	$789
Rohnert Park	$237,300	15,502	58.4%	2.83	2.40	3.1	1.8	1979	5.8	1980	6.2	$1,520	$841
Petaluma	$289,500	19,932	70.1%	2.75	2.59	3.2	2	1976	11.3	1972	6	$1,622	$870
Santa Rosa	$245,000	56,036	48.5%	2.56	2.57	2.9	1.8	1976	8.5	1974	4.8	$1,490	$862
N. Marin[2]	$381,400	12,512	67.5%	2.5	2.56	3.2	1.9	1971	3.0	1974	0.6	$1,970	$1,093
SFPUC	$396,400	329,700	35.0%	2.73	2.06	2.5	1.3	1940	2.5	1941	1.8	$1,886	$883
EBMUD[3]	$235,500	62,489	44.0%	2.76	2.49	2.6	1.3	1943	2.7	1955	1.8	$1,504	$631
SDCWA	$227,200	994,677	55.4%	2.78	2.68	3.0	1.7	1975	8.1	1974	4.0	$1,541	$710
City of Davis	$238,500	22,948	44.6%	2.64	2.39	3.3	1.9	1978	18.5	1976	8.3	$1,547	$775
Redwood City	$517,800	28,060	53.0%	2.61	2.63	2.8	1.5	1959	9.4	1965	4.1	$2,351	$1,014
LVMWD[4]	$366,600	5,399	85.7%	3.05	2.64	3.6	2.3	1980	0.6	1977	1.5	$2,138	$1,153
SDWD	$233,100	450,691	49.5%	2.71	2.52	2.9	1.6	1972	6.7	1972	4.5	$1,546	$714

1 Statistics for IRWD are based on the City of Irvine, not the entire service area.
2 Statistics for North Marin WD are based on the City of Novato, not the entire service area.
3 Population given for EBMUD service area, Econometric statistics are not available for entire service area.
4 Population given for LVMWD service area. Econometric statistics are given only for Agoura Hills.

Climate

Although it is well known by professionals in the landscape and irrigation industry that local weather data affects the amount of water needed for healthy landscapes, it is less clear if homeowners are aware of these effects. It is even less clear whether homeowners respond to the changing water demands in their landscape by increasing or decreasing the application of water in response to changes in weather.

Reference evapotranspiration (ETo) is the industry standard for determining irrigation requirements. It measures the moisture lost from a reference crop (normally cool season grass for urban purposes) and the soil due to temperature, solar radiation, wind speed, and relative humidity. Precipitation is not included in the measurement of Eto, although it does affect several of the parameters in the ET equation such as solar radiation and relative humidity. The California Department of Water Resources (DWR) manages a network of over 120 weather stations through their California Irrigation Management Information System (CIMIS) located throughout the state of California in an effort to make this information available to landscapers, irrigators, and homeowners.

As part of the analysis of water use for this study, Aquacraft disaggregated indoor and outdoor usage for each of the study homes, and determined the irrigable and irrigated area for each lot[30]. Both the theoretical irrigation requirements and the actual outdoor use were determined. In most cases determination of irrigated areas was clear from the aerial photos and visual inspection. In a few large lots built into native forest areas we relied on seeing a distinct difference in plant materials between the native land and the landscape parcel in order to decide that the area was being irrigated. Lands that had the same appearance as the surrounding native lands were generally classified as non-irrigated land.

Customer Base

Each utility supplied the number of customer connections to the municipal water supply in each of several sectors that typically include single family, multi-family, commercial, industrial, irrigation, and other. There is considerable variation in the make-up of the customer base from one municipality to the next. For example, in the City of San Diego only 38% of the customer base consists of single-family accounts whereas in North Marin Water District fully 90% of the customer base is single-family accounts. Knowing both the percentage of accounts that are residential and the percentage of the overall demand placed on the system by residential customers is one more tool available to water providers for water resource planning and water conservation.

Water Supply and Demand

As California's population continues to grow, it is often difficult to keep up with the increased demand for potable water. Water providers are continually looking for ways to reduce demand. Providing information on the water supply for each municipality helps to show the extent to

[30] The landscapes were divided into areas of turf, non-turf plants and trees, low water use plants and non-irrigated land. The latter category was not included as part of irrigated area.

which each municipality is vulnerable to increased demand on the system from a number of factors such as rapid growth, drought, limited supply, or limited supply sources. The annual demand placed on the supply by various customer sectors is included in this section. Where available, the demand for 2000 and 2005 is given, making it possible to see if overall demand has increased or decreased and in what sectors the change has occurred.

Water Rates, Rate Structure and Sewer Charges

The water and sewer rates, rate structure, and billing frequency were provided for each utility for the study period. Some of these have been modified since that time. Although most water providers use bi-monthly billing, there are others, such as the City of San Diego and IRWD, which send monthly bills. The billing unit used by most utilities is HCF or CCF (one hundred cubic feet or 748 gallons).

There are typically two charges for water – a base rate and a commodity charge. During the study period the base rate ranged from a low of $4.60 per month ($55.20 annually) in San Francisco to a high of $15.87 per month ($190.44 annually) in the City of San Diego. There was also considerable variation in commodity charges and rate structures. For example, San Francisco Public Utilities Commission charged a uniform rate of $1.71 per CCF while the IRWD has a five-tiered water-budget-based rate structure, with the cost per CCF ranging from $0.88 for Tier 1 to $7.04 for Tier 5.

Sewer rates varied considerably as well and most utilities charge a flat monthly or bi-monthly rate for sewer service. Irvine Ranch Water District charges the majority of its single-family customers a flat rate of $10 per month based on an annual review of sewer use, while Rohnert Park in Sonoma County charges a base rate of $1.35 per month plus $9.15 per thousand gallons. Because irrigation water does not place a demand on the wastewater system, several utilities charge a commodity fee that is based on the customer's average winter consumption. An example of this type of rate structure is in the City of San Diego, where customers are charged a monthly service fee of $11.32 plus a commodity charge of $3.218 per CCF based on average winter consumption.

Conservation

All of the study participants are signatories to the California Urban Water Conservation Council's Memorandum of Understanding (MOU). "Signatories of the Council's Memorandum of Understanding agree to meet certain requirements to achieve full implementation of the BMPs. These coverage requirements may be expressed either in terms of activity levels by water suppliers or as water savings achieved."[31]

The Memorandum of Understanding Regarding Urban Water Conservation in California was first adopted in 1991. Signatories to the MOU recognized the importance of maintaining a reliable water supply for uses as varied as agriculture, environmental protection, and urban demand. As demand for this finite resource increases, so does the need to develop conservation

[31] http://bmp.cuwcc.org/bmp/read_only/home.lasso?rui=5021. Best Management Practices Report Filing. California Urban Water Conservation Council. Accessed January 20, 2010.

measures or best management practices (BMPs) that would give water providers tools that are economically feasible to implement. Water conserved through these measures can be used to offset increased demand as well as provide long-term protection of both urban water supply and the environment. Implementation of the BMPs serves "to expedite implementation of reasonable water conservation measures in urban areas; and (…) to establish assumptions for use in calculating estimates of reliable future water conservation savings resulting from proven and reasonable conservation measures."[32]

Since its adoption in 1991 the MOU has been amended numerous times and substantially revised in September 2007. The BMPs developed for the MOU provide utilities with a guideline for implementing each BMP while recognizing that utilities may develop their own method of implementation that is at least as effective as those laid out in the BMPs. Also defined in the MOU is a schedule of implementation, expected level and progress of implementation, reporting requirements and estimates of reliable savings. The feasibility and efficacy of the BMPs are assessed by the CUWCC on a periodic basis.

Detailed Information on Each Participating Utility

Appendix B includes a detailed description of the water supply and conservation strategy of each participating agency in this study. In that appendix readers will find:

- Demographic information from the U.S. Census and other sources, specific to the utility service area
- Climate and ET information
- Customer base description and statistics
- Water supply and demand statistics
- Rate structure and water and sewer commodity charges and service fees
- Conservation program information

[32] http://www.cuwcc.org/WorkArea/showcontent.aspx?id=8540. Memorandum of Understanding Regarding Urban Water Conservation. Terms. Section 2. Purposes. Accessed January 20, 2010.

CHAPTER 5 – RESEARCH METHODS

The procedures for sample selection were designed to ensure that the sample was representative of the residential customer base as a whole. Sample selection was designed to minimize the possibility of selection bias by choosing customers randomly from the single-family customer base in each participating agency. Billing data for the sample population were compared to and matched with the billing data of the single-family population as a whole for the period of the study. The analysis of water efficiencies discussed in this report is based on performance criteria rather than identification of specific makes and models of fixtures and appliances. The intent was to determine at what level of efficiency the homes were operating rather than what models of toilets and appliances they had. From the standpoint of judging water conservation effectiveness this is the relevant parameter. From the standpoint of knowing models it begs several key questions. For example, in the results section of the report there are histograms that show toilet flushing volumes. Toilets that are flushing at 2.2 gpf or less are considered efficient, but some of these may be high volume toilets that have been modified to flush at lower volumes. In addition, toilets that are flushing at 3.5 gallons may include an indeterminate number of mal-functioning ULF type toilets. ULF toilets that are flushing at more than 2.2 gpf would be counted as high volume or high water use toilets in this analysis.

Overall Study Organization

Figure 10 shows how the overall project was organized and how the various elements tied together. The study began with collection of single-family billing data for each of the study sites, for the period from 2005 through 2007. Statistical analyses were then performed on the billing information to provide summaries of annual and seasonal use patterns and to provide sample frames for surveying and the selection of study homes for data logging. Representative samples of homes were selected from the billing data on the basis of annual water use, and each of these homes was then the subject for data logging during the period from 2006 through 2008, to allow for disaggregation of uses, and GIS analysis, to determine landscape characteristics. The Trace Wizard analysis provided disaggregated water use during the two-week data logging period. The end use data from this was combined with billing information to generate estimates of indoor and outdoor annual use and gallons per day for individual indoor uses. Outdoor use was estimated as the annual use from the billing data minus the best estimate of annual indoor water use, taken primarily from the flow trace analysis, but occasionally from the minimum month billed consumption.

The indoor and outdoor end use data were combined with data from the surveys and flow trace analysis in order to generate regression models. These models showed which of the data factors collected for the study were significant in predicting indoor and outdoor household water use, and how household use varied with each. These models were then used to predict the impact of changing household characteristics on water use, which allowed estimates of water savings from various demand management strategies to be tested. The report provides a set of conclusions and recommendations.

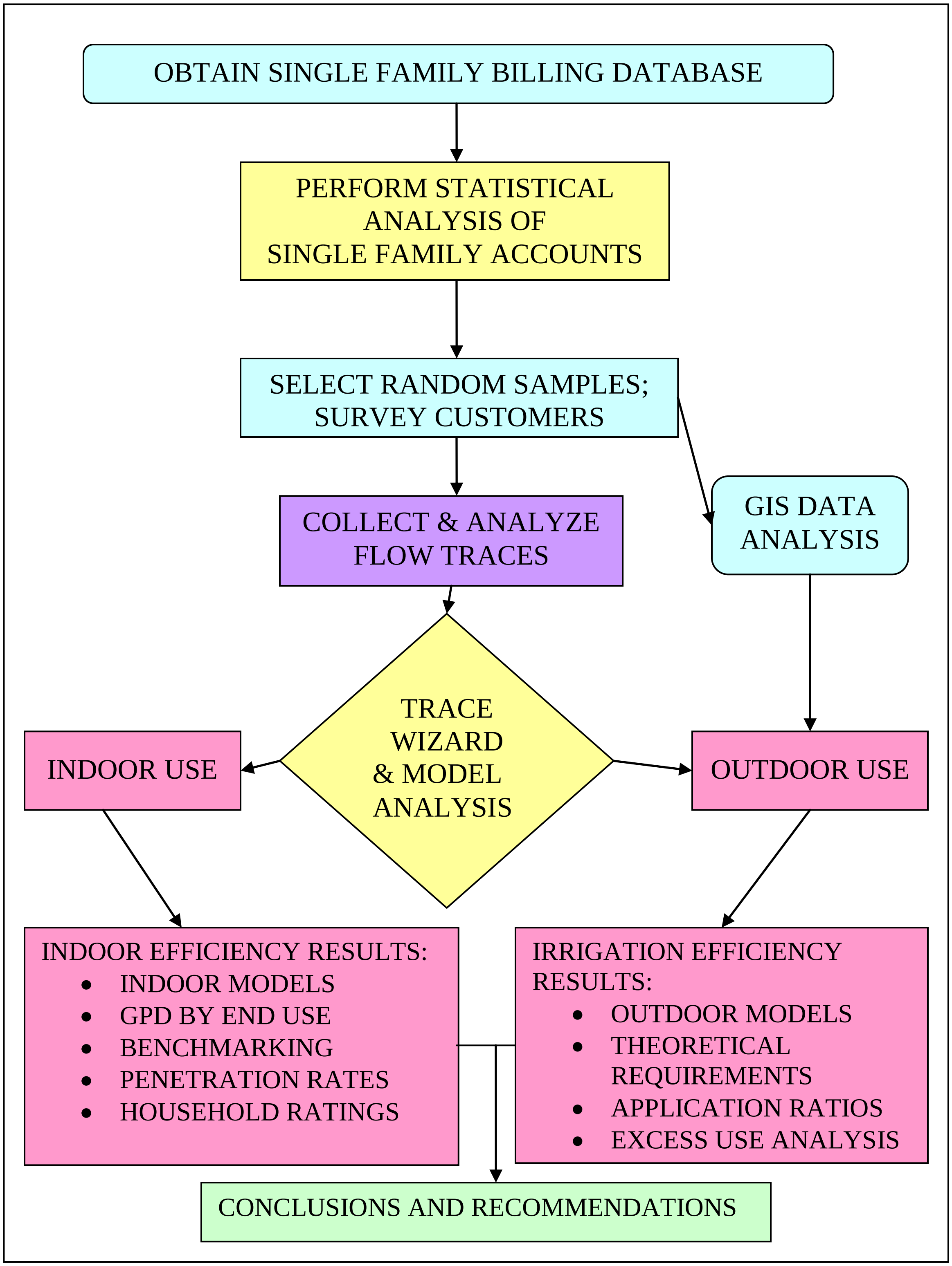


Figure 10: Project flow chart

Solicitation of Agencies

Because the goal of the sampling was to match the sample to the population by county, the solicitation process began with county population data for the most populous counties in the State, which are shown in Table 7. The goal of the selection process was to obtain participating agencies within these counties such that each county was represented in proportion to that county's percentage of the state population, to the extent practical. The results are shown in Table 7. Results on a county-by-county basis were mixed, but on a regional level the sample mix was fairly good. A total of 46% of the state population is found in Los Angeles, Orange, and San Diego Counties, and 45% of the study sample was located in those counties. The remainder of the sample was located in the San Francisco Bay and Sacramento areas. Given the fact that participation in the study was purely voluntary, we consider the sample mix to be a very acceptable working group containing a good mix of demographic, economic, and climate characteristics.

Selection of Samples

Each of the participating agencies provided the research team with a full year of monthly or bi-monthly water consumption data for their single-family customers. These lists were then trimmed to eliminate any customers with less than a full year of consumption data, or with very small or very large consumption. The remaining records were then sorted from lowest to highest annual consumption and divided into groups according to how many homes were desired in the sample. For example, in a system with 60,000 records in the trimmed data set, from which a sample of 60 homes was desired, the data would be divided into 60 groups of 1000 homes each. A random number between 1 and the number of homes in each group was chosen and this number was selected from each sample group. In our example, if the random number was 548 then the 548th home in each 1000-home sample group would have been selected for the logging group.

The selection of the logging sample was based on the most recent billing data that could be obtained at the time that the logging sample was selected. This ranged from 2005 to 2007. In some cases the average of more than one year was used. The years for which the billing data were obtained for purposes of selecting samples are shown in Table 10.

To the extent that the billing data included meter errors, these errors were carried over into the selection process. For example, if meters were malfunctioning and under-recording water use, then this would be reflected in the billing data and in the selection process. We screened the billing data for very low consumption, which would eliminate customers with non-functioning meters. Meters that failed to register very low flows associated with leaks would also fail to register on the data loggers. So, systematic meter errors due to under-registrations would affect the household use data used for this study. The analysis of non-recording meters was not part of this scope, but the fact that it occurs should be kept in mind when analyzing residential water use. Utilities were encouraged to replace old meters in order to minimize meter-related errors during the logging.

Table 7: Sites solicited for study

Agencies in Sample	County	Percent of State Population	Number of Homes in Target Sample	Percent of Sample
LADWP	Los Angeles	28%	120	15%
IRWD	Orange	8%	120	15%
San Diego City & County	San Diego	8%	120	15%
	San Bernardino	5%	0	0%
	Santa Clara	5%	0	0%
	Riverside	5%	0	0%
EBMUD	Alameda	4%	60	8%
City of Davis	Yolo (Sacramento Area)	4%	60	8%
EBMUD	Contra Costa	3%	60	8%
	Fresno	2%	0	0%
San Francisco Public Utilities	San Francisco	2%	60	8%
Las Virgenes MWD	Los Angeles	2%	60	8%
Redwood City	San Mateo	2%	60	8%
	Kern	2%	0	0%
	San Joaquin	2%	0	0%
Sonoma County Water Agency	Sonoma/Marin	1%	60	8%
	Stanislaus	1%	0	0%
	Monterey	1%	0	0%
	Santa Barbara	1%	0	0%
	Solano	1%	0	0%
Total		89.2%	780	100%

In some cases this process was broken up into two steps, where the agency selected a group of 1000 homes using the sampling approach described above, and the final sample for logging was selected from the group of 1000 (called the Q1000). The net result was the same in both cases, where a logging group was created that matched the annual water use characteristics for the populations in terms of mean annual use, median use and the distribution of use.

In all cases extra homes were selected to provide replacements for homes that proved impossible to log due to problems with their meters, or being unoccupied at the time of the logging, for example.

Assignment of Keycodes

Each home in the study group was assigned a 5-digit keycode that allowed the home to be included in the analysis on an anonymous basis. The first two digits of the code identified the agency in which the residence was located. The last three digits identified the specific home. While the account and address of each home can be linked to the specific keycode for research purposes (such as follow up studies) none of the published data includes any customer identification.

Table 8: Water Agency Keycodes

Agency	Starting Keycode
City of Davis	11101
Sonoma County Water Agency	12101
San Francisco PUC	13101
East Bay Municipal Utility District	14101
Redwood City	15101
Las Virgenes MWD	16101
Los Angeles DWP	17101
Irvine Ranch Water District	18101
City of San Diego	19101
San Diego County Water Authority	20101

Comparison Studies

In order to gauge the water use efficiency of the study homes, three other study groups have been used for comparison purposes. These studies are discussed and cited in the Literature Review, but, for convenience are summarized here.

Residential End Uses of Water Study

The Residential End Uses of Water Study (REUWS) is a group of approximately 1200 single-family homes chosen at random from the service areas of 12 water providers across the country. These homes provide a baseline for existing single-family homes for the period from 1996-1998. The homes were selected only on the basis of having their water use match the water use of the populations from which they were drawn.

EPA Retrofit Study

The EPA Retrofit Study comprised a group of approximately 100 homes that were chosen at random from the single-family populations in Seattle, EBMUD and Tampa. After baseline surveys and logging, approximately 30 of the homes were retrofitted with high-efficiency fixtures and appliances. The post-retrofit data from the homes was used as a benchmark for high-efficiency single-family indoor water use that might be obtained from retrofits and repair of major leaks. The homes in the study were existing homes in their respective service areas, and their only significant modifications were the installation of high-efficiency toilets, showers, clothes washers and faucets. The homeowners in the retrofit group were volunteers and they were given the new fixtures and appliances at no cost, so this may have increased their level of commitment to the study. Aside from that, however, they were typical single-family households.

EPA New Home Study

The EPA New Home Study consisted of approximately 330 homes built after 2001 and selected from eight water agencies. Each home was surveyed and data logged between 2008 and 2010. The end use data from these homes was used as a benchmark for standard new homes built after 2001. These homes were especially useful in comparing toilet flush volume distributions since they were known to contain predominantly ULF (1.6 gpf) toilets. In addition to the 330 standard new homes, the study included approximately 30 homes built to Water Sense standards. The data from the high-efficiency new homes was not used for comparisons in this study.

Surveys

Separate surveys were sent to the retail customers and the water agencies. The purpose of the customer surveys was to obtain information to use in the modeling of factors that affect residential water use. The purpose of the agency survey was to determine what types of water conservation programs were in place at each during the study period, and whether it might be possible to detect an impact on the customers' water use from different programs.

Utility Surveys

The water agencies provided answers to questions about their water conservation programs and other related topics in a separate survey. This survey asked 46 questions about the types of residential, CII, Irrigation and system conservation measures employed by the agencies. It also asked about other conservation programs and whether the agency had a formal water conservation plan and/or drought plan in place. A blank copy of the utility survey is shown in APPENDIX A.

Customer Surveys

Each of the homes selected for logging were provided with a survey to fill out. Copies of the survey were delivered or mailed to the customers, and follow-up mailings were sent out approximately two weeks after the first survey was delivered. Post card reminders were mailed out two to four weeks after that. The resident surveys asked for information about a broad range of physical and demographic information that was thought to have potential explanatory value for water use. A copy of the resident survey is provided in APPENDIX C. The resident survey contained a total of 58 questions divided into the following categories:

- Indoor water fixtures present in the home
- Hot water system
- Outdoor/landscaping
- Outdoor water fixtures
- Swimming pools
- Questions on attitudes and demographics

The surveys were sent to the homes that had been randomly selected for logging from the billing database. It was known that this was going to reduce the number of survey responses available for the modeling effort. This process offered a major advantage in the simplicity of logging home selection. If we relied upon just the homes that returned surveys for our logging sample there was a potential for selection bias based on having what amounted to a volunteer selection group. We felt that with sufficient effort we could obtain a large enough group of survey respondents to provide an adequate modeling group, and this proved to be the case. The exception to this was the Los Angeles DWP sample. In that case the agency required that the sampling group be selected only from customers who gave signed permissions to participate in the study. In order to minimize the chances of a selection bias, surveys were mailed to 3,000 homeowners and the logging sample, obtained from the respondents was verified to ensure that it was statistically similar to the population of single-family homes with respect to the annual water use.

Landscape Analyses

Irrigated Areas

The landscape for each of the study homes was analyzed according to the plant type and the area estimated from the photo analysis, using the best aerial photos that could be provided by the agencies or obtained from public sources. A fairly typical analysis is shown in

Figure 11. Areas of turf, xeriscape and tree canopy have been identified on this lot. The legend in the bottom left corner of the figure shows the various ground covers available for the analysis. Pools were identified and measured during this process, and were assigned a water requirement. The impacts of swimming pools and spas on outdoor water use was also determined as part of the modeling process during which the presence of pools was used as an explanatory variable for outdoor use, faucet use, and leaks to see if the presence of a pool was found to correlate with any of these categories of water use.

Each water agency was asked to provide the best ortho-rectified aerial photos with the necessary parcel shape files and addresses for the analysis. In some cases no aerial images were available from the agency at the time of the analysis, so it was necessary to use other sources such as Google Earth or various GIS sources. Landscapes change over time, so we would anticipate that updated landscape analyses using more recent photos, with higher resolution, would result in different landscape area determinations. The estimates contained in this study are based on aerial photos dating from or before 2006.[33]

The use of aerial photos for determination of irrigated areas was always intended as the primary method of measurement because this approach was deemed the most accurate approach. Field measurements mentioned in the proposal were intended primarily to verify the scaling of the aerials and to resolve inconclusive aerial information. There were two reasons for this. First most landscapes are not composed of simple geometric shapes that lend themselves to measurement with a wheel or a tape. Landscapes almost always include complex curves and irregular areas. Secondly, most of the landscapes are on slopes, and measuring slope areas distorts the actual area compared to the true horizontal projection. This means that to properly

[33] In 2010 IRWD independently analyzed the irrigated area from their study homes using new photos. Their results (based only on total irrigated areas) varied from Aquacraft's by an average of +30%. Using the same new photos Aquacraft re-analyzed a random sample of lots and found that using the same photo our analyses were within 10% of theirs. To avoid under-estimating irrigated areas, we re-analyzed the outdoor results with IRWD areas scaled up 30%, in all plant types. The results in this report are based on these revised areas.

survey the area the vertical angles of all measurements must be taken, and then all of the data must be reduced and analyzed mathematically. None of this information is required from rectified aerial photos since they show the true horizontal projections, and the irregular areas can be digitized with a high degree of precision. The types of information that aerial photos sometimes lack are the actual type of plants on the ground and whether these are irrigated. Verification of these details was a primary goal of the site visits.

Five ground covers were used for the analysis, shown in Table 9. The area of the entire lot was determined from the aerial photo so that the irrigated area could be compared to the lot size as part of the analysis. This also served as a check for the scale. Non-turf plants comprised tree canopies, shrubs, and other landscape plants that were not grass. Pools were measured, and assigned a crop coefficient of 1.25. Turf and vegetable gardens were treated the same and xeriscape consisted of low water use plant materials. On several lots there were areas that appeared to be non-irrigated outlots, or parcels of native plants that had been left untouched. Since these clearly were not irrigated, they were classified as non-irrigated land and not given a crop coefficient. Hence, even though they were included in the total irrigable areas, they did not get a water allocation as part of the theoretical irrigation requirement calculation and were not included in the irrigated area totals.

Each plant type was assigned an irrigation efficiency based on whether it would be expected to have a spray or drip system. The combined factors were calculated as the crop coefficient/efficiency.

Table 9: Landscape parameters

Ground Cover	Crop Coefficient	Irrigation Efficiency Allowed	Combined Factor
Entire Lot	NA	NA	NA
Non-Turf Plants	0.65	71%	0.92
Pool or Fountain	1.25	100%	1.25
Turf	0.80	71%	1.13
Vegetable Garden	0.80	71%	1.13
Xeriscape	0.30	90%	0.33
Non-irrigated Ground	0	0	0

The theoretical irrigation requirement (TIR) was calculated for each lot using the areas for each plant type on the lots with the ET data and efficiency allowances shown above. First, the Net ETo was determined for each site based on the best available weather data. Net ETo was determined by doing daily soil moisture analyses from sample weather stations. The daily ETo and daily rainfall for the billing year were input, and only rainfall that reduced ETo either directly or via soil moisture storage was counted as effective. This excluded rainfall that fell in excess of the soil moisture capacity, soil uptake rates, or which was such a small quantity that it would not be expected to enter the root zone. In the northern sites, rainfall was found to reduce ETo by 25%, while in the southern sites the net ET was just 9% less than the gross ETo.

The Net ETo was then converted from inches to gallons per square foot using the conversion factor 1 inch = 0.624 gpsf. The area for each landscape sub-area was then multiplied by the Net ETo and the crop coefficient for the plant material. The result was divided by the allowed irrigation efficiency based on the Maximum Applied Water Allowance criteria (MAWA) for a well designed and maintained irrigation system to arrive at the TIR.[34]

The equation used for estimating the TIR for this study was:

$$TIR = 0.624 \times ET_{O\,net} \times \sum_{i=1}^{n} \left[\frac{A_i}{Eff_i} \times K_{zi} \right]$$

Where:
TIR= theoretical irrigation requirement (gal)
0.624= converts from inches of ETo_{net} (Net ETo) to gallons per square foot
ETo_{net} = reference ETo (inches) minus effective rainfall (inches)
n= number of zones in the landscape
i= individual zone
A_i= area of individual zone (sf)
Eff_i = irrigation efficiency allowance of individual zone
K_{zi}= zone coefficient for individual zone = $k_{species}$ x $k_{density}$ x $k_{microclimate}$

The outdoor water use for each lot was estimated by taking the annual water use from the billing data and subtracting the best estimate of annual indoor water use, obtained mainly from the projected indoor use from the logged data. In some cases the indoor use during the logging period did not give the best estimate for annual indoor use, for instance if no one was home during the logging period. In cases where the logged indoor use did not appear to give the best estimate of the annual indoor use, then the minimum month water use was used as a proxy for indoor use. Due to the necessary lag time between sample selection and data logging, the logging data were usually not collected in the same year as was the billing data. Since we know that indoor use tends to be stable, use of indoor data for a period different from the billing data is not a bad assumption as long as it is checked for reasonableness, as was done.

When only a single water meter is present there is no completely accurate method of separating indoor and outdoor uses. In most cases having indoor use from the flow trace analysis gives good results, but not always. Use of minimum month as a proxy for indoor use is reasonable, but especially in areas where irrigation occurs on a year-round basis it can overstate the indoor use significantly.

Independent Verification of Areas

Both IRWD and EBMUD performed independent analyses of the irrigated areas in their respective service areas using new aerial photos. In comparing the results, the overall averages and total areas were found to agree well, but there were differences in how individual lots were analyzed.

[34] There was some discussion of using irrigation efficiencies less than 0.71, but since this is the minimum acceptable efficiency in the MAWA calculations it was agreed in September 2009 to use 0.71. We recognize that achieving this may be a challenge for many older systems.

As part of the review process IRWD performed an independent analysis of the irrigated areas on the study homes from their service area. They did this by using newer photos from 2010 to digitize total irrigated areas, and also performed field verifications. Their assessment of the total irrigated areas was approximately 20% greater than the assessment performed by Aquacraft using older, lower quality photos from around 2005. In order to determine whether the differences were due to just the photos or an inherent lack of accuracy in the technique they sent Aquacraft copies of the new photos, and the analysis was repeated from the beginning. The analysts who did the measurement of areas from the 2010 photos did not see the analyzed images from IRWD, and they were not given the area totals provided from the agency. They were simply given the original field notes and told to repeat the assessment of the irrigated areas using the same methodology as used for all other sites with the new photos. This is a very important exercise, since if two analysts working from the same photos cannot generate similar results this casts doubt on the reliability of the technique of using aerial photos as a basis for measuring irrigated areas. Conversely, if two analysts generate similar results, working independently, then this confirms the reliability of the technique. The results from these two parallel analyses, compared in CHAPTER 7, lie within 2% of each other.

Pools

Pools were treated as irrigated areas with coefficients of 1.25 to allow for the evaporation from an open water surface. Including pools in this way provided them with a water allocation. Water used to fill the pool could be categorized by Trace Wizard as either faucet use (indoor) or irrigation (outdoor) depending on how the pool is filled. A low trickle fill from a float valve would normally get categorized as a faucet use, while the use of a hose to fill the pool from a hose bib would probably get categorized as irrigation, an outdoor use. To the extent that pool fill water is categorized as outdoor use, then the water used for the pool would be counted as total outdoor use, and would increase the calculated irrigation application.

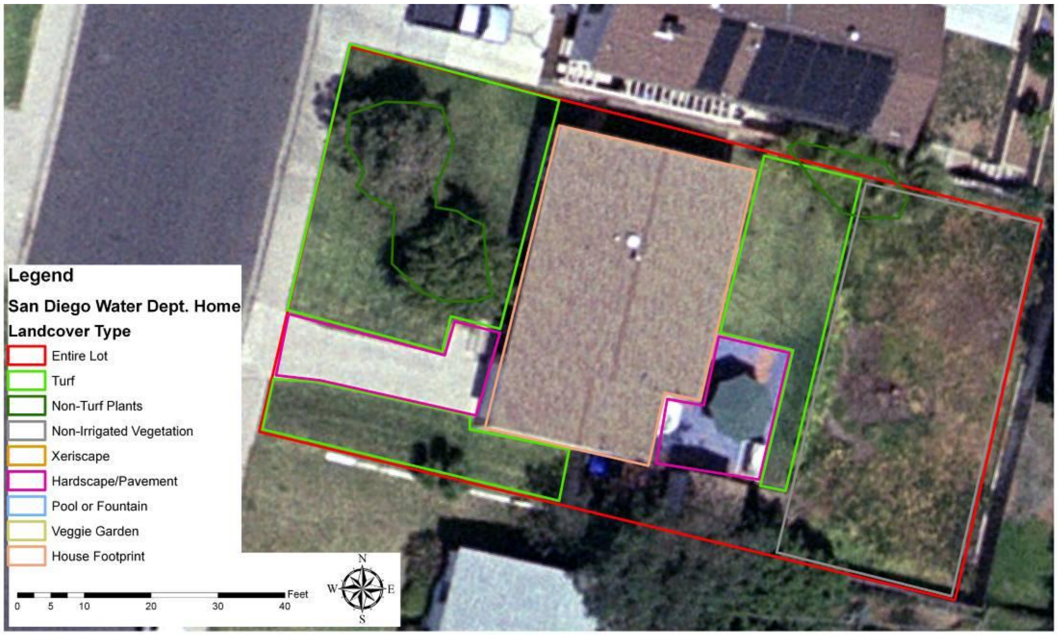


Figure 11: Typical aerial landscape analysis

Site Visits and Data Logging

After the logging groups were selected, as described in more detail in CHAPTER 6, each home was visited by a member of the research team. The site visits and logging occurred during a 22-month period from November 2006 to August 2008. The main purpose of these visits was to install the data logger on the customers' water meter. In some cases surveys with return mail envelopes were delivered as well. The homes were compared to the aerial image used for the landscape analysis in order to verify that the correct image was used. The landscape was observed in the field, and the types of landscape material present were compared to the landscape types selected by the GIS analysis to catch situations where landscape types were mismatched. This verification of the aerial photo information was performed on all of the homes visited. The main goals of the verification were to determine that the correct plant types were used, and to identify areas of non-irrigated land. In addition, measurements were made to verify the scale of the photos for example by measuring the width of the driveway so that this could be compared to the aerial data. No attempt was made to conduct detailed surveys of the landscapes because the errors introduced by the many irregularities in the landscapes, and the effects of slopes on area calculations would be much greater than those arising from the aerial photo analysis. The following table shows the approximate dates during which the site visits occurred.

Table 10: Dates for site visits and billing data

Keycode	Participant	Site Visit Dates	Year of Billing Data Used for Annual and Seasonal Analysis
11000	Davis	January 2007	2005
12000	SCWA	May 2007	2005
13000	San Francisco	December 2006	Avg. 2006, 2007

14000	EBMUD	April 2007	Avg. 2004-2007
15000	Redwood City	November 2006	2005
16000	Las Virgenes MWD	February 2008	2006
17000	LADWP	August 2008	2006
18000	IRWD	June 2007	2005
19000	City of San Diego	September 2007	2006
20000	San Diego County	November 2007	2005

The fact that many of the sites were logged during non-irrigation periods should not be a cause for concern since for purposes of this study the logging data were used primarily to quantify and disaggregate the indoor water use. Outdoor water use for each home was determined by taking the annual billed consumption and subtracting the best estimate of the annual indoor use from this value. Outdoor traces during irrigation periods would only be required for studies involving daily or hourly water use patterns, and this study was focused on annual use.

Flow Trace Data Analysis

In order to properly interpret the results of this study it is important to understand how flow trace analysis works, and consider its strengths and weaknesses. The goal of flow trace analysis is to disaggregate water use in a single-family home based on a highly precise pattern of flow over time obtained from the main water meter for the house. The key is that the main water uses, such as toilets, clothes washers, dish washers, irrigation systems, and showers in the home provide very clear flow patterns that are relatively easy to identify. Other uses, such as faucets, leaks, water treatment and pools are more ambiguous. The idea is to extract the information for the easily identified events, which leaves behind a smaller volume of water in the remaining categories. This smaller volume of water can then be analyzed statistically to examine the factors that appear to have an influence.

Flow trace is a very good tool when understood in this way, but it does involve a degree of uncertainty and random error. When one balances the information provided by flow trace analysis against the practical impossibility of sub-metering a home to provide end use information of equal detail, its value is clear. Working with flow traces and the Trace Wizard program, an experienced analyst can determine the important information related to the daily household use for the key fixtures and appliances, and can determine the efficiency levels of these as measured by their volumes of use. Water use for categories like faucets and leaks is more ambiguous since sometimes events produced by a faucet may appear to be a leak, and vice versa. This is where the information from the surveys can be used to identify relationships between household characteristic and the end use in question. This process can help clarify the factors that are probably linked to the use. For example, leak events may sometimes include very small faucet uses, intermittent flows for automatic pool filling, ice machine, or continuous flows from certain water treatment systems. By modeling leakage against the presence of pools, home water treatment, automatic irrigation systems etc., it is possible to see what factors explain increased leakage or leak-like events. Leakage estimates and can be tempered with the knowledge that in some cases what appears to be a "leak" may be a reverse osmosis system that has been left running continuously in an attempt to treat all of the water used in the home. These types of issues tend to work on the fringes of the data. The main body of information provided by the analysis is the core household water use patterns and efficiency levels for the household.

Each flow trace file obtained during the site visits was analyzed into individual water use events using the Trace Wizard software. During Trace Wizard analysis each event is characterized according to its end use, start time, duration, volume, maximum flow rate and mode flow rate. This is a stepwise process. Each trace is first checked to verify that the logged volume agrees with the meter volume. When the volumes agree then the trace can analyzed as is. When the volumes do not agree further investigation is required. In some cases the data logger records the data but the volume recorded differs from that of the meter by a small amount. These traces usually are used with a correction factor applied so that the volumes agree. In other cases the volume of the data logger and the meter volumes differ by a substantial amount. These traces are opened for inspection. In some cases the trace files may contain a few erroneous events, caused by infrequent electrical interference with the sensor, which causes extremely high flow rates to be recorded. If these are isolated events they can be removed manually during analysis, and the rest of the trace can be used. If the entire trace is contaminated with interference then it has to be discarded. In some cases the logger simply fails to record any data, in which case the trace is discarded and if necessary the site is re-logged.

After the volumes are evaluated and, if needed, correction factors applied, each of the traces with usable data is disaggregated into individual events. The Trace Wizard program contains a template of indoor fixtures and appliances that serve as the starting point for the analysis. If these templates are set up carefully they can identify many of devices on the initial calculation. The Trace Wizard program is similar to an expert system in that the analyst identifies how events should be categorized according to fixture type, and then the program uses this information to find all similar events in the trace and assign them to the chosen fixture. For example, if on Day 1 of the trace a toilet is identified that has a volume of 3.5 gallons, a peak flow of 4 gpm, and a duration of 90 seconds, these fixture parameters are adopted by the analyst. The program will then find other similar events throughout the duration of the logging period that match the first event. Each of these events is labeled as a toilet with no further intervention required on the part of the analyst.

The analyst works through the flow trace to find all of the major fixtures, assigns the fixture parameters, and verifies that the fixtures have been identified successfully by the program. When multiple events occur simultaneously it may be necessary for the analyst to identify events by inspection and separate these events manually. The analyst also identifies the first cycle of all clothes washer and dishwasher events in a trace and assigns an "@" in the name: e.g. clotheswasher@. This allows the number of clothes washer and dishwasher events to be counted, from which the gallons per load can be determined.

The analyst may need to evaluate other events on a case-by-case basis. Water treatment systems, pool filling, and evaporative cooling can have enough variability from one trace to another that it can be difficult to develop a template that contains all of the necessary parameters to identify them automatically. On-site regenerating water treatment systems may have similar patterns from one trace to the next, but it is impossible to have a template that accounts for all of the variability. Events such as these are identified through inspection by the analyst. Visual inspection may be necessary for identifying more common events as well. For example, if someone leaves a kitchen faucet running for 10 minutes while they wash the dishes it may look like a shower. In these cases classification of the event is a judgment call supported by factors such as frequency, time of day (showers are more likely to occur in the morning) and the proximity of other events (long periods of faucet use may be followed by the dishwasher).

Each water use event in the flow trace is characterized by fixture type, flow rate, duration and volume. The analysis does not however, reveal the make or model of a fixture or appliance. The efficiency of devices like toilets, showers, and clothes washers is inferred from their measured volumes or flow rates. There may, for example, be many "standard" showerheads that flow at 2.5 gpm or less. These would be classified as "high-efficiency showers" because they meet the EPAct 2005[35] criterion, which requires a flow rate of 2.5 gpm @ 80 psi.

Toilets with flush volumes of 2.2 gpf or less were classified in this report as efficient toilets, meaning that they flush at or below a volume most likely due to a ULF or high-efficiency toilet.[36] High-efficiency toilet refers to a specific model of toilet designed to flush at 1.28 gpf or less. It is possible that a number of these toilets are high volume flush units that have had displacement devices installed or modified in some way to make them flush at 2.2 gpf or less. Conversely, there may be some ULF toilets with flush volumes as high as 3+ gallons as a result of being poorly adjusted or because of a malfunction. These toilets would not be considered "efficient" in our analysis.

Following the initial disaggregation and analysis process, the trace is checked by another analyst to make sure there are no obvious errors and that events that require a judgment call seem reasonable. Once all questions are resolved, the trace is then ready for further processing, and the process is repeated on another trace. Simple traces can be analyzed in as little as 30 minutes. Analysis of complex traces may take several hours to complete. The level of complexity is normally related to the volume of water used in the home during the logging period and the frequency of events occurring simultaneously.

During the logging of the northern sites a series of traces was sent to an independent consultant, who provided analysis of the traces separately from our staff. The results of the two analyses were compared to see if there were differences that would affect the characterization of the home. While there were variations in the volumes assigned to individual events, there were no differences in how the homes were characterized with respect to toilet or clothes washer efficiencies. The results of this double blind analysis are discussed in CHAPTER 7.

Trace Wizard Identification of Common Household Fixtures

Trace Wizard analysis provides a visual tool for identifying individual events that take place during the two-week data logging period. The most common events found during trace analysis are toilets, faucets, showers, clothes washers, dishwashers and leaks. Examples of these events follow along with a description of a typical profile. While flow trace analysis is not perfect it performs very well in identifying the key household end uses. There are always ambiguous events that can be categorized differently by different analysts, and these create scatter to the results.

[35] EPAct 1992: Energy Policy Act of 1992 National Efficiency Standards and Specifications for Residential and Commercial Water-Using Fixtures and Appliances

[36] The EPAct 1992 standard for ULF toilets is 1.6 gpf

Trace Wizard is at its best in identifying anything that is controlled by a timer or a mechanical controller. These include toilets, dish washers, clothes washers, irrigation timers and water treatment regeneration systems. Fixtures that are limited by a valve or which operate in a repeatable fashion are also fairly easy to identify. The program deals with multiple events by splitting out the super-event from the base event. This covers the situation of the toilet flush on top of the shower or irrigation. It also has the ability to split out events that run into each other, but this requires the analyst to manually identify the point at which one event ends and another begins. This covers the situation where a faucet is turned on before a toilet stops filling.

The following sections provide some examples of how typical fixtures and appliances are recognized in flow trace analysis, and discuss issues encountered in dealing with each category of end use.

Toilets

Trace Wizard determines the time of day, the volume, the duration, the peak flow and the mode flow of toilet events. From this it is possible to draw inferences about what type of toilet might be behind the trace. However, this inference process is not perfect, and must be used with discretion. Trace Wizard cannot tell if a 3.0 gallon flush is coming from a malfunctioning ULF toilet or a modified high volume flush toilet.

There are also two ways of looking at toilets. From the perspective of a household efficiency study what is important is the actual volume of the flush, the distribution of flush volumes and the overall average gallons per flush in the home. From the perspective of a water agency that is interested in tracking the percent of all toilets that have been replaced, the key is the actual make and model of the toilet. The flow trace data can be helpful in making judgments about the market penetration rates, but it is inherently ambiguous when it comes to assigning actual toilet designs.

The other complicating factor about toilet analysis is that houses contain mixtures of different types of toilets. This makes it necessary to look at things like the percent of flushes at different volumes (toilet heterogeneity) in an effort to determine the mixture of toilets in the home. All of these techniques are used and discussed in the report.

Figure 12 is an excellent example of four toilet flush events (green) that take place over a two hour period and were identified using the Trace Wizard program. The program identifies flow events with similar properties including volume, peak flow, and duration. Also shown in the figure are faucet events (yellow) that have been separated from the toilet events and are not included in the toilet volume. The baseline flow (blue) has been labeled leakage. Although the flow rate is less than a tenth of a gallon per minute, it is continuous through the entire trace and accounts for nearly 1,400 gallons of water during the two week data logging period. In these cases the presumption is that these represent leaks unless there is evidence that the household has some sort of continuous use water device (e.g. for medical or water treatment purposes).

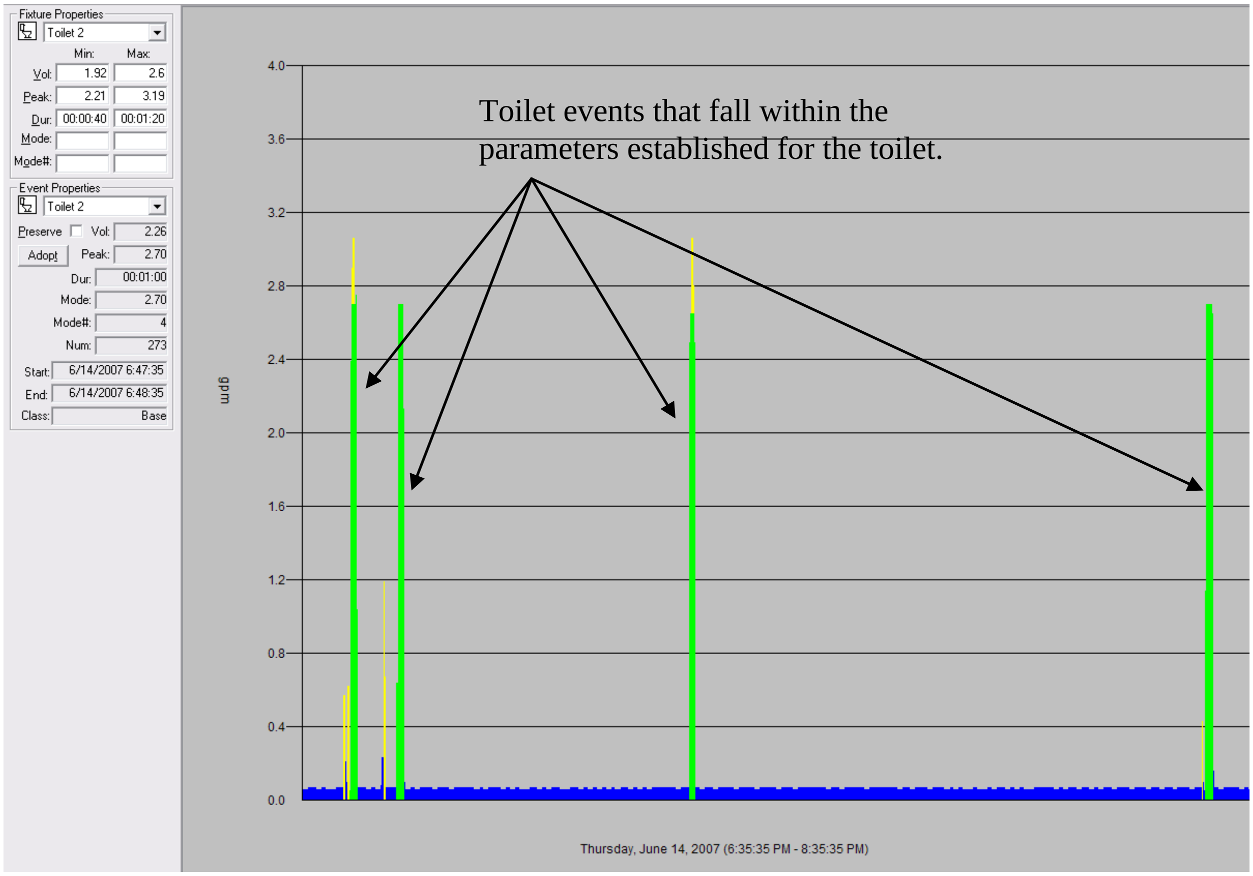


Figure 12: An example of four toilet flushes, faucet use, and baseline “leak” identified using the Trace Wizard program

It is not uncommon to find several different toilet profiles in the same residence. This may be the result of replacing only one of the toilets with a ULFT or HET, toilets of different brands in the home, flapper replacement, or the addition of a displacement device or some other conservation measure in one of the toilets. Figure 13 is an example of two different toilet profiles in the same home; two of the toilet flushes are from a ULF toilet and the other two flushes are from a high volume or high water use toilet with a flush volume of 2.7 gallons.

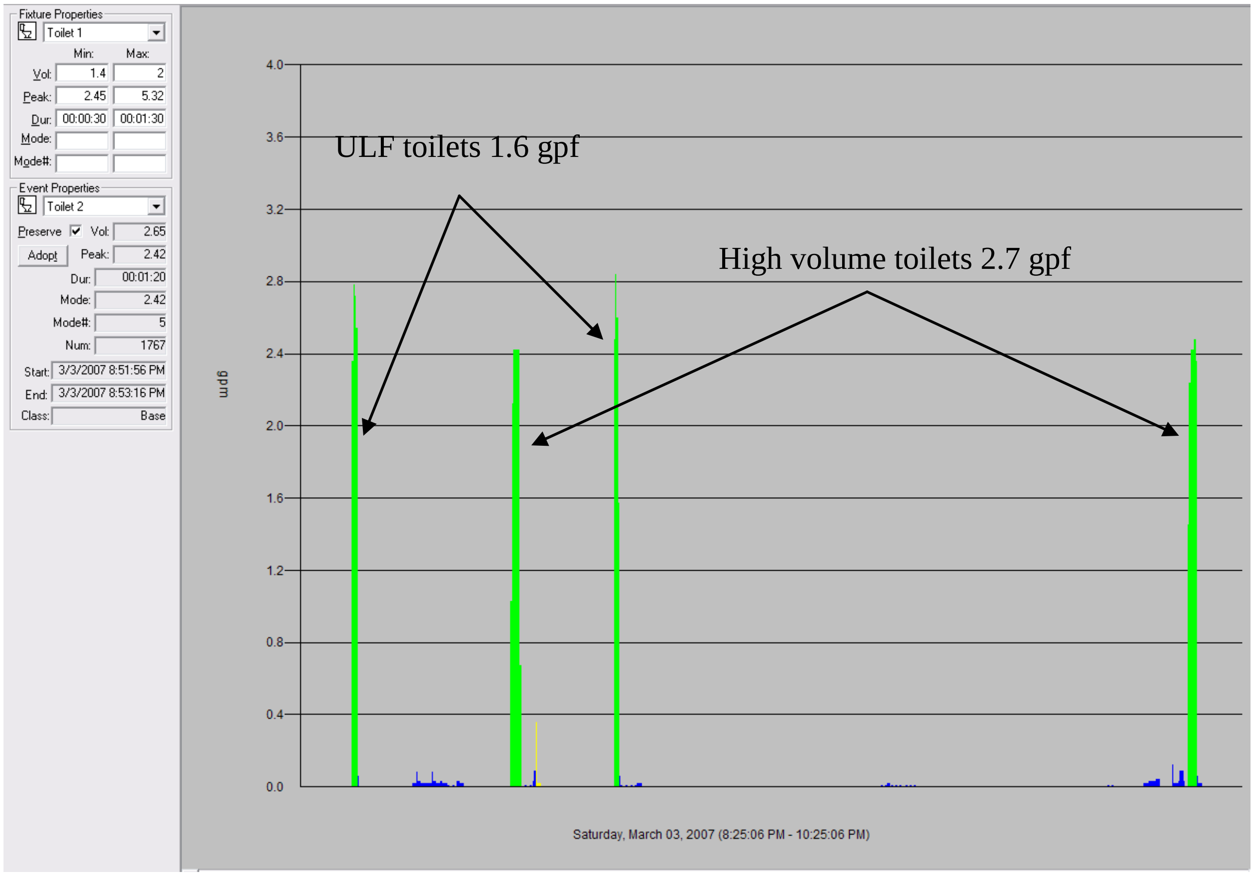


Figure 13: Four toilet flushes with two different profiles identified in Trace Wizard

Clothes Washers

Although there are many brands of residential clothes washers available, there are enough similarities in their profile to make them easily recognizable in the Trace Wizard program. Figure 14 is an example of the characteristics of a top-loading, non-conserving clothes washer, shown in light blue. Each cycle is similar in volume (22-24 gallons) and represents filling of the clothes washer tub. Cleaning and rinsing is accomplished by agitating clothing in a volume of water sufficient to submerge the clothing. The initial cycle is labeled clothes washer @ and allows the total volume of the clothes washer to be calculated for statistical purposes.

This figure also shows a typical intermittent “leak” consisting of very low flow rates going on and off during the trace period. These are most likely dripping faucets or valves that “leak” at a low rate, which are very common.

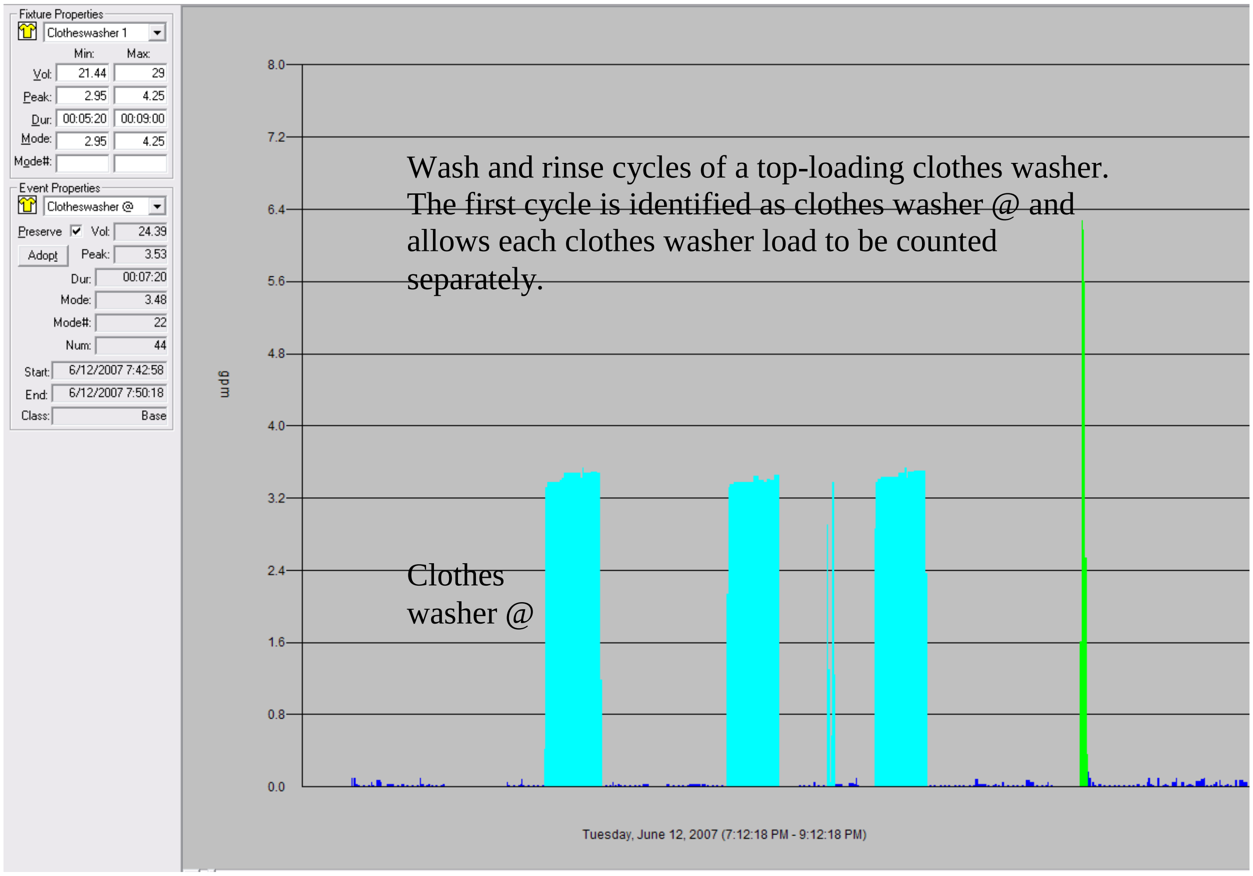


Figure 14: Typical profile of a top-loading clothes washer

High-efficiency clothes washers are designed to use less water than the standard top-loading clothes washers. They use a tumbling action that provides cleaning by continually dropping and lifting clothes through a small pool of water. The clothes washer loads, shown in light blue in Figure 15, use less than 15 gallons per load. As with a standard top-loading clothes washer, the initial cycle is labeled clothes washer @ which allows the volume of each cycle to be identified.

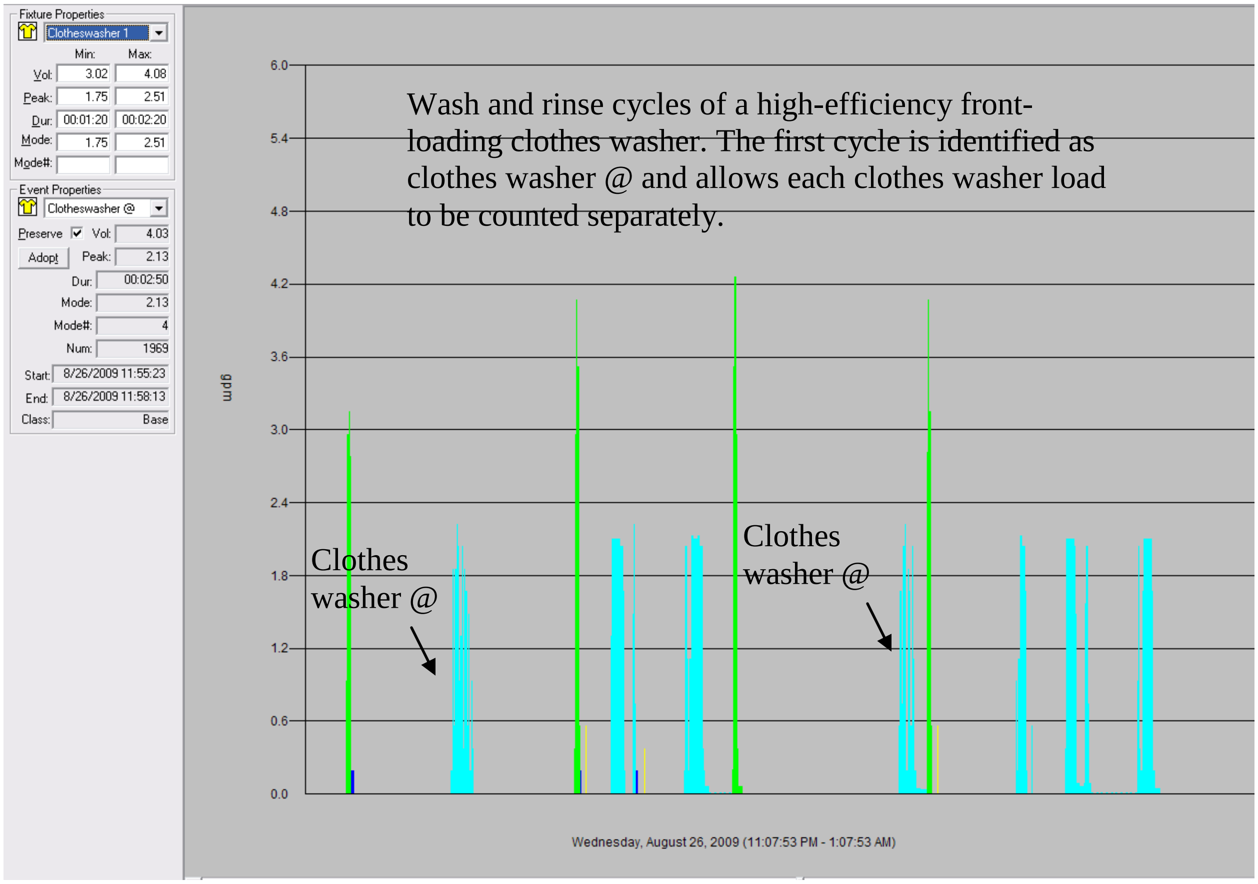


Figure 15: Typical profile of two high-efficiency clothes washer loads identified in Trace Wizard

Showers

Showers typically have one of two profiles. The profile shown in Figure 16 is representative of homes that have what is commonly referred to as a tub/shower combo, in which the shower and bathtub are operated by the same faucets. This results in a high flow when the faucets are turned on initially and the temperature is being adjusted; the diverter is then pulled and the flow is restricted by the shower head. The flow then remains constant until the faucets are turned off. The shower shown in Figure 16 has an initial flow of 5.6 gpm, which drops to 2.0 gpm for the duration of the shower. There are a number of HET toilet flush events (1.28 gpf) that occur during the two-hour time period shown in the figure, one of which occurred during the shower, and has been separated from the shower.

The second shower profile, shown in Figure 17, is typical of a stall shower where the flow goes directly through the showerhead and is therefore limited by the flow rate of the showerhead. The flow rate of a showerhead is dependent on the flow rating of the showerhead and the operating water pressure. The shower in Figure 17 is 14 minutes in duration with a flow rate of 1.7 gpm. Also shown is a clothes washer event and several toilet and faucet events.

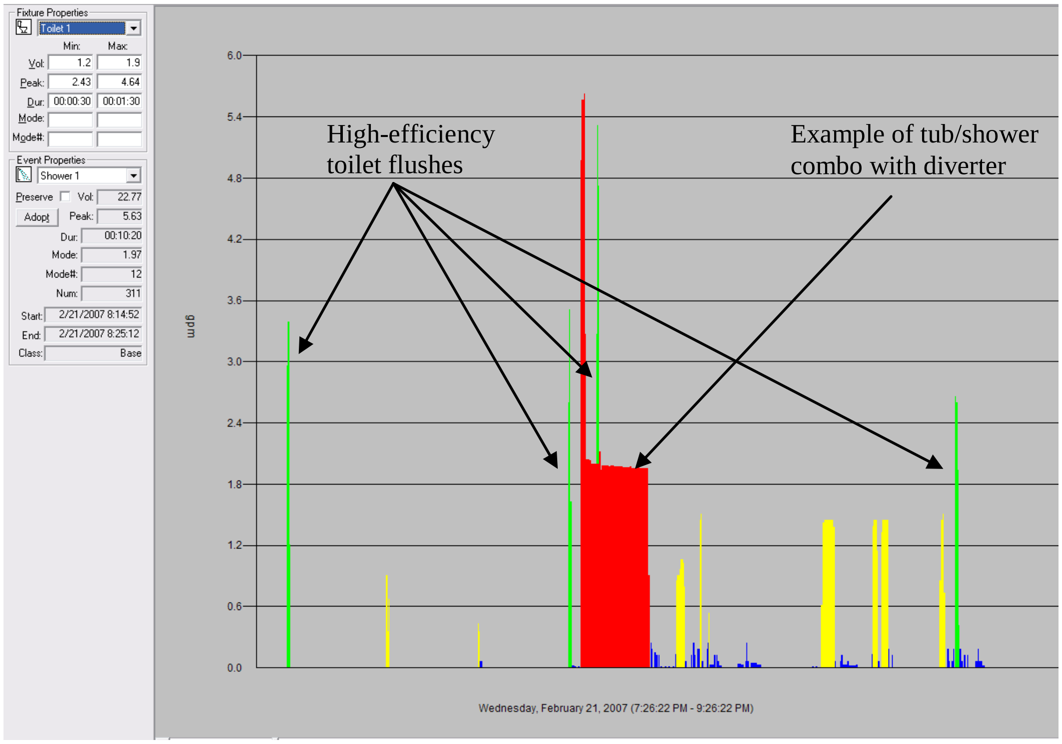


Figure 16: Classic profile of tub/shower combo with HE toilet events and some faucet use

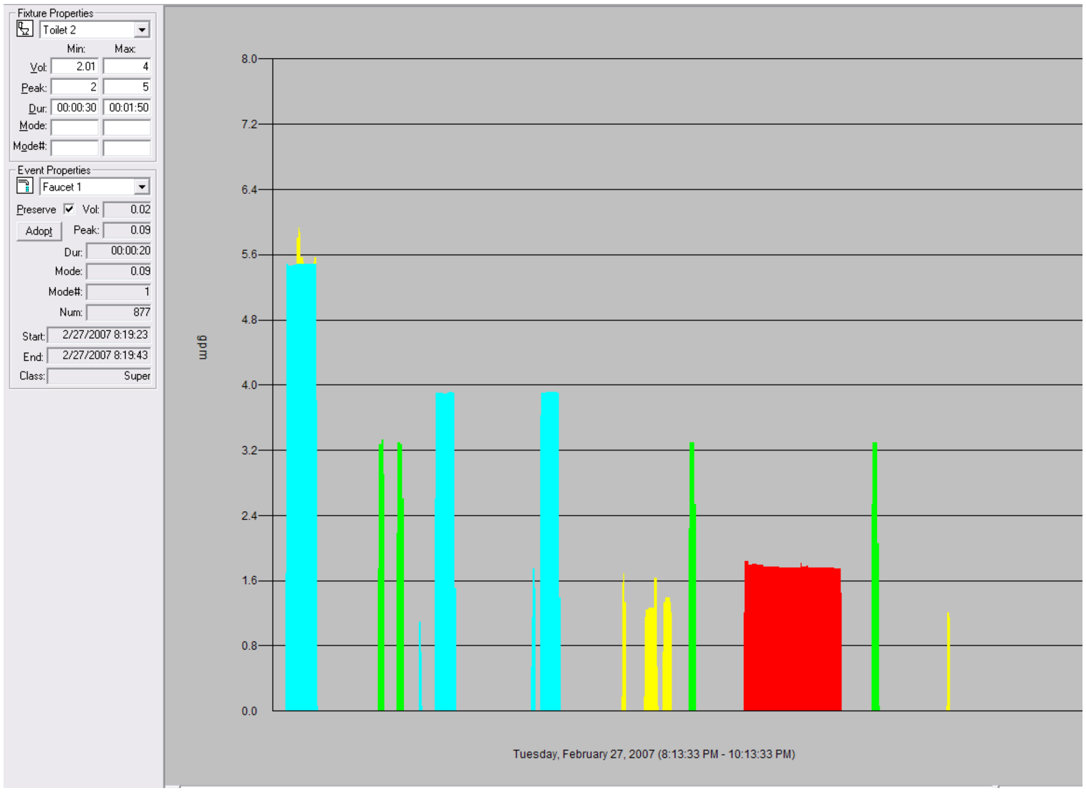


Figure 17: Profile typical of a stall shower with clothes washer, faucet, and toilet events

Dishwashers

Although dishwashers are multiple cycle events, their water use typically accounts for less than 5% of the total indoor use. Because they are cyclical and there is very little variation in the flow rate or volume of the cycles, dishwasher events are easily identifiable. And, like clothes washers, the first cycle of the dishwasher event is labeled using the @ symbol which enables the number of events to be counted. Figure 18 is an example of a dishwasher event with six cycles. Faucet use often precedes or occurs during dishwasher events as dishes are rinsed, or items are being hand washed. In the flow trace analysis the dishwasher category includes only water being used by mechanical dishwashing machines. Water used for hand-washing of dishes would be counted as part of the faucet category.

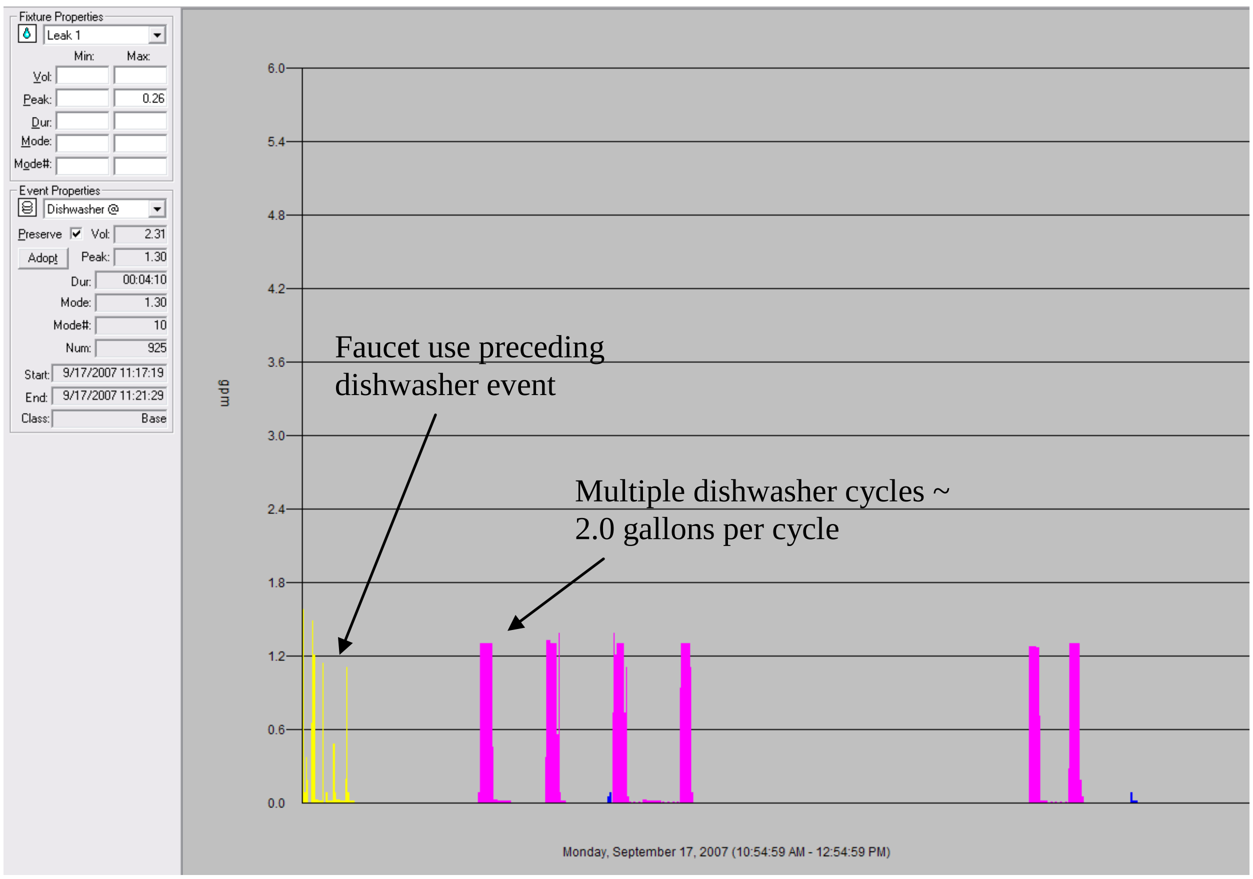


Figure 18: Multiple cycles typical of dishwasher usage

Water Treatment

There are two kinds of water treatment that need to be considered. The most common is the water softening device, which works by ion exchange. Raw water is run through a resin bed and the hardness ions (calcium and magnesium, primarily) are adsorbed onto the resin in exchange for sodium. This reduces the hardness of the water, but does not affect its total dissolved solids. Once the exchange capacity of the bed is exhausted it is regenerated by backwashing with salt water. This backwash process is the only water consumed by the process. The treated water simply flows into the water pipes for use by the occupants as needed. Figure 19 shows a typical regeneration cycle for a home water softener. These are sometime controlled with a timer and sometimes by a sensor. These types of systems are very simple to identify in Trace Wizard.

The other type of home treatment is reverse osmosis. These systems run the potable water through a membrane, which separates the water from the salt. Typically around 25% of the total water input to the system emerges as product water and 75% is wasted. Whenever water is being treated the system is using water. The flow rates are typically low, and can be mistaken for leaks. The difficulty in identifying them as water treatment as opposed to leakage is the pattern of use. If only a few gallons are produced at a time, the system will show a repeatable pattern that can be identified. For example, if once or twice a week two gallons of product water are treated for drinking and cooking this will show up on the trace as a 10 gallon event with a fairly repeatable flow rate. If the system is used to treat large volumes of water it will start to look like a continuous leak. Having survey information to identify houses with RO systems can help with this. In the modeling chapter we discuss the relationship between home treatment systems and identified leakage.

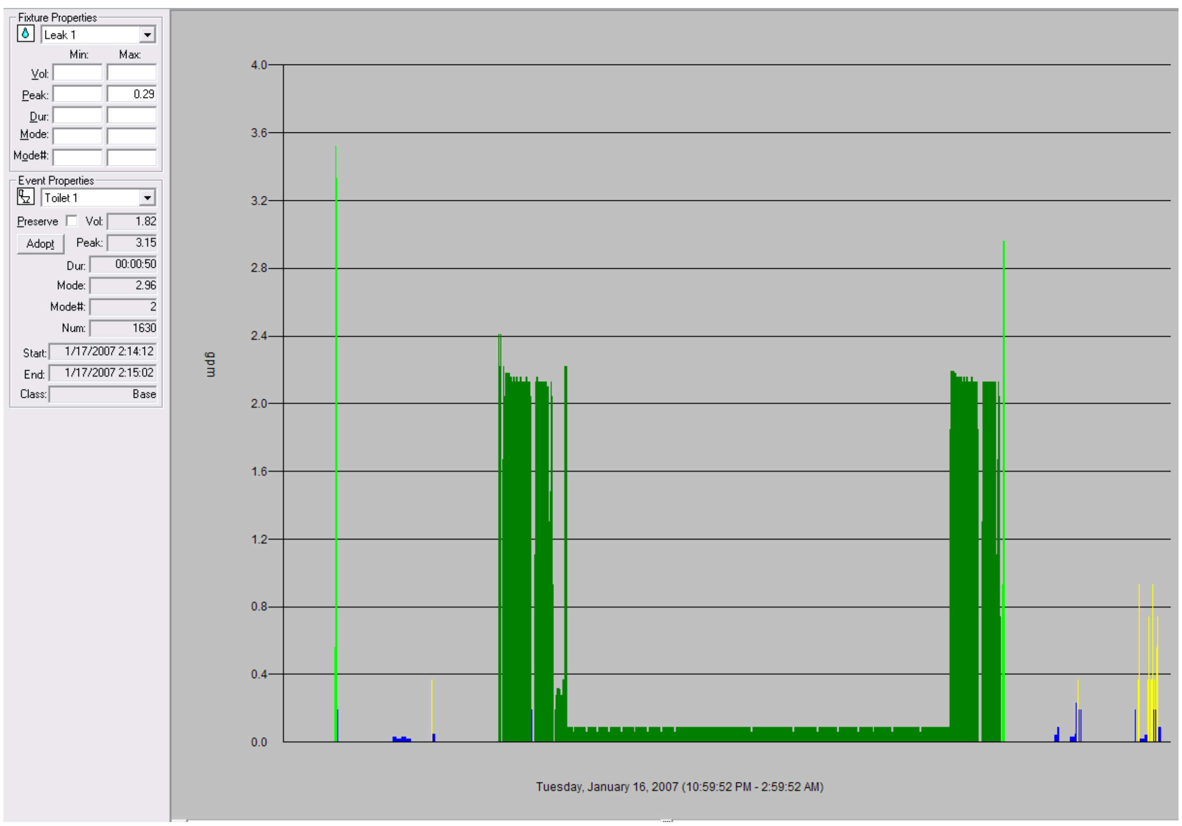


Figure 19: An example of a residential water softener in Trace Wizard

Leakage & Continuous Events

There are two kinds of leaks identified in Trace Wizard. The first type is intermittent leaks, such as toilet flappers or faucet drips and the second is continuous leaks due to broken valves or leaky pipes. Intermittent leaks are identified by their very low flow rates (too low to be faucets), association with other events that might initiate a leak, or the fact that they simply do not appear to be faucet use, and because they occur too frequently to be explained by someone standing at a sink and operating a faucet for hours at a time. Intermittent leaks are very common, and most traces contain a number of these types of leaks. The lower limit of “leak” detection is based on the ability of the water meter to register the flow. To the extent that the meters cannot register very low flows, leakage measurements would be under-estimated.

Constant leaks, on the other hand, are continuous events. In some cases these may not be leaks at all, but instead represent a device that has a constant water demand, such as a reverse osmosis system or a once-through cooler. The presumption, though, is that these are leaks. Use of survey information can be used in conjunction with the end use data to look for correlations between leakage and fixtures in the home to see if there might be a relationship that helps clarify the source of the “leak” and leak-like events. These correlations have been done in Chapter 9.

Figure 20 is an example of an event that is classified as leakage in the Trace Wizard program. Although the flow rate is quite low – averaging less than 0.5 gpm – over the 2 week period of the trace nearly 5,400 gallons were attributed to this event. Leakage is flow that cannot be easily classified as a typical fixture, such as use for toilet flushing, clothes washing, faucets, showering, irrigation, or other commonly found household use. Leaks can be attributable to malfunctioning fixtures such as a leaking toilet or irrigation system or due to process uses, such as a reverse osmosis system, evaporative cooling, or a non-recirculating pond or fountain. The cause of flow attributed to leakage may be discovered during a site visit or from information provided on the survey returned by the homeowner. Often, however, this information is unavailable, and the cause of leakage remains unknown. Since the “leak” category represents such an important part of single-family residential water use, looking further into the causes of these types of events would be beneficial.

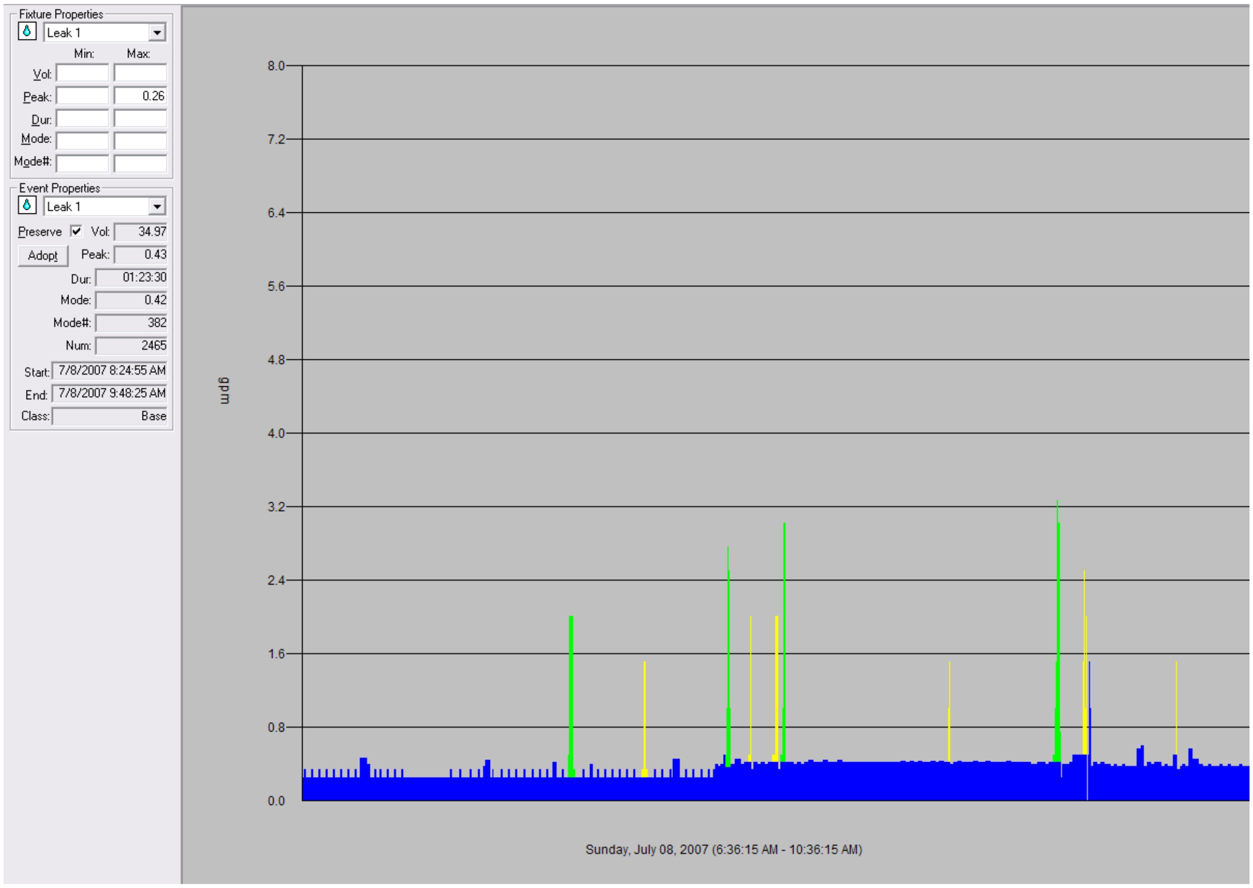


Figure 20: Four-hour period showing a continuous event classified as a leak

Irrigation

Overhead irrigation events are the easiest to identify and are usually characterized by a large event consisting of several very distinct segments, each with its own duration and flow rate as the various zone valves open and close. Automatic irrigation is generally operated by a timer device that turns on the irrigation at a set time, on specified days, and irrigates multiple zones in sequence. The flow rate for each zone varies depending on the type and number of sprinkler heads located on that zone. Figure 21 shows an irrigation event that occurs Monday, October 29, 2007 at 1:12:10 PM. The event properties show that the volume of the irrigation event is 949 gallons with a peak flow of 18.4 gallons per minute, and a duration of 1 hour and 12 minutes. This event is repeated daily throughout the duration of the data logging period. The change in flow rate occurs -seven times during the irrigation event and is indicative of different irrigation zones.

Drip irrigation is typically lower flow than overhead irrigation and may be operated manually or as a separate zone on an automatic irrigation system. Drip irrigation is generally used for non-turf type plants that require less water and less frequent watering than turf or other high water-use plants. Figure 22 is an example of a drip irrigation event with a flow rate of 2.5 gpm and a duration of 96 minutes. The total volume of the event is 190 gallons. There are several toilet flushes and some faucet use that are running concurrently to the irrigation event.

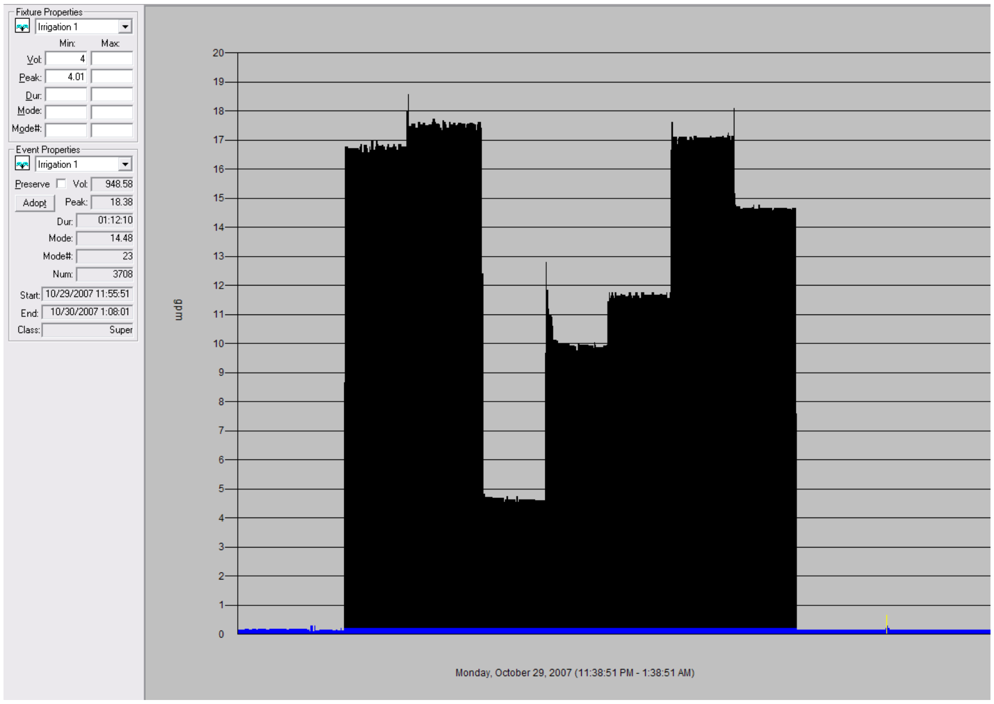


Figure 21: Irrigation event with multiple zones

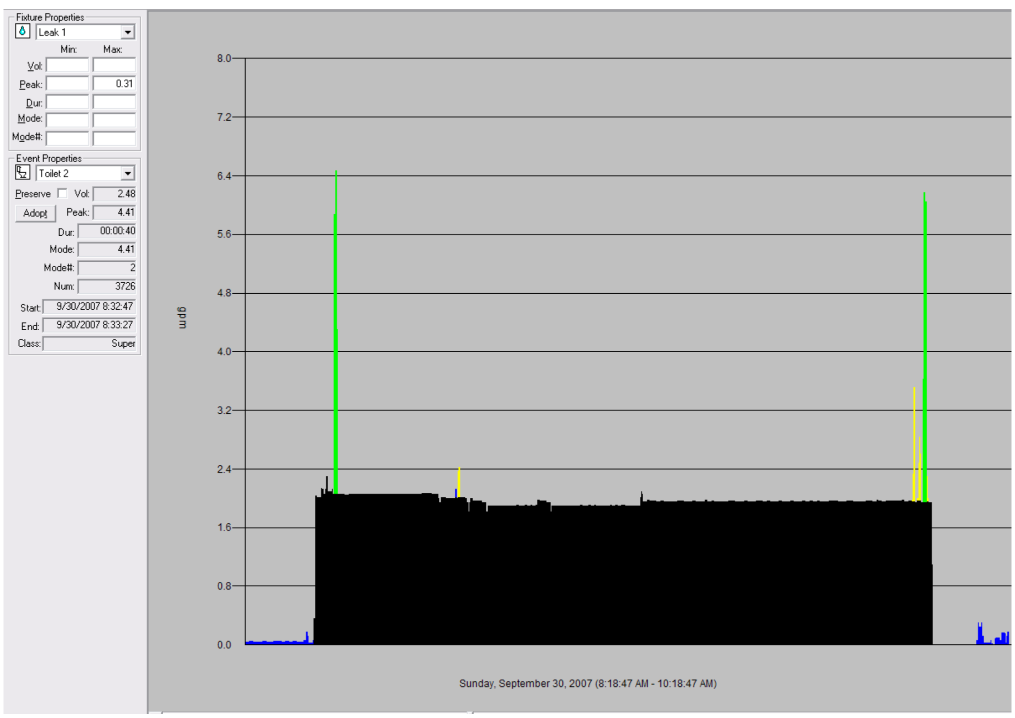


Figure 22: Trace Wizard profile of drip irrigation

The end result of the flow trace analysis is a Microsoft Access database file with a unique keycode that identifies the home. The file for each home contains one record for each water use event along with the fixture name, volume, flow rate, start time and duration. A typical two-week trace will contain anywhere from 1,500 to 10,000 events.

Faucet Use

Basically, faucet events are generally intended to identify uses for kitchen and bathroom faucets. These include a wide range of events that are similar, with flow rates less than 2.5 gpm and durations and volumes that are reasonable with respect to what one would expect from a bathroom or kitchen sink. Exceptions to this would include flows at higher flow rates that might come from a utility sink or a bath tub with a volume too low to be a bath fill. Another quality of faucet use is their irregular and random type of pattern, with fairly short durations and low volumes. Use of faucets to hand-wash dishes while leaving the water run continuously is one of the largest types of faucet uses encountered in the analysis.

Other Uses

Events that simply do not fit neatly into any other category are listed as "other uses". They might have flow rates too large for a sink, but volumes too small for irrigation or a bath. These events are set into the category of miscellaneous other uses.

Database Construction

An overall project database was assembled that contained the following items:

- Customer logging information
- Billing data
- ET data
- The water event data from all traces (~ 2 million records)
- Survey responses
- Landscape information

The customer logging information consists of names, addresses and meter information for the homes in the logging group. Billing data consisted of the monthly or bi-monthly water consumption data provided by the water agency from the billing database. These records are from either 2005 or 2006. The billing data were used to select the logging sets and to ensure the statistical similarity between the logging group and the respective populations.

ET data were obtained primarily from the CIMIS system. Both ETo and rainfall data were obtained in order to calculate the theoretical irrigation requirements for each lot using ETo and effective precipitation.

The water event data consists of the combined set of water event databases assembled from all of the valid flow traces collected in the study. In the California Single-Family study the water event database contained over 2 million individual records. The event database is very simple but extensive. It contains the following fields for each water event identified in the flow trace.

There are only a few parameters listed in the event database, but these are all that are needed to allow a wide range of analyses to be performed during subsequent stages of the analysis.

Table 11: Water event database fields

Field Name	Description
Keycode	5 digit code that identifies the study site and the home
Start	Start time of event
End	End time of event
Duration	Duration of event (seconds)
Name	End Use category of event
Volume	Volume of event
Max Flow Rate	Max flow rate of event (gpm)
Mode flow rate	The most frequent flow rate in event (gpm)
Mode number	The number of times the mode flow rate occurred during event

The survey responses were tabulated for each respondent (identified by key-code and by question number. This allowed the responses to be used as variables in the regression modeling.

Landscape information was generally obtained from the best available rectified aerial photograph of the homes in the study groups. The landscape data consisted of the total area of each landscape type on each lot. The landscape types consisted of turf, non-turf trees and shrubs, xeriscape, vegetable gardens, and non-irrigated native landscape. Swimming pools were measured, but as discussed above, were not assigned a crop coefficient. The landscape table consisted of the areas by plant type for each of the lots listed by keycode. These areas were used along with the ET data to estimate the theoretical irrigation requirements for each lot.

Each plant type was assigned a crop coefficient. In the case of tree canopies, the entire canopy was delineated, including areas that overhang the adjacent properties if the tree trunk was located on the lot. Where tree canopies occurred from neighboring trees over lawns the coefficient for the lawn was used.

Table 12: Annual Crop Coefficients

Plant Type	Crop Coefficient
Turf	0.80
Non-turf trees, shrubs	0.65
Vegetable Gardens	0.80
Xeriscape	0.30
Non-irrigated areas	0.00

Descriptive Statistics

A series of queries were designed to provide summaries for indoor and outdoor analyses. These summary workbooks were used to prepare descriptive statistics in tabular and graphical form for inclusion into this report. These queries were later linked with the survey responses and other data for regression analysis.

For the indoor statistics, the water event database was queried in order to obtain the parameters listed in Table 13. This worksheet contains a summary of the dates, durations, total volumes by end use, gallons per day by end use, counts of events by end use and volumes per event. Some are taken directly from the events database, but most are derived from the events data through various arithmetic calculations.

Table 13: Parameters extracted for indoor summary

Parameter	Units
Keycode	na
TraceBegins	days
TraceEnds	days
Trace Length Days	days
Total Volume	gal
Indoor total gal	gal
Outdoor total gal	gal
Bathtub total gal	gal
Clotheswasher total gal	gal
Dishwasher total gal	gal
Faucet total gal	gal
“leak” total gal	gal
Other total gal	gal
Shower total gal	gal
Toilet total gal	gal
Total GPD	gpd
Indoor GPD	gpd
Outdoor GPD	gpd
Bathtub gpd	gpd
Clothes washer gpd	gpd
Dishwasher gpd	gpd
Faucet gpd	gpd
“leak” gpd	gpd
Other gpd	gpd
Shower gpd	gpd
Toilet gpd	gpd
Bathtub events	count
Clothes washer events	count
Dishwasher events	count
Faucet events	count
“leak” events	count
Other events	count
Shower events	count

Parameter	Units
Toilet events	count
Number of flushes less than 2_2 Gal	count
Number of flushes greater than 2_2 Gal	count
Percent of flushes less than 2_2 Gal	%
Average toilet flush volume	gal
Toilet flush stdev	gal
Average clothes washer load gal	gal./event
Clothes washer loads per day	events/day
Average shower gal	gal/event
Showers per day	count/day
Total shower minutes	min
Average shower seconds	sec
Average Shower (minutes)	min
Average shower mode flow gpm	gpm
Shower minutes per day	min

The results from the query that prepares Table 13 consist of a table that contains one row for each keycode and one column for each of the parameters shown in the table. From this a set of descriptive statistics was developed for the key parameters, as shown in Table 14. This table shows the number of study homes with data for the specific parameters, the means, medians, standard deviations and confidence intervals of each. The range of the results and the sums of the data are also included. Not every parameter is meaningful for all categories. For example, the sum of the volumes logged is significant: a total of 3.42 million gallons of water were included in the flow traces, but the sum of the GPD is not a useful statistic. These data are discussed in detail in following sections, and are provided here simply to give the reader an understanding of the procedures used for the analysis.

Table 14: Statistics extracted from indoor summary table

Parameter	N	Mean	Median	StDev	95th CI	Min	Max	Sum
Total Volume	734	4666	3515	4098	296	0.05	28058.27	3424729
Trace Length Days	734	12.3	13.0	1.4	0.1	6	20	9009
Total GPD	734	378	292	323	23	0.01	2338.19	277220.3
Indoor GPD	732	175	157	107	8	0.01	833.25	127970
Outdoor GPD	589	243	145	289	23	0.06	1939.40	143154.6
Indoor total gal	732	2148	1898	1341	97	0.05	10832.31	1572674
Outdoor total gal	589	3019	1809	3647	294	0.84	27151.61	1778284
Bathtub total gal	393	85.4	52.4	111.6	11.0	4.91	1376.53	33568.28
Clothes washer total gal	677	408	328	313	24	16.17	2553.26	276308.1
Dishwasher total gal	444	30	23	26	2	0.65	153.04	13143.85

Parameter	N	Mean	Median	StDev	95th CI	Min	Max	Sum
Faucet total gal	729	402	320	326	24	1.57	2522.87	293153.2
“leak” total gal	732	380	141	751	54	0.05	8924.64	278057
Other total gal	421	78	14	238	23	0.18	3347.53	32881.66
Shower total gal	714	433	365	319	23	5.62	2068.87	309380.8
Toilet total gal	727	462	399	323	24	1.87	2450.05	335904.7
Bathtub events	393	4.14	3.00	4.26	0.42	1.00	40.00	1627
Clothes washer events	674	11.77	10.00	8.48	0.64	1.00	85.00	7935
Dishwasher events	426	4.56	4.00	3.70	0.35	1.00	33.00	1942
Faucet events	729	739	555	889	65	5.00	10515.00	538484
“leak” events	732	1942	1266	2328	169	3.00	25022.00	1421599
Other events	421	15.4	5.0	42.9	4.1	1.00	503.00	6491
Shower events	714	24.0	21.0	16.3	1.2	1.00	132.00	17168
Toilet events	727	169	155	100	7	1.00	628.00	122777
Bathtub gpd	393	6.9	4.2	8.9	0.9	0.41	105.89	2719.757
Clothes washer gpd	677	33.2	26.9	25.2	1.9	1.35	196.40	22469.61
Dishwasher gpd	444	2.4	1.9	2.1	0.2	0.07	11.77	1070.435
Faucet gpd	729	33	27	26	2	0.15	194.07	23907.95
“leak” gpd	732	30.8	11.4	60	4	0.01	686.51	22537.34
Other gpd	421	6.3	1.2	18.9	1.8	0.01	257.50	2660.237
Shower gpd	714	35	30	26	2	0.47	159.14	25198.87
Toilet gpd	727	38	32	26	2	0.16	204.17	27384.55
Average clothes wash load gal	677	36	37	12	1	9.58	94.00	24521.23
Clothes washer loads per day	674	0.96	0.85	0.67	0.05	0.07	6.54	643.831
Total shower minutes	716	211	178	159	12	3.67	1254.67	150808.7
Average shower seconds	716	520	497	172	13	120.77	1648.33	372203.7
Total shower gal	716	433	365	318	23	5.62	2068.87	310038.7
Average shower (gal)	716	18.2	17.3	7.1	0.5	3.52	61.49	13013.8
Avg. shower mode flow gpm	716	2.15	1.99	0.67	0.05	0.46	5.34	1536.4
Showers per day	716	1.96	1.72	1.32	0.10	0.08	10.15	1401.9
Shower minutes per day	716	17.2	14.5	12.8	0.9	0.31	96.51	12283.2
Average toilet flush volume	729	2.76	2.45	1.08	0.08	0.69	7.04	2014.0
Toilet flush stdev	728	0.64	0.53	0.39	0.03	0.02	2.86	462.7
No. of flushes <	734	75	48	85	6	0.00	570.00	54896.0

Parameter	N	Mean	Median	StDev	95th CI	Min	Max	Sum
2.2 gal								
No. of flushes > 2.2 gal	734	93	70	90	7	0.00	609.00	68184.0
% of flushes less than 2.2 gal	727	45%	44%	37%	3%	0.00	1.00	326.2
Average shower (minutes)	716	8.66	8.28	2.86	0.21	2.01	27.47	6203.4

The water event and billing databases were queried to generate the information for each of the key codes needed for the outdoor analysis, shown in Table 16.

Table 15: Parameters extracted and calculated for outdoor summary

Parameter	Units	Description
Annual use (from billing data)	kgal	Annual water use for 2006-2007
Non-seasonal use	kgal	12 x average winter use (Dec, Jan, Feb)
Seasonal use	kgal	Annual use – non-seasonal use
Trace projected indoor water use	kgal	Indoor GPHD from trace x 365
Area of lot (entire lot)	sf	Area of lot determined from aerials and checked against plat maps
Hardscape	sf	Areas of patios, decks, walks, etc.
House footprint	sf	Footprint of house
Non-irrigated area	sf	Lot areas that are pervious, but obviously non-irrigated. These were identified from the aerials and verified during the site visits.
Non-turf plants	sf	Trees, shrubs and other cultivated non-turf plants
Pool	sf	Swimming pool area
Turf	sf	Turf areas
Vegetable garden	sf	Vegetable gardens
Xeriscape	sf	Areas that are planted and irrigated with low water use plants
Annual ET	in	ET obtained from nearest weather station for year of billing data
Annual precipitation	in	Annual rainfall
Net ET	in	Gross ET corrected for effective rainfall
Indoor use (best estimate of indoor use)	kgal	Best estimate of annual indoor use from the projected flow trace data, non-seasonal use or minimum month use.
Outdoor use (best estimate of outdoor use)	kgal	Best estimate of outdoor use, from either seasonal use or annual use minus projected indoor use from flow trace
Total irrigated area (sum of sub-areas)	sf	Sum of irrigated areas above

Parameter	Units	Description
Irrigation application	in	Outdoor use/irrigated area x 1.604
Reference demand	in	Irrigation demand for 100% reference crop landscape=irrigated area x net ET
Theoretical demand	in/kgal	Demand for actual landscape based on actual areas, crop coefficients and allowed irrigation efficiencies
Application ratio		Ratio of actual application to theoretical requirement
Excess irrigation application	kgal	Actual application – theoretical irrigation requirement
Landscape ratio		Ratio of theoretical irrigation requirement to reference irrigation requirement
Excess irrigation flag	0/1	Flag to identify lots that are over-irrigating

Table 16: Statistics extracted from outdoor summary table

Parameter	N	Mean	95th CI	Median
Annual (kgal)	614	153.39	7.55	126.41
Nonseasonal (kgal)	614	95.13	5.29	77.53
Seasonal (kgal)	556	69.11	6.20	48.25
Trace projected indoor (kgal)	614	68.11	3.07	62.49
Entire Lot	614	9199.68	982.63	6840.39
Hardscape/Pavement	614	345.85	63.22	0.00
House Footprint	614	754.45	110.56	0.00
Non-Irrigated vegetation	614	629.84	704.09	0.00
Non-Turf plants	614	1980.96	186.98	1229.50
Pool or fountain	614	68.04	13.98	0.00
Turf	614	1234.04	110.08	902.81
Vegetable garden	614	5.33	3.84	0.00
Xeriscape	614	665.07	266.62	0.00
Annual ETo	614	21.46	1.86	0.00
Annual precipitation	614	14.26	1.65	0.00
Net ET	614	42.19	0.47	43.49
Indoor (kgal)	614	61.01	2.52	56.35
Outdoor (kgal)	614	92.38	7.01	66.64
Total irrigated area (sq ft)	614	3885.41	374.73	2686.30
Application (in)	607	60.94	5.70	39.28
Reference demand (kgal)	614	102.62	10.29	68.95
Theoretical demand (kgal/year)	614	89.99	6.74	65.71
Theoretical demand (in)	607	40.46	0.62	42.34
Application ratio	607	1.44	0.12	1.00
Excess application (kgal)	614	30.06	4.11	0.05
Landscape ratio	607	0.96	0.01	0.99

The data extracted for the summary worksheet was used to generate descriptive statistics provided in Chapter 7.

Regression Modeling

Multiple regression is a common statistical technique usually applied to quantify the effect of several independent variables on a dependent variable. It provides an accessible and convenient formula for predicting a dependent variable given estimates of the independent variables. Visualizing the data as a cloud of data points, the results of multiple regression (the formula for prediction) is a surface (a regression plane) slicing through the cloud of observed data.

Regression in this study serves two purposes: (1) to correct for certain variables that are known to influence water use; and (2) to broadly predict characteristics of water use for the population given fewer variables than the study sample. Correcting for certain factors is necessary to compare study sites on a level playing field. Previous research has indicated that income, price of water, and physical characteristics such as the number of residents and indoor or outdoor area influence water use. Reporting the mean water use for a number of homes based on an average number of residents (that is, without regression) is valid, but regression techniques offer a quantified relationship with quantifiable smaller error. This relative reduction in error is reported as r^2. Prediction is the second aspect noted above; the model can be used to generalize, or predict the impacts of changing key parameter on water use in the population.

Different regression models may result from the same data, especially since different software packages employ slightly different algorithms for selecting the components of regression. Since this study is based on sample data, the model design is influenced heavily by consideration for how replicable the modeling technique's results fare when used on different samples. Moreover, predictions via a regression model are useful to intermediate cases and generalizing a regression can be quite sensitive to outliers in the sample. Overall water use does contain these outliers in the sample and in the population, and a conventional approach of eliminating them is not convenient if the model is designed to predict mean population water use. However, in general, eliminating outliers does improve a regression model's performance. At the expense of higher performance measures, this study uses a very conservative design for regression parameters and elimination of outliers.

The aspect of regression that "corrects for" certain variables is intended to apply to factors with a rational relationship to water use[37]. For indoor use, the dependent variable is projected indoor use, or the expected annual indoor use using the flow trace as a representation. For outdoor use, the dependent variable is annual billed use minus projected indoor use. The first regression applied to either uses independent variables presented in other research to have a statistically significant relationship; as in those studies, a log-log transformation is used. The result of these regressions is a prediction of the effect of change in particular variable to indoor or outdoor billed use.

Regression produces a value called the residual, which for each case represents the numerical departure away from what the model predicts. The residual is a large positive number if water use exceeds the model greatly and a large negative number if the model over-predicts water use.

[37] For modeling purposes, it's important to note that these techniques work indiscriminately to whether the variable has any rational relationship at all. The number of available variables is indeed quite large, growing out of a combination of billed use, structural data from assessors, aerial analysis, flow trace data, localized historical weather, and survey responses.

Dividing the sample into categories (along categorical variables), ANOVA (or t-tests, a dichotomous case of ANOVA) on the mean residual for each category are reported as the change in water use associated with that variable, along with test significance.

Using data from all of the sources, regression models were prepared for both indoor and outdoor water use. Indoor models were first prepared for total indoor use as a function of all of the survey data that could reasonably be thought to affect indoor use. These variables were screened to determine which were statistically significant, and a final model was selected for analysis. Individual indoor use models were created for each end use in order to determine if impacts could be detected for variables that did not appear for the total indoor use. This sometimes resulted in additional variables being identified as significant. For example, whether the occupants knew how much water they used the previous year, or considered the cost of water in their water use, decisions could not be identified as a significant variable for predicting overall indoor water use. When just faucet use was modeled, however, it was found to be significant.

Discussions of Statewide Implications

The study concludes with a discussion of the implications of the findings for statewide water use. This discussion looks at the water savings potential identified for the study group, considers how best to extrapolate the results to the state as a whole, and then make projections of the water conservation potential for the state as a whole based on the results of the study group. The discussion includes comments on the success of past conservation programs and BMPs for reducing water use, and suggestions for future modifications to conservation efforts.

CHAPTER 6 – END USE STUDY GROUPS

There were three main sources of information used for the study: the monthly billing data obtained from the agencies, customer surveys, and the field visits. The primary purpose of the field visits was to install a data logger to create a two-week flow trace. These traces capture end use patterns in the home. A second purpose of the site visit was to verify data. The field technician verified type of landscapes assigned to the parcels. It generally proved impossible to determine the make and model of the irrigation controllers, since people were not home when the loggers were installed and the controllers were inaccessible. So this information and the presence of sensors were obtained from the surveys. At the end of the two-week logging period, staff returned to collect the loggers.

Logging samples were determined by the following procedure: each of the 10 participating utilities provided a random sample of the annual water consumption data for 1,000 single-family water accounts (Q1000). Approximately 70 single-family customers were selected from these lists. These included 60 homes for logging and 10 homes to be used as replacements if one of the original sites was not logged. Sites were not logged in cases where logging was not feasible, such as a filled meter pit.

It was verified that study samples represented the general population in terms of water use. This means the key criterion for creating samples was matching the water use of study participants to that of the population as a whole. For samples to be valid, both the mean and the median, which is less sensitive to outliers, had to be comparable to the mean and median of the population. The water use statistics of both sample groups were compared to the population to ensure similarity.

Redwood City

Using the selection procedure described above, the Redwood City staff provided the descriptive statistics for their entire population of single-family homes, and then identified a random group of approximately 1,000 homes from which the logging sample was selected. Table 17 shows the summary statistics for the three groups of homes. Records were extracted for a total of 15,777 single-family accounts in the Redwood City service area. The average annual consumption of the entire population was 101 kgal. The median annual consumption was 88.3 kgal. The statistics for the 1000 home sample (Q1000) matched those of the population very closely, as shown in the table. A total of 70 homes were selected from the Q1000. Houses with less than 15 kgal/yr of consumption, houses which declined to participate, and houses that were found to be unusable in the field—for instance because of a bad meter or vacancy—were trimmed from the sample. The final group of 60 homes on which loggers were installed had an average annual use of 106 kgal and a median use of 98 kgal. Elimination of the houses with very low or only partial year consumption caused the mean of the logging group to be slightly larger than the mean of the population, but was thought to constitute a more meaningful sample because of this trimming.

Table 17: Annual water use statistics for Redwood City study group

Redwood City	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	101.09	101.66	105.89
95% Confidence Interval	1.04	4.10	13.45
Median	88.26	88.26	98.36
Count	15,777	1,046	60

Even though the sample was not selected on the basis of geography, it covers the entire service area of Redwood City with remarkable consistency, as can be seen in Figure 23. According to the commercial mapping program used for locating the study homes[38] there are a total of five populated zip codes in Redwood City. The logging sample contains homes from all of these. Table 18 shows the number of homes randomly selected from each zip code and the average annual water use of these homes. Zip code 94061 contains the most homes that are closest to the median water use of the population. It also has the most logging homes within its boundaries. The largest water use was in zip code 94070, and there was a single home selected from this area. According to Zillow™ the average home value in the study group was $977,916 and the median value was $927,022.

Table 18: Zip Code Distribution of Redwood City Logging Sample

Zip Code	Log Sample			Population (Q1000)	
	N	Avg. kgal/yr	Percent of Total Sample	N	Percent of Total
94061	26	89.5	43.3%	447	42.7%
94062	19	123.1	31.7%	299	28.6%
94063	4	120.0	6.7%	123	11.8%
94065	10	107.7	16.7%	167	16.2%
94070	1	130.2	1.7%	7	0.7%
All	60	105.9	100%	1046	100%

[38] Delorme, Street Atlas 2006 Pro.

Figure 23: Location of study homes in Redwood City

San Francisco

The San Francisco Public Utilities Commission provided a complete list of all of their single-family accounts and annual water consumption for 2005. Customer name and contact information was not included in this list to protect the confidentiality of the customers. Also, records were only provided for customers with magnetically driven water meters. There were 61,615 accounts in the list provided by SFPUC. Their average annual water use in 2005 was 59 kgal, or 161 gallons per day per account. According to the census data there are 2.7 persons per house in San Francisco, which implies a per capita use of 59 gpcd. This relatively low total water use indicates that irrigation and other outdoor uses is not a major factor for the city customers in general.

The single-family account list provided by SFPUC was used to select the Q1000 sample using the random stratified sampling approach described above. The list of account numbers was sent to SFPUC, and they returned a list of 1000 accounts with addresses and other customer information. Aquacraft took the Q1000 data and after eliminating all accounts that used less than 15 kgal per year, selected 70 accounts as the logging sample. The analysis of the monthly water use of the Q1000 sample confirmed the low outdoor use for the customers, and showed that on average, the group used only 10 kgal per year for seasonal uses.[39] Summary statistics for the population and logging sample are shown in Table 19.

Table 19: Annual water use for San Francisco study group

	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	65.1	64.0	69.2
95% Conf. Interval	0.37	2.72	9.34
Median	56.1	56.1	56.1
Count	52,349	825	60

Table 19 shows that the final 60 home logging group was only slightly biased towards larger than average water users. The average water use for the logging group was approximately 8% greater than the use of the population. This variation was not considered a problem since it is impossible to control who drops out of the study. During the data logger installation process a choice was made to eliminate some homes in semi-industrial areas, which the City did not believe were representative of the customer base, in favor of more typical single-family homes. The location of the houses in the logging group is shown in Figure 24.

[39] Seasonal use was estimated as the difference between the annual use and non seasonal use estimated from average winter consumption.Seasonal use in accounts where this resulted in a negative number was set to zero.

Figure 24: Location of study homes in San Francisco

A visual inspection of Figure 24 shows that there is a cluster of homes in the southern portion of the city, primarily in zip code 94112, which is the Ingleside neighborhood. Normally, the random stratified sampling approach yields fairly well distributed samples according to the density of the homes and average water use in each area. In order to explore whether or not the sample in San Francisco had somehow yielded a disproportionate sample from zip code 94112 some analyses were done to check for differences between the population and sample.

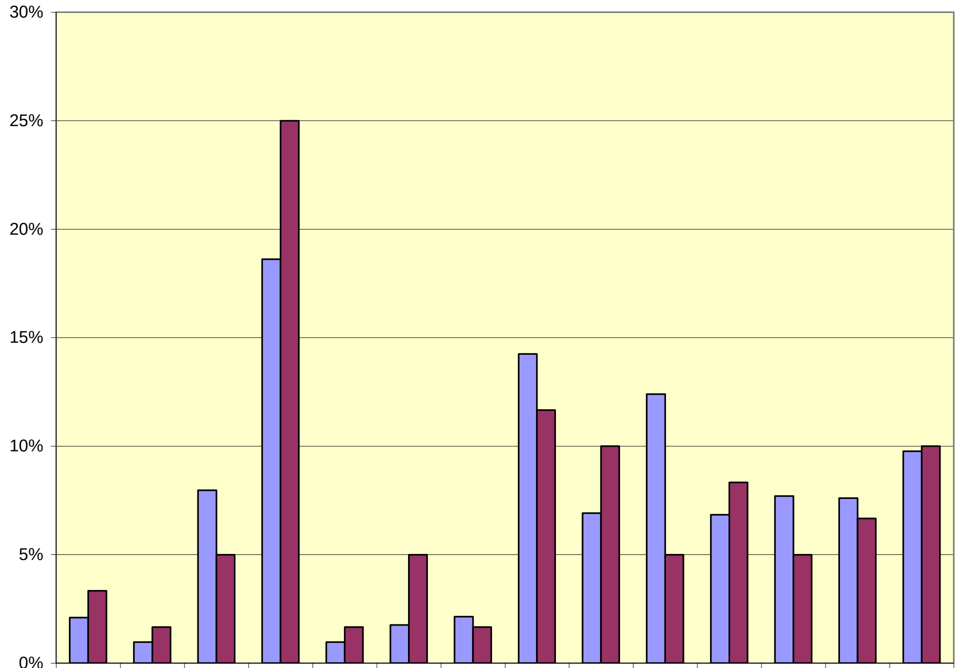
First the number of logging homes in each of the zip codes in San Francisco was determined. The percent of the logging sample was then calculated by dividing the sample in each zip code by 60. Also the average annual water use of the sample homes in each zip code was determined. This information was then compared to housing information obtained from the 2000 U.S. Census. These comparisons are shown in Table 20.

Table 19 shows that in most cases the percent of the logging homes in each zip code comes reasonably close to the percent of all single-family homes contained in each zip code. For example, Ingleside contains 17,204 single-family homes, which equals 19% of all the single-family homes in the city. This is the largest number of single-family homes in any of the zip codes. Consequently one would expect that the logging sample would have the highest concentration of homes in Ingleside, which it does. The second largest concentration of homes is in the Sunset district, zip code 94116. Sunset contains 14% of all single-family homes in the City, and 12% of the logging sample are in this zip code. Figure 25 shows the comparisons in percentages for each zip code.

Examination of Figure 25 shows that there was a striking similarity in the percentage of homes in the logging sample and the population. This argues against any gross bias in the sample. The two zip codes with the most divergence are 94112, which had a 6% greater number in the sample than in the population, and zip code 94122, which had a 7% lower number in the sample than in the population. Every other zip code was within a few percent.

Table 20: Comparison of single-family home distributions in population and logging sample for San Francisco

		Log Sample			Data from 2000 U.S. Census			
Zip	Neighborhood	Number of SF Homes	Mean Annual Use (kgal)	% of Total in Log Sample	Total of All Housing	Total SF Houses	% of Homes that are SF	% of total SF in each zip
All	All	60	70.10		242,429	92,424	38%	
94107	North Portero	2	57.97	3%	9,705	1,942	20%	2%
94109	Nob Hill	1	32.91	2%	36,038	894	2%	1%
94110	Mission	3	73.55	5%	26,913	7,364	27%	8%
94112	Ingleside	15	73.45	25%	20,699	17,204	83%	19%
94133	Ghirardelli Sq.	1	163.81	2%	14,810	898	6%	1%
94114	Castro	3	59.84	5%	17,324	1,627	9%	2%
94115	Western Addition	1	43.38	2%	18,452	1,980	11%	2%
94116	Sunset	7	47.34	12%	15,420	13,172	85%	14%
94121	Richmond/Pt. Lobos	6	77.42	10%	18,052	6,390	35%	7%
94122	Golden Gate Park S.	3	119.93	5%	22,371	11,458	51%	12%
94124	Bayview/Hunters Pt.	5	72.71	8%	9,508	6,319	66%	7%
94127	Mt Davidson	3	72.31	5%	7,834	7,121	91%	8%
94131	Diamond Hts.	4	46.94	7%	14,261	7,029	49%	8%
94134	McLaren Park	6	70.19	10%	11,042	9,026	82%	10%



	94107	94109	94110	94112	94133	94114	94115	94116	94121	94122	94124	94127	94131	94134
Percent of SF in Zip	2%	1%	8%	19%	1%	2%	2%	14%	7%	12%	7%	8%	8%	10%
Percent of Sample in Zip	3%	2%	5%	25%	2%	5%	2%	12%	10%	5%	8%	5%	7%	10%

Figure 25: Single family home percentages in San Francisco zip codes and log sample

The question arises as to whether the logging sample should have been adjusted to eliminate the geographical clustering. For example, if we took four houses out of the Ingleside zip and put them into the Golden Gate South zip, the samples in those two zip codes would match the population very closely. The problem with doing this is that the average water use in zip code 94122 is nearly 60% greater than that in zip code 94112. By attempting to balance out the geographic distribution, we would have increased the bias towards larger water users in the sample. Since the stated goal of the sampling was to create a sample that represented the water use pattern of the service area, and the sample as selected accomplished this goal, but with a slight bias towards higher water users, it seemed advisable to keep the sample as it was chosen.

Another factor arguing in favor of keeping the sample as selected is that it is probable that the water use in zip code 94112 was less variable than that in 94122 because it was smaller, and hence had less outdoor use, which is more variable than indoor use. Zip code 94112 contained a large number of homes with water use close to the average for the group. When this occurs it tends to create a cluster in the sorted list, and hence these homes will have a greater chance of being selected than a group with greater variability. Greater variability would tend to scatter the residents among more strata and favor them being sampled less frequently.

We know that the sample as chosen matches the water use distribution very well, and matches the geographic distribution well with small discrepancies in just two zip codes. Furthermore, we know that if we adjusted the sample to include more homes in Golden Gate and fewer in Ingleside we would definitely create a larger bias in the annual water use patterns it seems most reasonable to keep the sample which matches the annual water use characteristics, and not attempt to make adjustments on the basis of geography.

City of San Diego

The City of San Diego purchases between 75 and 90 percent of its water from the San Diego County Water Authority. In 2005 there were a total of 270,526 customer accounts served by San Diego Water Department. Of these, 245,995 were residential connections (217,893 single-family and 28,102 multi-family). Single-family water use accounted for 38% of total demand.

Because San Diego is a major population center, the logging sample size was 120. This was evenly split between city and county customers. There were 60 samples in the City of San Diego.

In order to generate statistically valid results, the surveyed sample and the logging sample needed to be representative of the water use of the population. For this reason, the samples were chosen so their water use closely matched the mean water use of the population. The mean annual water use of the population was 114 kgal. The mean water use of the surveyed sample was identical to the mean use of the population. The logged sample also had comparable water use at 115 kgal. Table 21shows the mean water use for the population, survey sample and log sample.

Table 21: Annual water use statistics for the City of San Diego study sites

City of San Diego	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	114	114	115
95% Confidence Interval	NA		
Median	NA	98	105
Count	217,893	842	66

Geographic distribution was not a criterion for sample selection; water use was. However, the distribution of sites in the City of San Diego area (Figure 26) shows that the sites were spread over the service area.

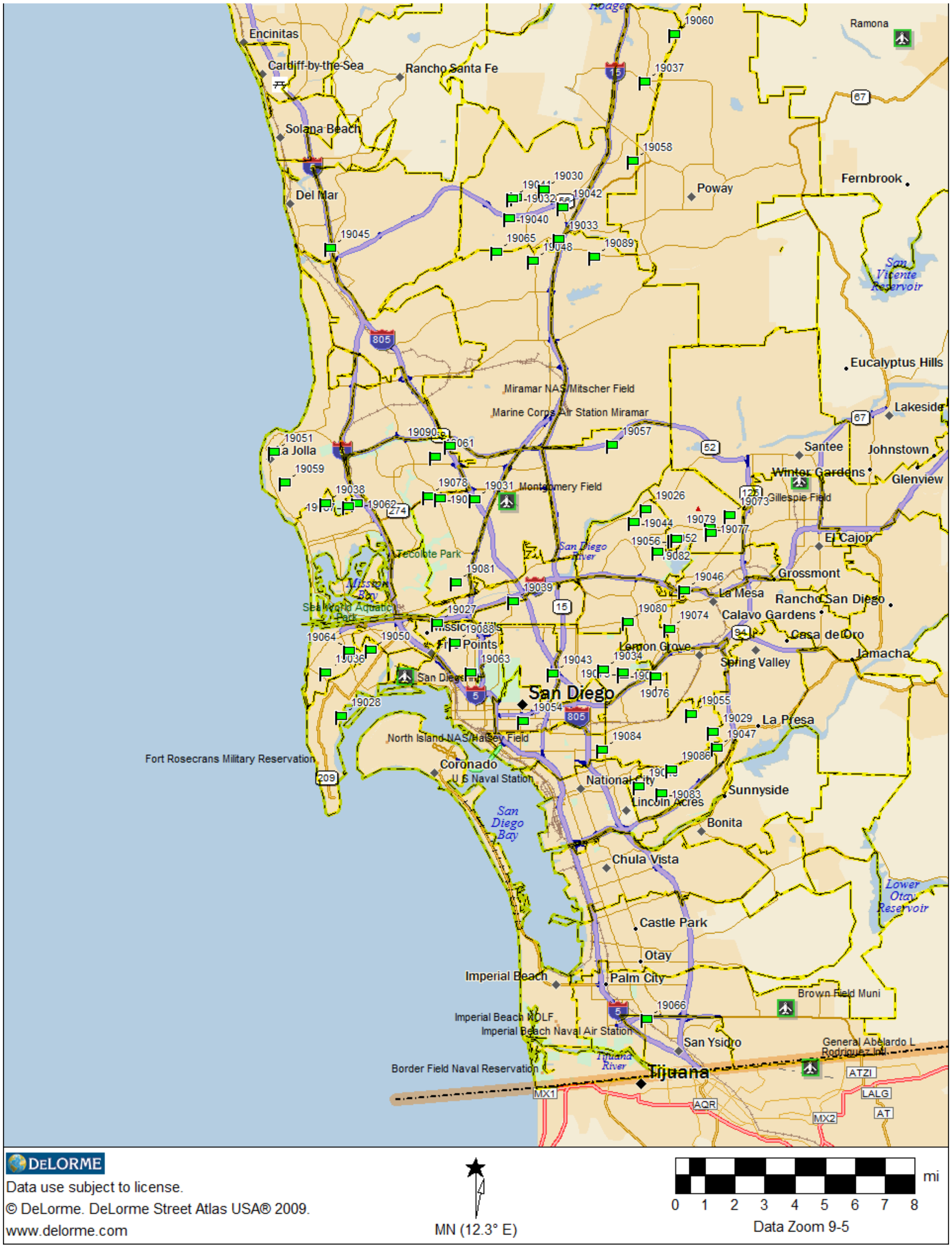


Figure 26: Logged sites in the City of San Diego service area

Las Virgenes Municipal Water District

Las Virgenes Municipal Water District (LVMWD) provides water service to a population of 71,000 over a 122 square mile service area. Of its 19,877 service connections, 17,016 are for single-family accounts. Sixty-six sites were logged in Las Virgenes with 59 good traces resulting.

Samples were created to ensure that the study sites had water use similar to the overall population of Las Virgenes. The mean water use for the population was 392 ±5.9 kgal, at a 95% confidence interval. The surveyed sample shows some variance with this (410 kgal) but the logged sample's mean water use equals the water use of the population. The median water uses do not match as well. The logged sample had a median water use of 372 kgal, while the population median use was 292 kgal. Table 22 shows these data.

Table 22: Water use statistics for population and samples in Las Virgenes

Las Virgenes MWD	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	392	410	392
95% Confidence Interval	5.9		
Median	292	312	372
Count	17,016	1,061	66

Water use was the metric for determining that the logged sample was representative of the population. However, geographic distribution of the logged sample sites should also be noted. Figure 27 shows the location of logged sites. These sites are not clustered but rather spread throughout the populated service area.

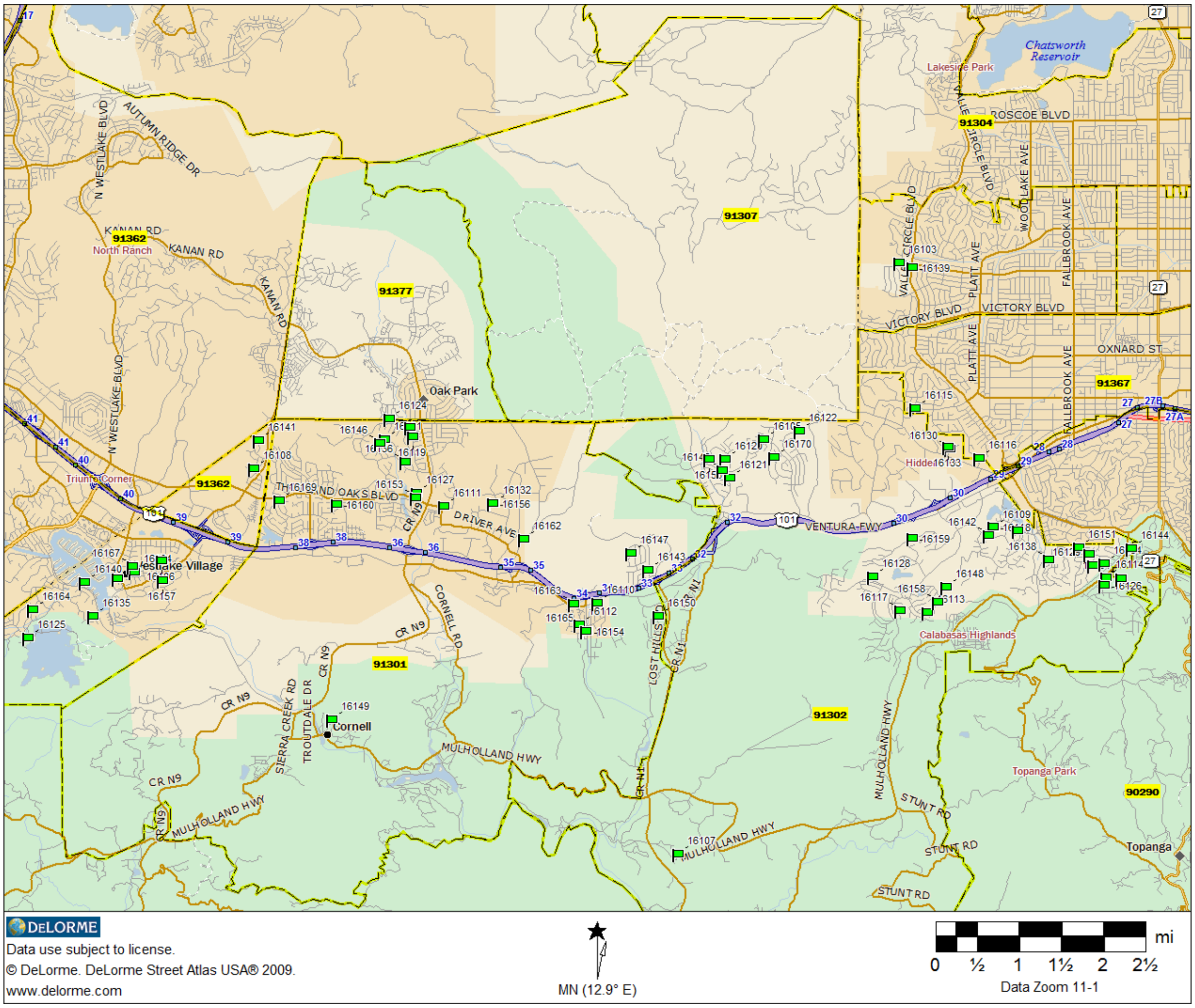


Figure 27: Logged sites in Las Virgenes MWD. Note that sites are distributed throughout several zip codes.

City of Davis

The City of Davis is located in Yolo County near Sacramento. For purposes of the sample it was used as a proxy for Sacramento County, due to its proximity. Single-family residences make up 88% of all of the services in the City of Davis and they account for 47% of the treated water use. Residential customers account for nearly two-thirds of total water use in the system. These homes were used to select the logging homes in Davis. The study sites were determined by matching the water use patterns of the population of single-family homes in the service area. Each of the homes had been mailed a survey and a letter requesting permission to participate in the study. The final logging group was selected from homes that had returned surveys and given their consent.

There were 73 sites selected for possible logging. Of these, 60 sites were actually logged, which matches the target number of sites for Davis. Single-family homes using less than 15 kgal per year were excluded. This figure was used to remove sites with unusually low use (such as accounts that were active for only part of the year). This sample was randomly selected from the sample provided by the water agency. The mean use for the City of Davis' population is in the range of 156.33 to 159.67 kgal annually, with a 95% confidence. The intermediate sample, which contains 1015 accounts, has a mean annual use of 159 kgal, which falls within likely range of the population mean. From this sample, Aquacraft selected sites for logging. The mean annual use of these sites was 160 kgal. This is just outside the 95% confidence bound for the population's water use. Table 23 makes for quick comparison of these numbers.

Table 23: Annual water use statistics for City of Davis study sites

City of Davis	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	158	159	160
95% Confidence Interval	1.67		
Median	142	142	141
Count	13,194	1,015	73

The logging sample was determined by creating a sample that had water use in line with the population of Davis. The location of samples within the city was not a determining factor. However, given that, the samples showed a relatively wide distribution throughout the city. Figure 28 shows the logging sample sites in Davis. To some degree, sites are more densely concentrated in the eastern portion of the city.

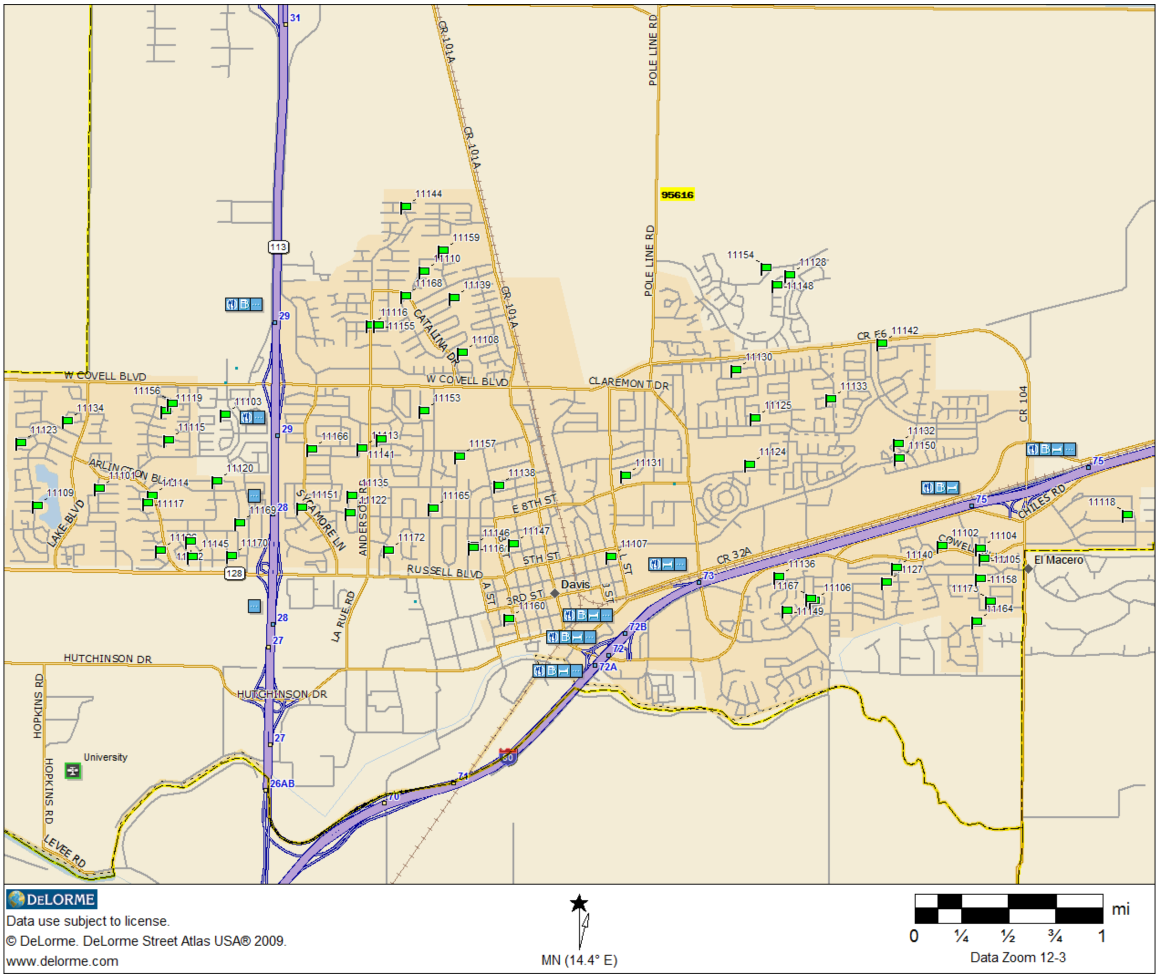


Figure 28: Distribution of logging sites around the City of Davis

San Diego County Water Authority

In 2005 there were approximately 694,995 customer accounts in the service area of the San Diego County Water Authority (SDCWA). Of these, 396,311 were single-family accounts. Single family water use makes up 55% of total demand.

The San Diego County Water Authority provides water to the City of San Diego, as well as other water retailers in the county. Both the City of San Diego and SDCWA participated in this study. Four other water retailers participated from the county: Helix WD, Otay WD, Rincon del Diablo MWD, and Sweetwater Authority. Because San Diego is a major population center, the logging sample size was 120. This was evenly split between customers within the City of San Diego and those outside the city, but still within San Diego County. The study plan called for 15 sites from each of the four participating SDCWA agencies to be included in the final analysis. Twenty potential logging sites were selected in case some sites were deemed infeasible for logging.

Samples were deemed representative if their water use matched the population water use for the given agency. For Helix, the mean water use (151 kgal) of the logged and surveyed samples was equal to the population's mean water use. The median water use for the population, surveyed sample and logging sample were also very close. Otay's surveyed sample had the same mean use as the population. The logged sample's mean water use was within the 95% confidence interval of the population's mean use. For Rincon del Diablo, both the surveyed and logged samples' mean water use exactly matched the population's mean water use. For Sweetwater, the surveyed sample, provided by the utility, had a significantly higher mean water use than the population. However, this was corrected in the logged sample, which had the same mean and median water use as the population. Table 24 shows these data.

Table 24: Annual water use statistics for San Diego County Water Authority – study sites

San Diego County Water Authority	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Helix			
Mean	151	151	151
95% Con. Inter.	1.1		
Median	122	122	118
Count	45,401	251	20
Otay			
Mean	161	161	159
95% Con. Inter.	3.08		
Median	129	129	134
Count	10,794	251	20
Rincon del Diablo			
Mean	184	184	184
95% Con. Inter.	4.4		
Median	131	131	114
Count	5,848	254	20
Sweetwater			
Mean	125	167	125
95% Con. Inter.	1.55		
Median	105	142	100
Count	22,170	252	20

Sample sites were selected based on water use, not geography. However, Figure 29 shows that the sites were spread throughout the service areas in a fairly even manner.

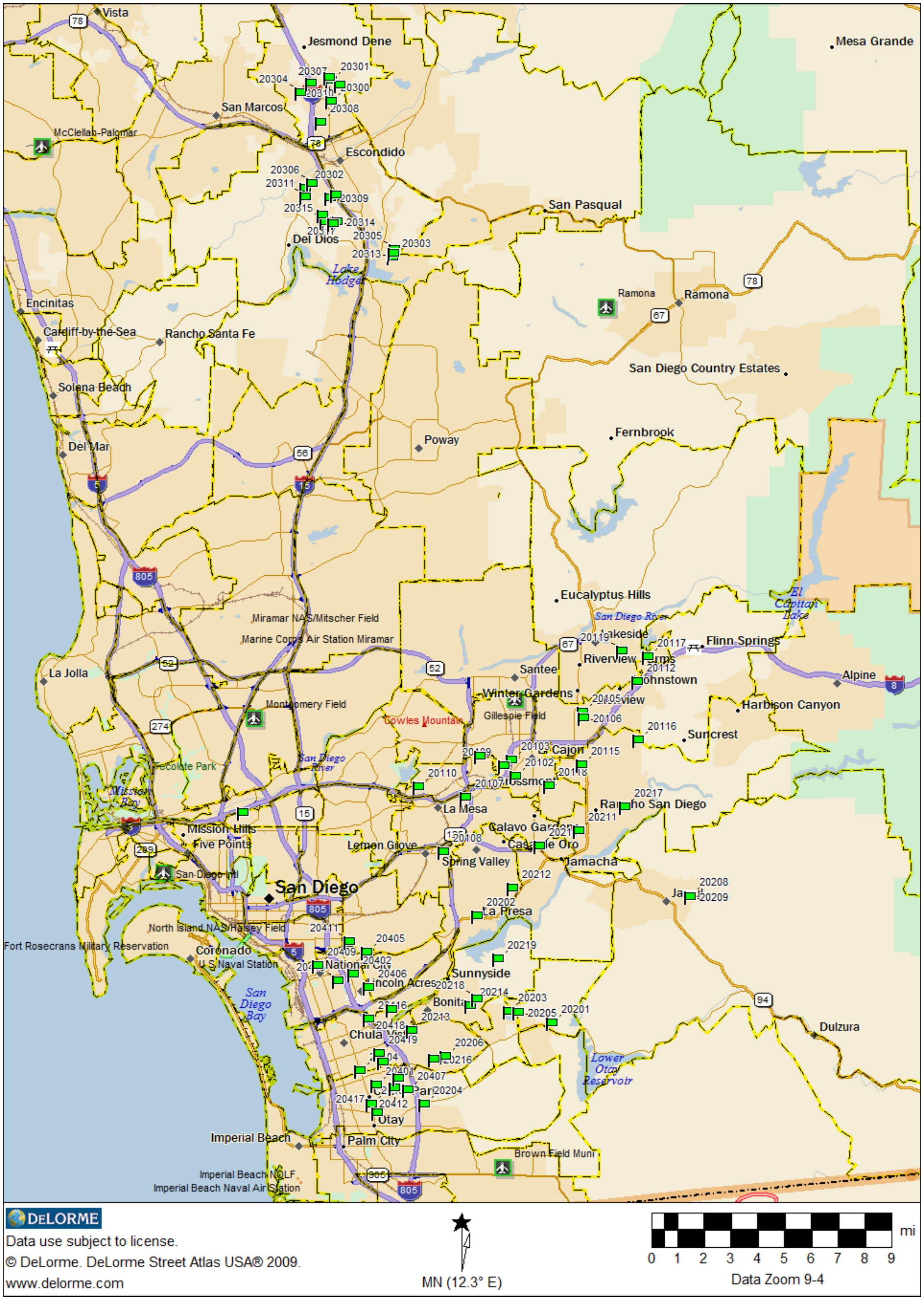


Figure 29: Distribution of logged sample sites for San Diego County Water Authority – county sites only

East Bay Municipal Utility District

There were a total of 321,765 single-family accounts listed in the billing database for the East Bay Municipal Utility District for the 2005 billing year. EBMUD selected a sample of 1000 accounts using the random systematic sampling approach provided by the consultants. The Q1000 was selected from all single-family accounts (which also include individually metered condos and town homes). The homes were sorted according to their annual water use, and no attempt was made to group them geographically.

EBMUD provided the Q1000 to Aquacraft in early September 2006. After verifying that the statistics of the sample matched those of the population, a logging sample was chosen. Because EBMUD had elected to log 120 homes, a total of 140 homes were selected as logging candidates. Notification letters were sent to these homes at the end of September. Six homes opted out of the study leaving a total of 134 homes in the logging sample. The statistics of the Q1000 matched those of the population very closely. The final logging sample had a mean use that was slightly smaller than the mean of the population. Because it is a smaller sample it was more susceptible to being affected by the loss of the homes that opted out.

Figure 30 shows the location of each of the 134 logging homes. These include both the 120 primary logging houses and 14 back-ups. This map shows a remarkably even distribution of the sample over the service area. As one would expect, the areas with higher population density have more sample homes than the areas with lower population density. Ultimately, good traces were obtained from 114 of the logged homes.

Table 25: Annual water use statistics for EBMUD single-family population and study samples

	All SF Accounts in Screened Billing Database Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean annual use	106.8	107.0	102.1
95% Con. Inter.	0.33	5.82	12.71
Median	82.1	82.1	83.8
Count	306,279	1,000	134

Even though geography was not a factor in the sample selections, the final logging sample appears to have an excellent geographical distribution over the EBMUD service area. Table 26 shows that the percent of the Q1000 in each city within EBMUD's service area is similar to the percent of the population living within each city.

Table 26: Proportion of Q1000 by city in EBMUD service area

City	Total SF Services	Q1000	% of…	
			Pop	Q1000
Alameda	15330	51	5%	5%
Alamo	5058	23	2%	2%
Albany	4222	9	1%	1%
Berkeley	23268	74	7%	7%
Castro Valley	16066	48	5%	5%
Crockett	1193	1	0%	0%
Danville	17789	58	6%	6%
Diablo	356	2	0%	0%
El Cerrito	8128	25	3%	2%
El Sobrante	1401	6	0%	1%
Emeryville	541	0	0%	0%
Hayward	7796	24	2%	2%
Hercules	6167	17	2%	2%
Kensington	2125	6	1%	1%
Lafayette	8791	34	3%	3%
Moraga	4480	12	1%	1%
Oakland	82277	245	26%	24%
Orinda	6395	16	2%	2%
Piedmont	3769	9	1%	1%
Pinole	5596	13	2%	1%
Pleasant Hill	2147	8	1%	1%
Richmond	33963	121	11%	12%
Rodeo	2455	6	1%	1%
San Leandro	24369	76	8%	8%
San Lorenzo	7692	17	2%	2%
San Pablo	4947	20	2%	2%
San Ramon	13490	50	4%	5%
Selby	1	0	0%	0%
Walnut Creek	11953	30	4%	3%
Total	321765	1001		100%

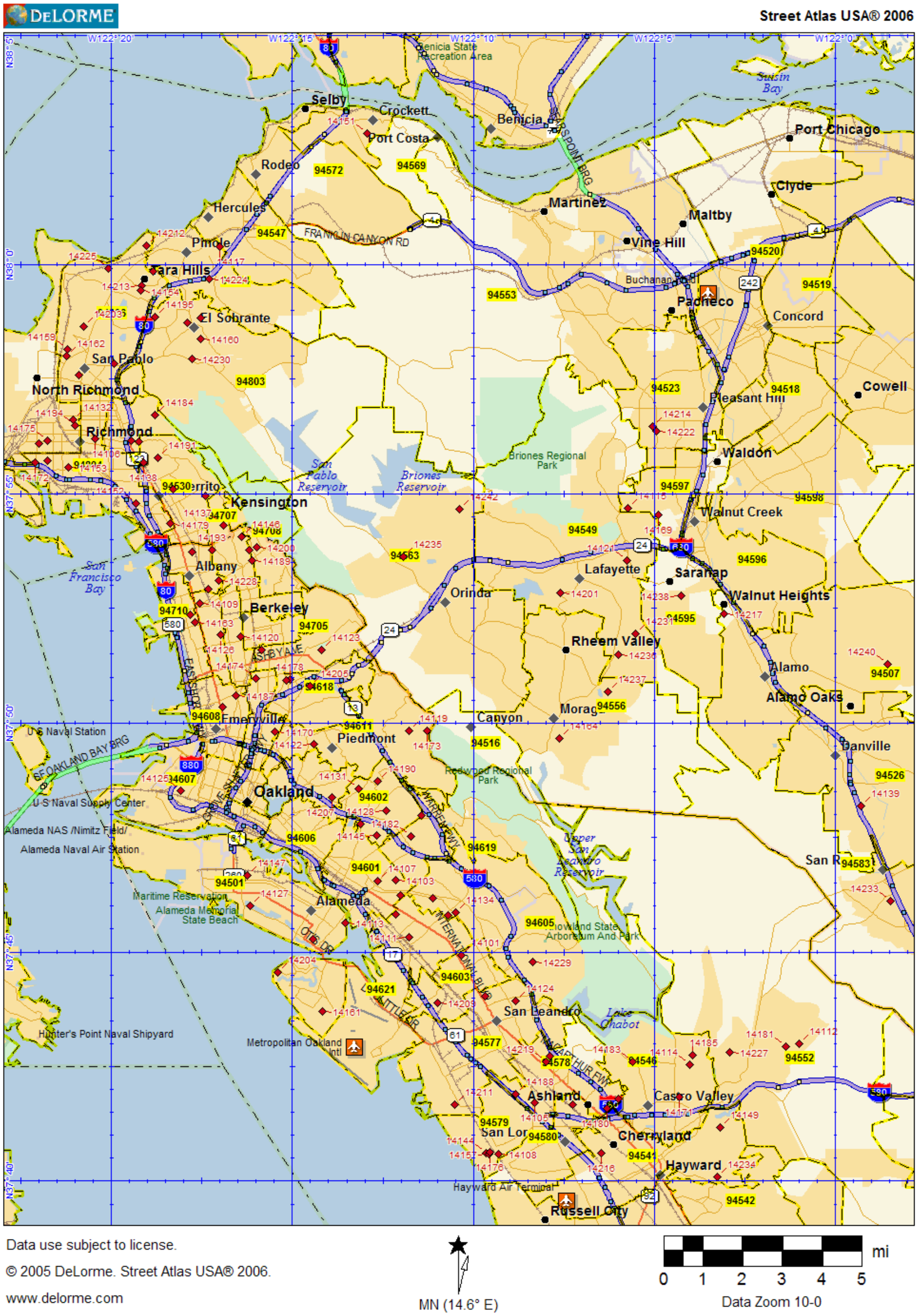


Figure 30: Locations of study homes in EBMUD

Sonoma County Water Agency

The Sonoma County Water Agency provides wholesale water to Sonoma and Marin counties, serving 600,000 people. Logging sites were selected from four retail agencies within Sonoma County Water Agency's service area: North Marin Water District, the City of Petaluma, Rohnert Park, and the City of Santa Rosa. The North Marin Water District service area covers approximately 100 square miles, primarily within the city of Novato, and 68.3% of the deliveries were to single-family residential customers. Petaluma has 17,014 single-family accounts, and these accounts use just over half of the city's delivered water. Rohnert Park has 8,717 customer accounts, 87% of which are single-family residences. In Santa Rosa, single-family customers make up 84% of its 50,352 customer accounts.

A total of 60 homes were logged for Sonoma County Water Agency. Valid data were obtained from 59 homes. Logging samples were selected in accordance with the basic sampling procedure outline above. The water agency provided a sample of approximately 250 sites for each of the four retail agencies studied (a total of 1000 sites). These samples had water use statistics that matched the population water use statistics in each service area. From this sample of 250, a smaller sample for each sub-site was created. Again, the statistical parameters of this sample matched the statistical parameters of the population in each service area. These homes were sampled at random. The study plan called for 15 sites from each participating retailer to be included in the final analysis. Twenty potential logging sites were selected in case some sites were deemed infeasible for logging.

The population of North Marin used 126 kgal per capita annually with a 0.8 kgal interval at 95% confidence. Both the surveyed sample and the logged sample used 125 kgal, which meets the confidence bounds of the mean use of the population. The median water use for the logging sample and the population were equal. For Petaluma the mean (110 kgal) and median (102 kgal) were the same for the population, the surveyed sample and the logged sample. For Rohnert Park the mean use (108 kgal) is the same for the population, surveyed sample and logged sample. The median for the surveyed sample and the logged sample match, but are slightly higher than the median use for the population (104 kgal versus 102 kgal). In Santa Rosa the mean use of the population was 100 ±0.71 kgal, with a 95% confidence. The surveyed sample and logged sample each had a mean use of 99 kgal, which is a close match to the population. The median use for the population and the surveyed sample are equal (88 kgal) and only slightly higher for the logged sample (89 kgal). These numbers are shown in Table 27.

Table 27: Annual water use statistics for Sonoma County Water Agency study sites

Sonoma County Water Agency	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
North Marin WD			
Mean	126	125	125
95% Con. Inter.	0.8		
Median	120	125	120
Count	10,303	250	20
Petaluma			
Mean	110	110	110
95% Con. Inter.	1.1		
Median	102	102	102
Count	13,743	244	20
Rohnert Park			
Mean	108	108	108
95% Con. Inter.	1.09		
Median	102	104	104
Count	6,691	236	20
Santa Rosa			
Mean	100	99	99
95% Con. Inter.	0.71		
Median	88	88	89
Count	32,887	248	20

Samples were selected on the bases of water use, not geographic distribution. However, the geographic distribution was relatively uniform. Figure 31 shows the Sonoma County Water Agency logging sites. The four clusters correspond to the four retail agencies participating in the study. These retail agency service areas are relatively small, so logged sites cover much of the area of interest.

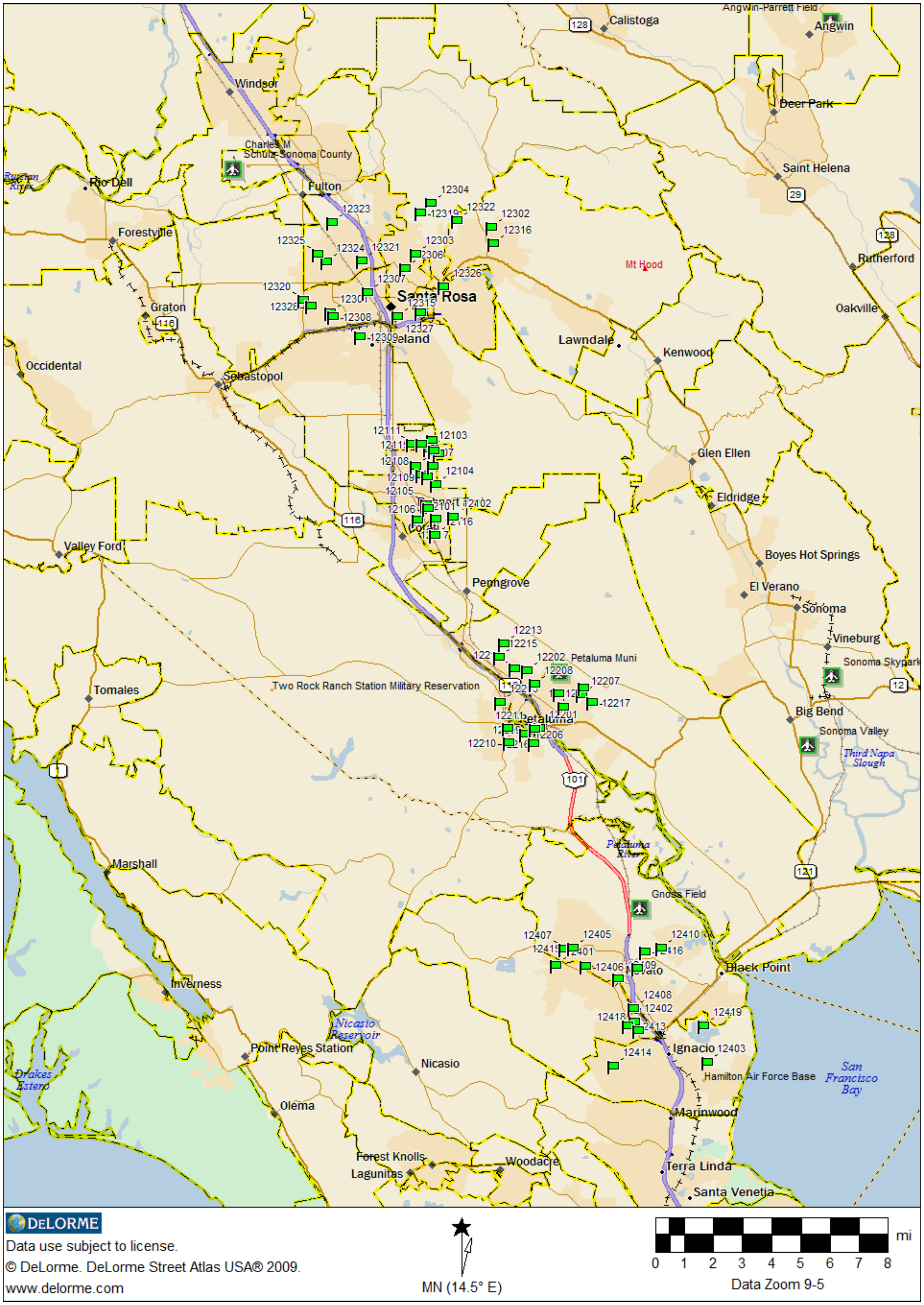


Figure 31: Logging sites for Sonoma County Water Agency

Irvine Ranch Water District

As of 2006, there were a total of 91,733 accounts served by the IRWD. Of these, 47,650 were for single-family residences. IRWD participated in the 1996 Residential End-Uses of Water study. The methodology and sampling characteristics of that study are directly comparable to this sampling 10 years later. Aligning the 2006 work with that from 1996 offers future research potential for household-by-household comparisons. IRWD provided a sample of approximately 1000 sites. From this sample of 1000, a smaller sample for logging was created. A total of 142 homes were logged for IRWD. Valid data were obtained from 115 homes.

It is important that the surveyed sample and the logged sites were representative of the population. In order to verify this, samples were selected to match water use of the population. The surveyed sample mean water use (148 kgal) is equal to the population mean water use. The logged sample mean water use was a bit lower, 147 kgal, but still very close to the 95% confidence interval range of 148±0.57 kgal. The median water use for both sample sets was equal to that of the population (135 kgal.) Table 28 summarizes these numbers.

Table 28: Annual water use statistics describing Irvine Ranch WD water use for the population and study samples

IRWD	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	148	148	147
95% Confidence Interval	0.57		
Median	135	135	135
Count	45,878	1,000	142

Water use was the determining factor for evaluating if samples were representative of the population. However, the geographic distribution of sites may be of interest. Figure 32 shows the location of logged sites. It is apparent that the sites were spread throughout the IRWD service area, rather than clustered together in one neighborhood that may not be representative of water use for the wider IRWD customer base.

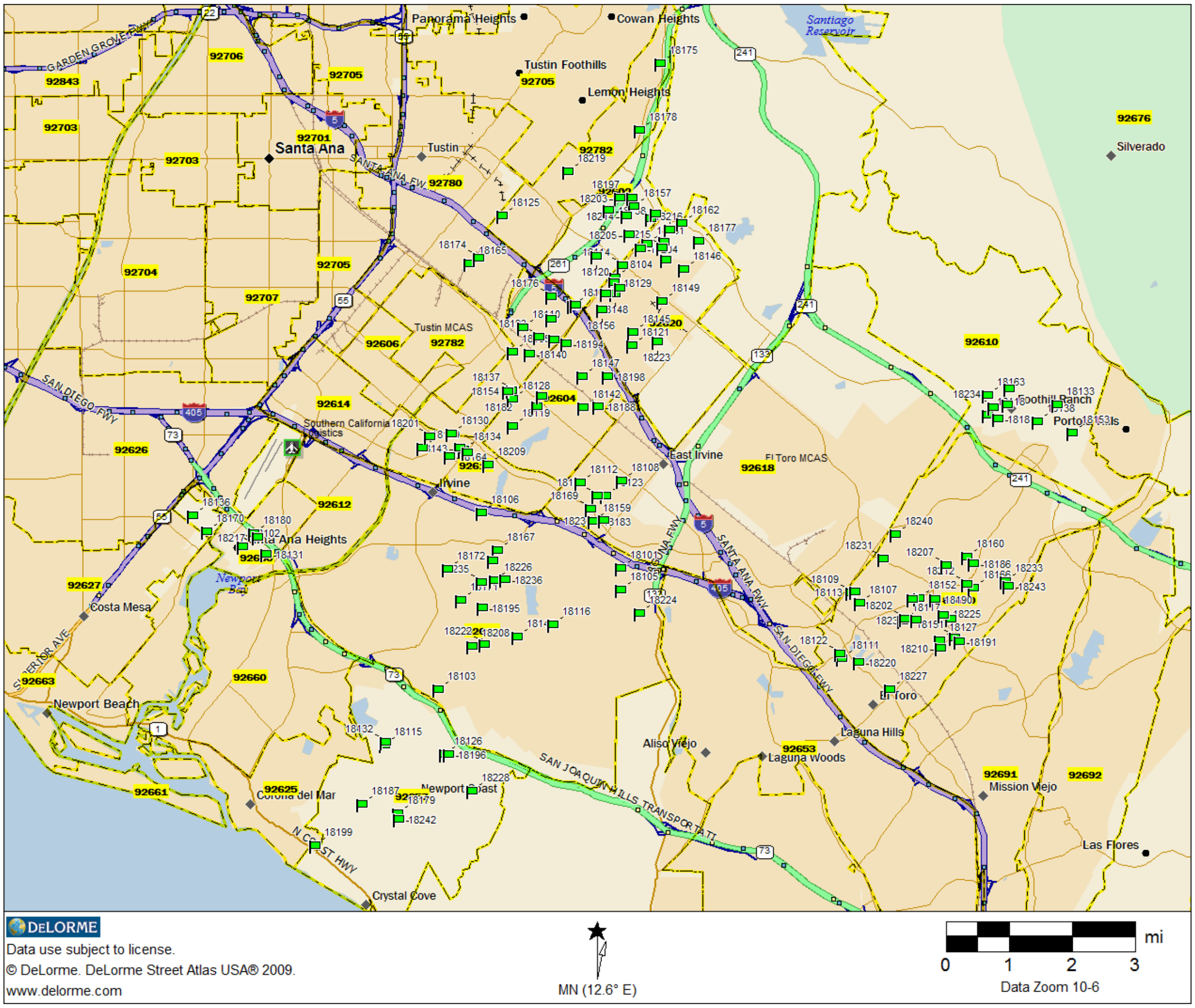


Figure 32: IRWD logged sample sites

Los Angeles Department of Water and Power

The Los Angeles Department of Water and Power (LADWP) provides water service to the nearly 4 million residents of the City of Los Angeles and surrounding areas. In 2000, LADWP delivered 677 million gallons of water; 240 MG of that went to single-family customers.

The sampling procedure for LADWP was different than the standard sampling procedure. In order to increase the efficiency of the site visits it was decided to limit the geographic area of the study. This was done by grouping the homes by zip code and selecting a sample of homes from a sample of zip codes. Instead of a three-stage process, as was standard for other sites in the study, a four stage process was used. Table 29 illustrates the difference.

Table 29: Sampling approach for LADWP compared to standard sampling approach

Standard Sampling Process	LADWP Sampling Process
1. Population	1. Population
	2. Narrow population by zip code
2. Draw survey sample from population	3. Draw survey sample from limited number of zip codes
3. Draw logging sample from survey sample	4. Draw logging sample from survey sample

The key concept with this alternative sampling procedure was that in each step, the mean water use of the sample matched the mean water use of the population.

First, accounts with unusually low or high water use were removed from the study population. The raw billing data submitted by LADWP contained 482,615 single-family accounts, but once these outliers were removed, there were 371,767 single-family accounts. The mean water use for this population was 153.01 with a 95% confidence interval from 152.7 to 153.2. The LADWP service area encompasses a total of 124 zip codes. The survey sample was taken from only 24 of those zip codes. Note that the statistics for the sample zip codes match those of the population very closely (Table 30).

Table 30: Comparison of sample zip codes to population

Sampling Group	No. of Zip Codes	No. of Candidate Accts.	% of Total	Mean Use (kgal)	Median Use (kgal)	Top Quartile (kgal)	Census Pop	Census Housing Units	Median House Value	Average Household Size
Sample zip codes	24	78,578	21%	158	140.6	204	1,029,460	338,876	$284,027	3.04
Service area pop	124	371,767	100%	153	134.6	198				
L.A. County							9,519,338	3,133,774	$209,300	2.98

From these 78,578 accounts in the sampling zip codes shown in Table 30 systematic random sampling was used again to select about 3000 candidates for surveying. This surveyed group had statistics shown in Table 31.

Table 31: Statistics of surveyed sample

Group Within Sampling Zip Codes	Total 2006 (kgal)	Mean	Median	Top Quartile	Accounts
Survey Sample (2)	477965	158.16	140.62	204.20	3022

From the surveyed sample set described in Table 31, a logged sample was drawn. A total of 120 homes were sampled in Los Angeles, and valid data were obtained from 102 homes. Each of the homes had been mailed a survey and a letter requesting permission to participate in the study. The final logging group was selected to match water use patterns of the population and from homes that had returned surveys and given their consent. Table 32 presents a side-by-side comparison of water use for the population, surveyed and logged samples. The mean water use of the study samples is very comparable to the water use of the population.

Table 32: Annual water use statistics for LADWP population and study samples

Las Angeles Department of Water and Power	Population Annual Use (kgal)	Surveyed Sample Annual Use (kgal)	Log Sample Q60 Annual Use (kgal)
Mean	153	158	159
95% Confidence Interval	0.23		
Median	134	141	144
Count	485,000	3022	132

Since geography was a consideration in sample selection, it is worthwhile to look at where logged sites were located.
Figure 33 shows site locations. Sites are not uniformly distributed throughout the service area. However, because water use patterns for study samples matched the population, the study samples were representative of the population.

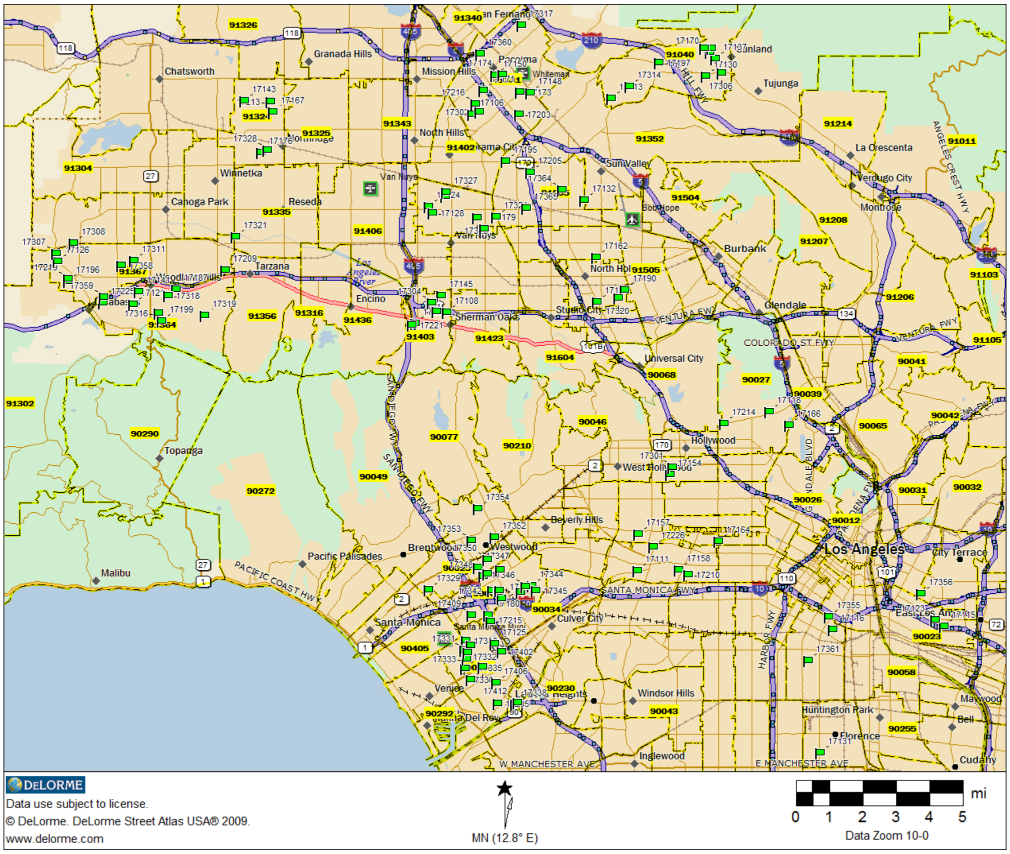


Figure 33: Distribution of logged sites in LADWP service area. Note that zip codes are highlighted in yellow.

Table 33 shows the number of logged sites for each agency in the study and the time frame when the sample sites were logged. The combined water use statistics comparing logged samples and population are also summarized in Table 33.

Table 33: Combined statistics of logged samples

City/Agency	Logging Sample Size	Logging Sample Mean Use (kgal)	Population Size	Population Mean Use (kgal)	Logging Period
Redwood	60	105.89	15,777	101.09	Oct 06 – Nov 06
San Francisco	60	69.2	52,349	65.1	Nov 06 – Jan 07
San Diego City	66	115	217,893	114	Sep 07 – Oct 07
Las Virgenes MWD	66	392	17,016	392	Feb 08
City of Davis	73	160	13,194	158	Jan 07 – Feb 07
San Diego County					Oct 07 – Nov 07
Helix	20	151	45,401	151	
Rincon del Diablo	20	184	5,848	184	
Otay	20	159	10,794	161	
Sweetwater	20	125	22,170	125	
East Bay MUD	134	102.1	306,279	106.8	Mar 07 – Apr 07
SCWA					Feb 07 – Mar 07
North Marin WD	20	125	10,303	126	
Petaluma	20	110	13,743	110	
Rohnert Park	20	108	6,691	108	
Santa Rosa	20	99	32,887	100	
Irvin Ranch Water District	142	147	45,878	148	Jun 07 – Jul 07
LADWP	132	159	485,000	153	Aug 08 – Sept 08

CHAPTER 7 – END USE DESCRIPTIVE STATISTICS

The purpose of collecting highly detailed water use data from the sampled homes was to allow their water use to be broken down into end use categories. Having end use data provides a much higher degree of clarity about the nature of water use in the homes than is normally available. Of prime interest for this study, is that it allows the relative efficiency or inefficiency of each type of water use to be characterized individually and unmasked by other uses in the home. This includes both indoor and outdoor uses. This chapter provides the descriptive statistics and comparisons of the water use by end use. As will be seen, the data are very encouraging in some areas, but raise questions in others. They also provide insights into how water conservation programs might be modified to more effectively reduce household water use.

There were a total of 735 homes from which indoor flow trace data files were successfully obtained. The total number of logged days was 9021, which was an average of 12.3 logged days per home. It is important to keep in mind that in this chapter the results are presented either in terms of annual water use per account, measured in thousands of gallons (kgal) or average daily household water use, measured in terms of gallons per household per day (gphd).

The research team has intentionally avoided normalizing the data on the basis of the number of residents per household for several reasons. First, the number of residents in the home is one of the most important variables for explaining indoor water use, and we did not want to normalize on a key variable since this would create problems in the modeling of the data. Primarily, it would result in trying to create models in which the same variable appears on both side of the equation. Secondly, every water agency provides water to households; not to individual customers. All of the single-family billing data comes in the form of water deliveries to households. Since this is the main form in which the agencies have their data, and little is known about the number or residents in individual homes, it seemed to make the most sense to do the water use analysis on the basis of household use. Finally, normalizing on the basis of number of residents invites readers to assume that there is a linear relationship between the number of residents and water use. As described in the modeling chapter, the results show that this is not the case, and the relationship is not linear; hence as additional people are added to a home the water use increases less with each additional person.

Another important fact to keep in mind when reviewing these results is that a set of efficiency metrics, discussed later in this chapter, were established for this study, by which the efficiency of household use for toilets, clothes washers and showers was evaluated. These performance metrics are generally in agreement with typical efficiency parameters used in the industry, but they are not official "standards" in the sense of having been adopted by a regulatory body. They are also metrics based on household use, rather than specific fixture definitions. For toilets, the metric chosen was that the average household flush volume in the home had to be 2.0 gpf[40] or less for the house to be tallied as meeting the toilet efficiency criteria. The value of 2.0 gpf was chosen because it would include only homes that used toilets flushing at ULF or better volumes,

[40] Note that 2.2 gpf was used as the criteria for individual toilet flushes and 2.0 gpf was used as the criteria for household average flush volumes.

but would allow a margin of error in their adjustments. This is an important performance measure, but is not attempting to say exactly what type of toilet was present in any home. The purpose of the study was not to determine the makes and models of toilets in the home, but the household water use efficiency. Toward that end, the model was not as important as the flush volume. A high volume toilet modified to flush at less than 2.0 gpf would be counted as a ULF device, even though it was not designed as such, while a ULF toilet flushing at more than 2.2 gallons would be counted as a high volume toilet. The only information we had on makes and models was from the survey results, which approximately half of the homes returned and, if the respondents can be trusted, indicated that approximately 67% of the toilets were ULF or better (See Table 66).

There are three graphs that show the percentage of homes that meet the efficiency criteria. For clothes washers the graphs come close to showing the "penetration rates" for high-efficiency clothes washers, since most homes typically only have one clothes washer. For toilets, however, the results are not so clear. The percent of homes that meet the efficiency criterion used for the study probably contain mostly ULF or better toilets. The homes that fail to reach this criterion may contain a mixture of high volume toilets and possibly ULF toilets that are not flushing properly. This distinction should be kept in mind when reviewing the statistical results. Histograms are also provided that show the percentage of individual fixture uses at varying volumes. These can be used to infer the percent of fixtures meeting various performance levels.

Annual and Seasonal Usage

As described in Chapter 5, a key goal of the logging group selection process was to have a group of homes for logging whose water use patterns were as similar as possible to those of the general population of single-family homes in each participating agency.

Table 34The fact that the sample values are so close to those of the populations shows that if there are surprises in the results of the analysis, they are not due to the fact that the logging samples were skewed. In all cases the logging group's annual water use matched that of the population.

Table 34 also shows the weighted average of the annual water use based on the number of households in each agency. The agencies, as a whole, served approximately 1.3 million single-family accounts in 2005. Of these, 35% were in the north and 65% were in the southern part of the state. The weighted average annual use for the group was 132 kgal per year (176 ccf/year). The annual water use for the logging samples was 134 kgal per year (179 ccf/yr). As explained below, the average daily indoor use for the agencies, as determined by the flow trace analysis, was 171 gallons per household per day (gphd). This represents the best estimate of actual indoor use (plus leakage) for the homes, through direct analysis of water use events, rather than reliance on minimum month estimates. By subtracting the indoor water use from the annual use, the outdoor use can be estimated. The weighted average annual outdoor use for the group was 190 gphd. As shown in Figure 34, approximately 47% of household use was for indoor purposes and 53% was for outdoor use. As discussed elsewhere in this report, use of non-seasonal water demands as a proxy for indoor use tends to underestimate outdoor use because it assumes that all of the non-seasonal use is indoor, when often there is significant irrigation during the winter period. This is especially true in California where the winter climates are mild.

Examination of the data from the individual sites shows that there is relatively little variation in indoor uses, which range from a low of 146 gphd to a high of 222 gphd. Outdoor use shows much more variability, ranging from a low of ~0 gphd to a high of over 850 gphd. Having such a range of use is a benefit for the study group, since it better captures the range of uses in the state population. It also allows for the models of water use to have a larger range of input values, which provides a greater responsiveness in the models to the factors that affect water use. If all of the homes had similar water use patterns, the models would not have been able to predict water use except over a very narrow range of values, which would greatly decrease their usefulness. Thus, having a wide range of data produces much more robust, realistic and useful models.

Table 34: Comparison of Annual Water Use for Agencies in Study Group

Agency	No. SF Accts.	Annual Use (kgal/yr)		Mean Daily Use (gpd)		
		Population SF	Sample SF	Annual	Indoor (from data logging)	Outdoor
Davis Water Dept.	13,194	158	160	432	171	261
EBMUD	306,950	107	105	293	164	129
SCWA	63,624	107	106	293	161	132
Redwood City	15,777	101	106	277	176	101
SFPUC	52,349	65	65	178	182	~0
City of San Diego	217,893	114	115	312	146	166
IRWD	45,878	148	147	406	179	227
LADWP	485,000	153	159	419	181	238
Las Virgenes MWD	17,016	392	392	1073	222	851
San Diego County	84,213	147	147	404	187	217
Total N	1,301,894	1,492	1,502	4,087	1,769	2,322
Weighted Avg.	NA	132	134	361	171	190
Percent of Total				100%	47%	53%

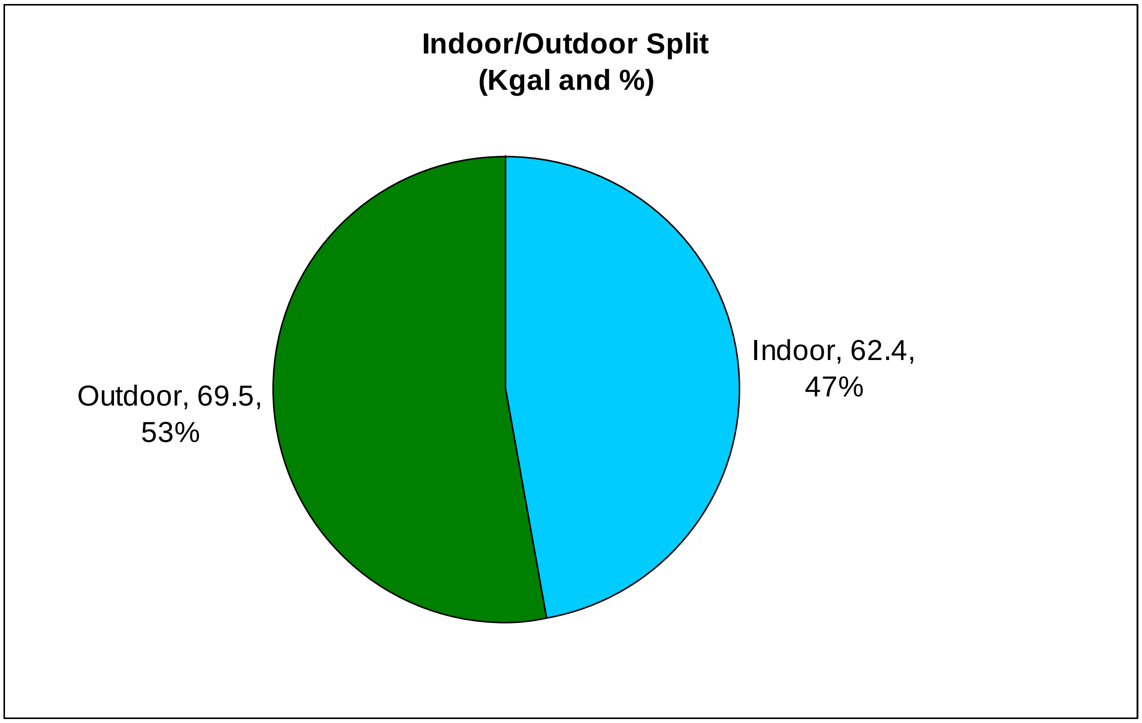


Figure 34: Relative indoor and outdoor annual water use for study group

Table 35 shows a comparison of the average daily water use for the study groups in Northern California versus Southern California. This shows that the indoor uses are very similar, but the outdoor use in Southern California is 272% of that in the Northern California sites. In this table the annual use was obtained from the agency billing data, the indoor use was determined from the data logging, and the outdoor use was the difference between the annual use and the indoor use.

Table 35: Comparison of water use by region

Average Daily Use by Geographic Region (gphd)			
	Annual	Indoor	Outdoor
Northern Sites	295	171	125
Southern Sites	523	183	340

Indoor Uses

The first set of analyses focus on indoor uses. Leakage is included among indoor uses, but it should be kept in mind that many of the "leaks" were likely associated with irrigation systems or pools. The analyses are also based on total household use (gphd), since we did not want to normalize the data on a per capita basis separately from the other important explanatory variables.

The flow trace analysis yielded a list of all of the water use events recorded during the logging periods. These data were contained in an Access database that was used to create a range of summaries for the analyses needed for the report. For the statistical end use analyses presented here, the information shown in Table 36 was extracted for each study home. Most of the parameters in the table are self-explanatory.

The last three parameters were conditional variables (having a value of either 0 or 1) which were used as flags to denote whether or not the home met an efficiency criterion that the research team established for toilets, showers and clothes washers. Houses that had values of less than 2.0 gpf, 2.5 gpm, and 30 gpl were designated as "efficient" homes for toilets, showers and clothes washers respectively. The efficiency parameters used for this study do not represent official standards for household use, but they are useful ways to categorize household water use in terms of well-recognized efficiency levels for these devices.

Table 36: End use parameters

Parameter	Description
Keycode	The unique code used to identify each study home
Agency	The water agency serving the home
Indoor Use	The total indoor water use in from all categories (gal)
Outdoor Use	The total volume of outdoor events (gal)
Total Used	The total water recorded in the trace (gal)
Total GPD	Total use divided by the number of days in trace (gpd)
Indoor GPD	Indoor water use divided by days in trace (gpd)
Days	The number of complete days in trace (days)
Leakage	The total leakage in trace (gal)
Toilet, CW, DW, Faucet, Leaks, Bath, Shower, Other (GPD)	The average daily leakage (gpd) for all identified end uses
Avg. Shower Mode	The average of the most frequent shower flow rates (gpm)
Count of Shower	Number of showers in trace
Avg. Shower Volume	Average of volume of water used per shower (gal)
Avg. Toilet Volume	Average toilet flush volume (gal)
Count of Toilet	Number of toilet flushes in trace
Total CW	Total water use for clothes washers (gal)
Count of CW	Number of clothes water loads in trace
CW GPL	Average gallons per load for clothes washers (gpl)

Toilet Criteria	Flag for house meeting ULF criteria (<2.0 gpf)
Shower Criteria	Flag for house meeting shower criteria (<2.5 gpm)
CW Criteria	Flag for house meeting CW criteria (<30 gpl)

Total Indoor Use

The average household indoor use for all of the logged homes in the California Single-Family Water Use study was 175 gphd with a 95% confidence interval of eight gpd. This is not significantly different from either the indoor use reported in the REUWS study group as a whole, or just the 400 REUWS study homes located in California. The REUWS study was based on data collected around 1997. Table 37 shows the statistics for household indoor use for the two REUWS study groups, the California Single-Family Study, plus the EPA Retrofit Study. The data from the EPA study is included as a benchmark, which shows the potential demands in houses using best available technologies in 1999. Neither the REUWS nor the California Single Home samples from this study approached the EPA consumption levels.

Figure 35 provides a scatter diagram of the average indoor water use in the sample of homes, broken down into the Northern and Southern California sites. This diagram shows that the indoor use for the two geographical areas is quite similar. The simple average of the indoor use for the homes in the respective logging groups for Northern and Southern California were 169 gpd for the northern homes, and 180 gpd for the southern homes.

It is interesting to note that the simple average, shown in Table 37, of the indoor use for the 732 study homes was 175 gphd. The weighted average computed for the 10 study sites based on the number of single-family homes in their service area, shown in Table 34, was 171 gphd. This is another indication of the high degree of similarity among the homes, and demonstrates that the results have not been skewed by over-weighting homes from any one agency. Table 37 also shows that the only significant difference in indoor use among the groups is the EPA Post Retrofit group, which shows significantly lower indoor use than any of the others.

Table 37: Household indoor use statistics for logged homes (gphd)

Parameter	REUWS All Sites	REUWS California Sites	California SF Sites	EPA Post Retrofit Study
Mean ± 95% C.I.	177 ± 5.5	186 ± 10.2	175 ± 8	107 ± 10.3
Median	160	165	157	100
N	1188	400	732	96
Std. Deviation	96.8	104	111	50.9

175 gphd = 63.8 kgal per year = 85 ccf per year

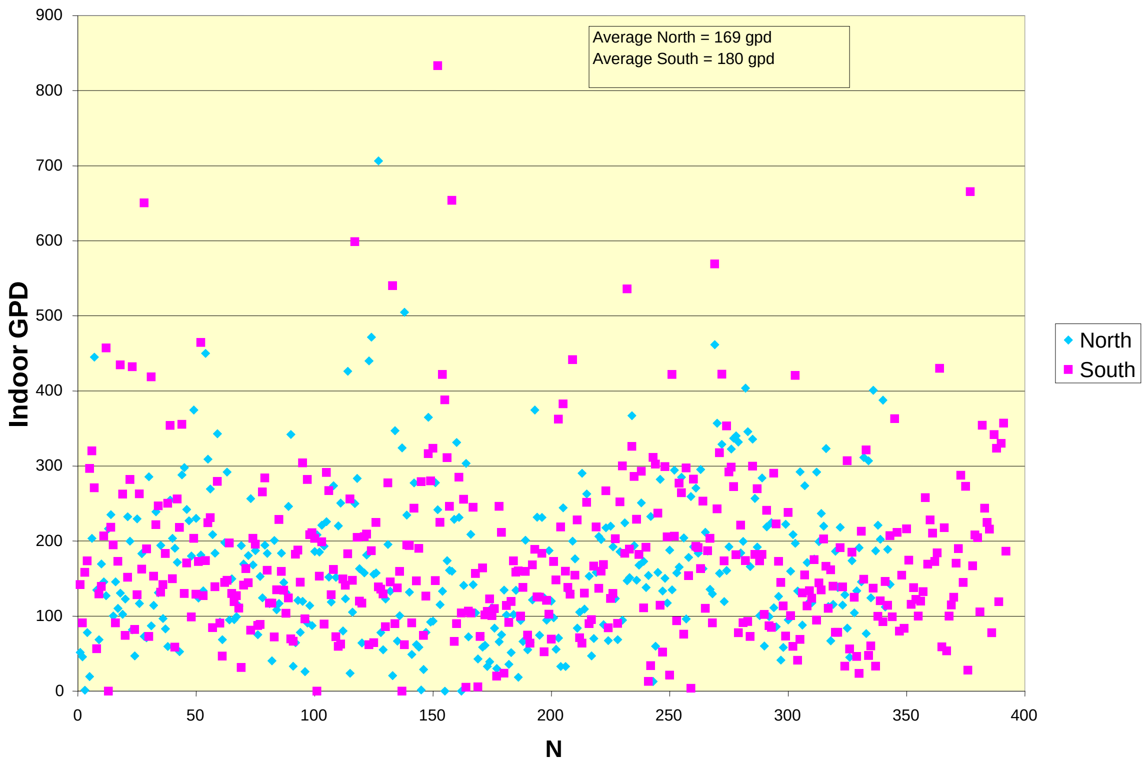
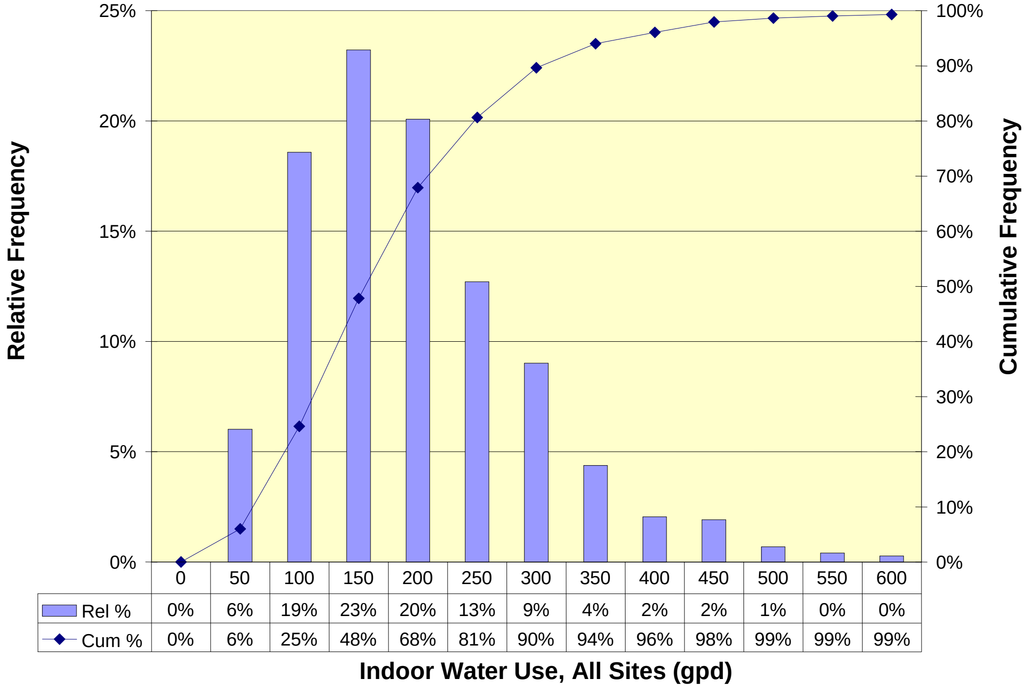


Figure 35: Scatter diagram of indoor household use (gphd)

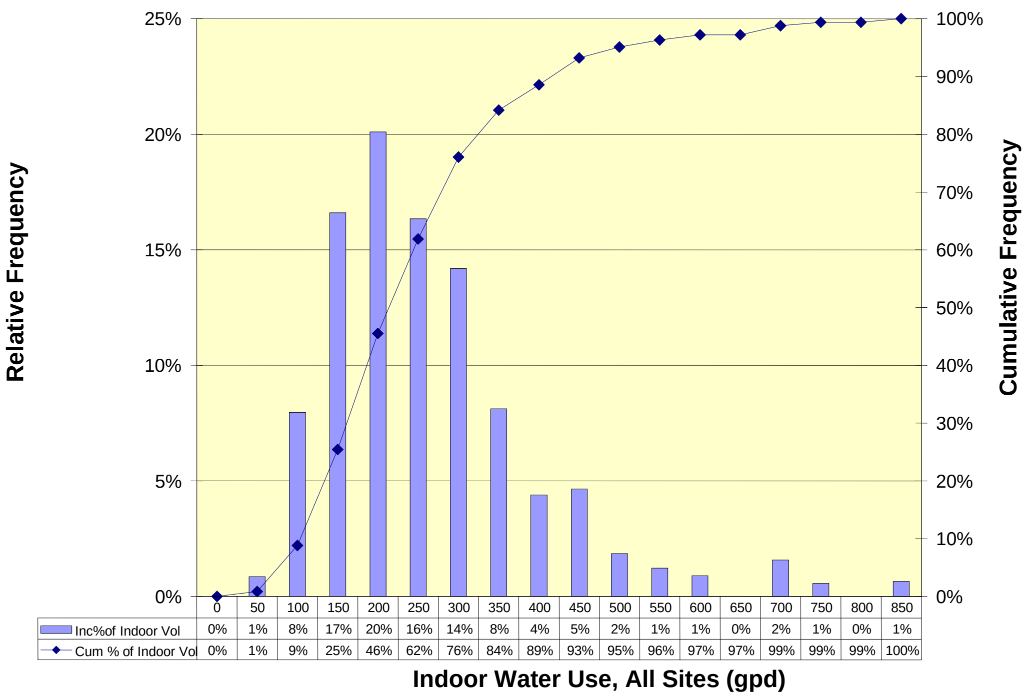
The indoor use results for each of the 10 study sites ranged from a low of 146 gphd to a high of 222 gphd. When evaluating these numbers, it is important to keep in mind that the indoor use also includes leakage, which may include leaks in pools and irrigation systems.

The distribution of indoor use for all homes in the California study group is shown in Figure 36. This shows that the indoor water use is skewed toward the high end by a small number of homes that use a high amount of water. The data show that 19% of the homes were using more than 250 gpd for indoor purposes. The high water consumption in the upper tier homes is clearly related to leakage events, as discussed below. Also, when the percentage of total indoor use accounted for by each use bin is examined, as shown in Figure 37, it shows that the 19% of the customers using more than 250 gphd account for 38% of the total indoor water use. This is just one of many examples of where large water users exert an impact on average use significantly out of proportion to their numbers.



	0	50	100	150	200	250	300	350	400	450	500	550	600
Rel %	0%	6%	19%	23%	20%	13%	9%	4%	2%	2%	1%	0%	0%
Cum %	0%	6%	25%	48%	68%	81%	90%	94%	96%	98%	99%	99%	99%

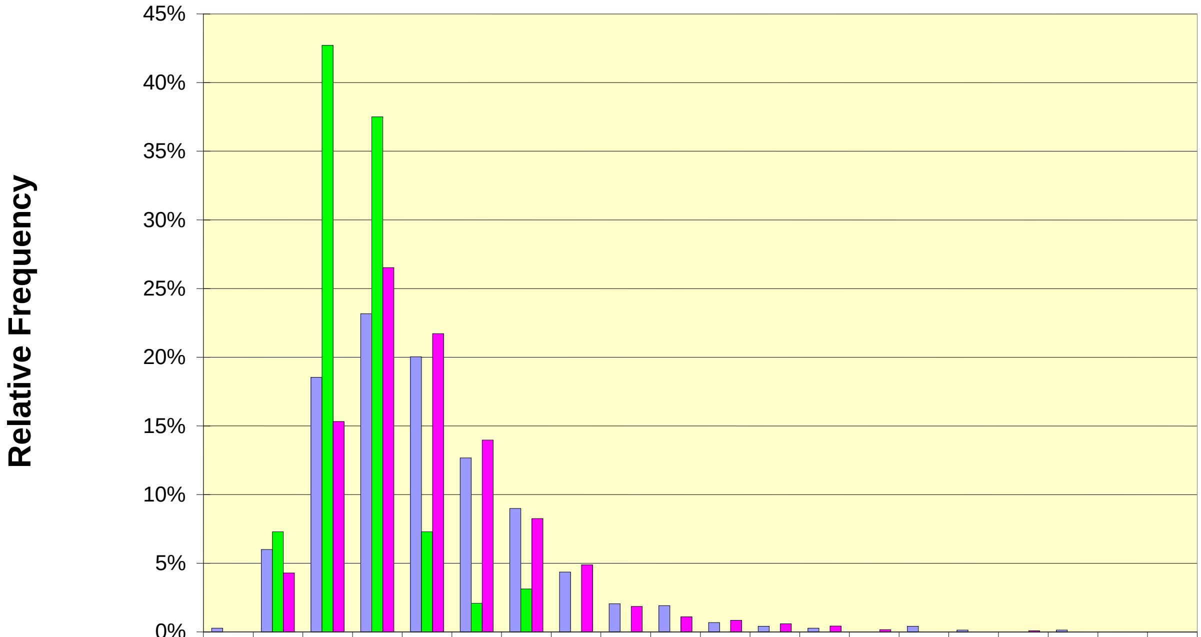
Figure 36: Percent of households by indoor use bin



	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850
Inc%of Indoor Vol	0%	1%	8%	17%	20%	16%	14%	8%	4%	5%	2%	1%	1%	0%	2%	1%	0%	1%
Cum % of Indoor Vol	0%	1%	9%	25%	46%	62%	76%	84%	89%	93%	95%	96%	97%	97%	99%	99%	99%	100%

Figure 37: Percent of total indoor use volume by indoor use bin

Figure 38 compares the indoor use for the study groups. The striking feature of this graph is the markedly higher percentages of the homes from the EPA Retrofit group that were in the 50-100 and 100-150 gphd bins, and the fact that none of the Retrofit homes were in bins greater than 300 gphd. The data from the Retrofit studies were obtained on two separate logging periods, three months and six months after the homes were upgraded. This approach was used to help maximize the reliability of the data, by avoiding the period of novelty immediately after the installations.



	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	
Cal SF Study	0%	6%	19%	23%	20%	13%	9%	4%	2%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EPA Retrofit	0%	7%	43%	38%	7%	2%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
REUWS	0%	4%	15%	27%	22%	14%	8%	5%	2%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	

Indoor Water Use (GPD) Comparison

Figure 38: Indoor use histogram for California SF Study sites, REUWS, and EPA Retrofit Homes

Disaggregated Household Use

When the indoor water in the California Single-Family homes is disaggregated, it is seen that five categories: "leaks", faucets, showers, clothes washers and toilets make up the bulk of indoor use. This is shown in Figure 39. In the REUWS sample, toilets and clothes washers accounted for 27% and 22% respectively. In the California sites these two categories account for 20% and 18% respectively. This suggests that these two important water use categories have decreased in volume since 1997.

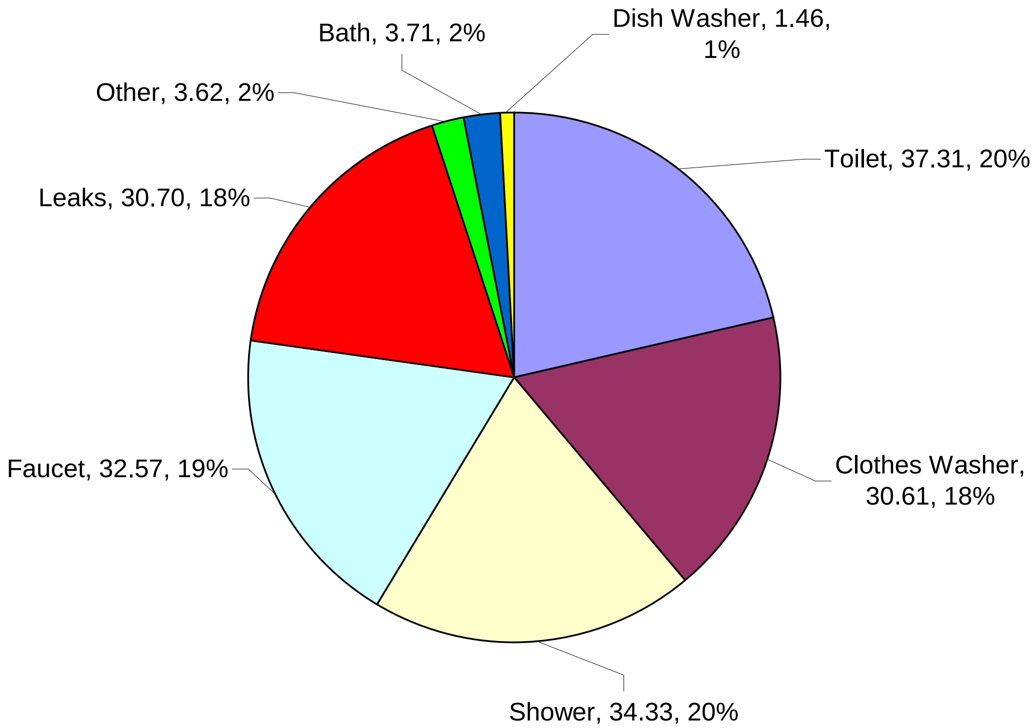
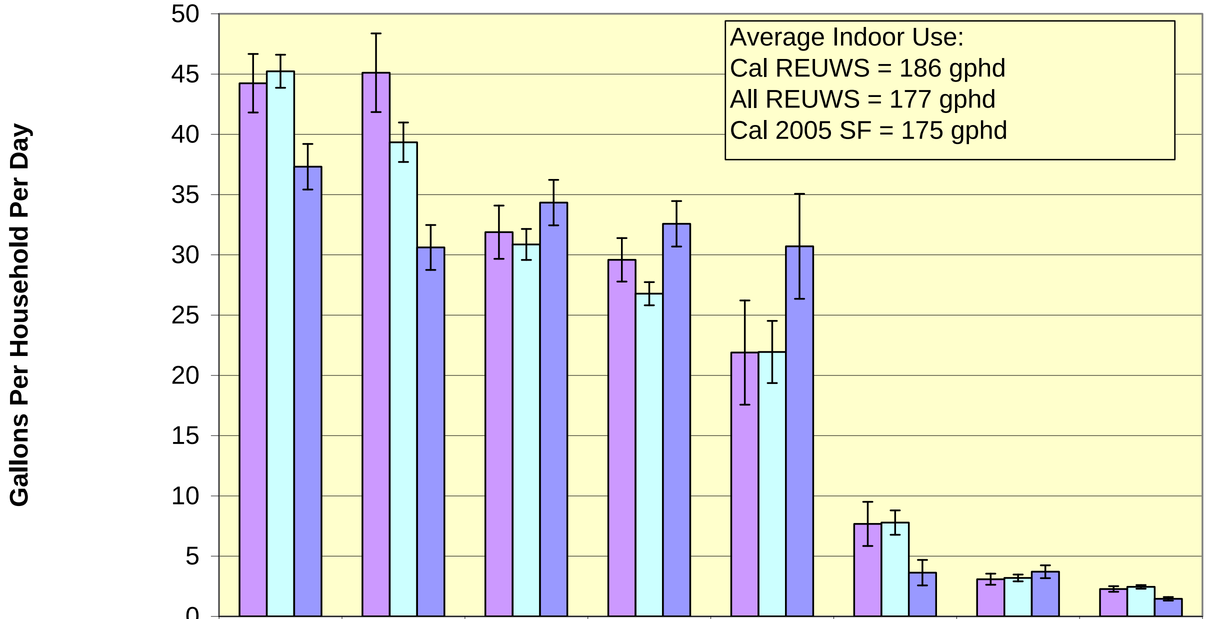


Figure 39: End use pie chart for all sites

The changes in the household end uses since the 1997 REUWS study can be seen more clearly in Figure 40. This figure shows the average daily water use by end use category for the California REUWS sites, all REUWS sites and the California Single-Family sites. The 95% confidence intervals around each mean value are also shown on the graph. This graph shows that there has been a significant reduction in both toilet and clothes washer water use. Unfortunately, there was a simultaneous increase in water use for showers, faucet and leaks/continuous uses. The increase in the shower, faucet and "leak" categories offset the reduction in the toilets and clothes washers. If the data were not disaggregated, these increases would have masked the benefits from the toilet and clothes washer improvements, and given the incorrect impression that the efforts to improve household water use efficiency had been totally ineffective.



	Toilet	Clothes Washer	Shower	Faucet	"Leaks"	Other	Bath	Dish Washer
Cal REUWS	44.2	45.1	31.9	29.6	21.9	7.7	3.1	2.3
All REUWS	45.2	39.3	30.9	26.8	21.9	7.8	3.2	2.4
Cal2005SF	37.3	30.6	34.3	32.6	30.7	3.6	3.7	1.5

Figure 40: Comparison of household end uses

Toilet Use

The toilet data presented in this study need to be understood carefully to avoid being misinterpreted. The data are presented from two perspectives: that of the volumes of the individual flushes, and also from the perspective of overall household use for toilet flushing and average flush volumes per home. For individual flushes, we have used a criterion of 2.2 gpf to designate a toilet meeting at least the 1.6 gpf ULF standard. The criterion for the household average flush volume was set to 2.0 gpf, because a greater margin of error was desired for individual toilets than for average household flush volumes.

The terminology for toilets is somewhat confusing due to the fact that what was once the best available technology, the ULF or 1.6 gpf toilet is now the standard toilet, and the new High Efficiency Toilets (or HET) represent the best available technology. A High Efficiency Toilet is one that flushes at 1.28 gpf or less. It is convenient to classify toilets into three groups: high-volume toilets, which use more than 1.6 gpf; ULF design toilets of 1.6 gpf; and High Efficiency Toilets, which use 1.28 gpf or less. The precise demarcation between ULF design toilets and high volume toilets is unclear since there is such a wide range at which ULF toilets actually flush.

Table 38 provides statistics on individual toilet flush volumes from the study sites. The data show that toilet use is still the number one category for water use, accounting for 36.1 gpd of the total indoor use.

One goal of the study was to use the data collected from the flow traces in order to make estimates of the penetration rate of ULF or better[41] toilets in the study group, and to compare the penetration rates from this study to previous studies such as the REUWS. The problem is complicated by the fact that although a toilet may flush at more than 1.6 gpf, it does not prove that it is a non-ULF designed toilet. Many ULF toilets may be flushing at 2.0 to 3.0 gpf, or more, if they are defective or have the wrong after-market flappers installed. On the other hand, there are products available for reducing high volume toilet flushes into the ULF range.

If there was a distinct dividing line between ULF or better and high volume toilets in terms of gallons per flush, one could simply take that volume and count all flushes with volumes equal to this or less as efficient toilets and all flushes with flushes greater than this as high volume or high water use toilets. As shown in Table 38 and Table 39, if that dividing line was 2.5 gpf then the estimate for efficient toilets would be 59%. If the line were raised a bit to 2.75 gpf then the estimate of efficient toilets would also rise to 64% of all flushes. If one assumes that all of the toilets are flushed at approximately the same rate then these percentages would equate to the percent of actual toilets in the population.[42]

Table 38: Toilet flush volume statistics

Parameter	Value
Events identified as flushes in database	122,869
Average flushes per house per day	13
Average toilet flush volume (gal)	2.76
Median flush volume (gal)	2.45
% of all flushes < 2.5 gal/flush	59%
% of all flushes < 2.75 gal/flush	64%
Average flushes per person per day	4.76
Median flushes per person per day	4.14

[41] Efficient toilet means any ULF or better toilet.

[42] If one is not willing to assume this then the percentages would represent the maximum penetration rates since one would have to assume that the newer, efficient toilets would be flushed more frequently than the older models.

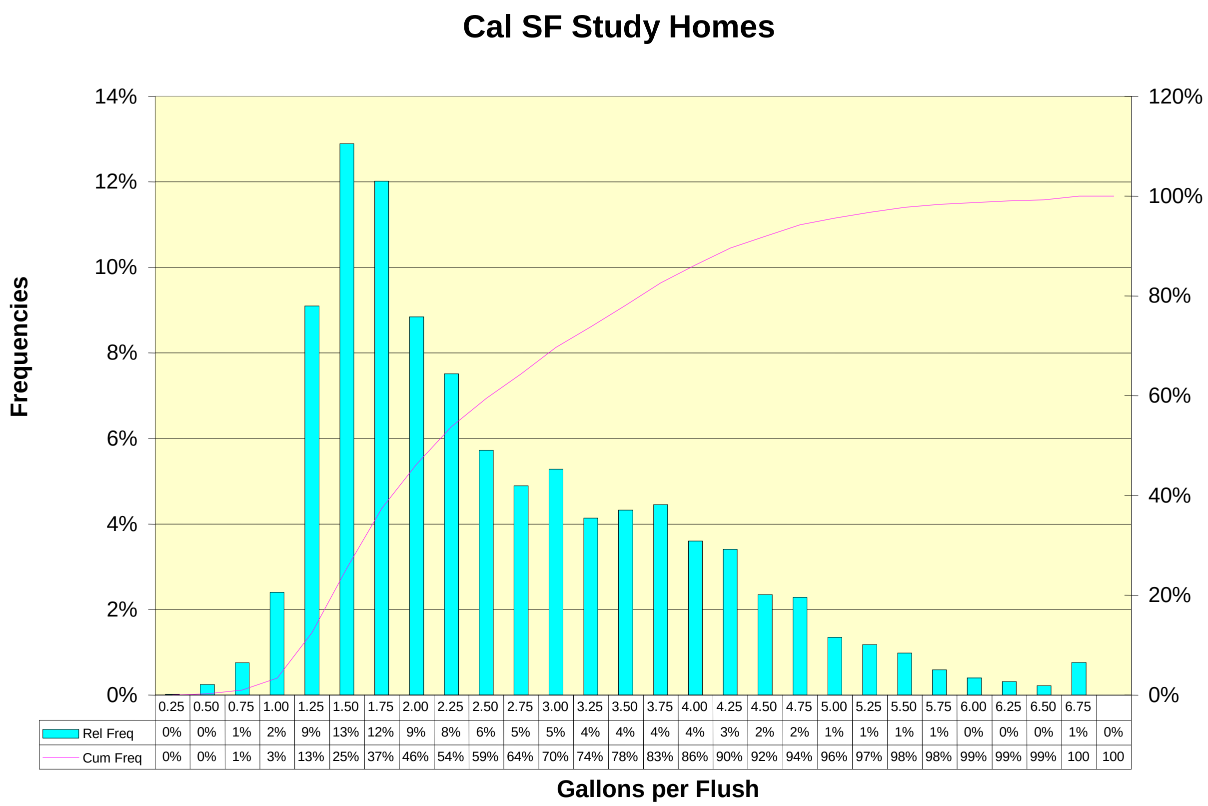


Figure 41: Histogram of individual toilet flushes (N= 122,869)

Table 39: Distribution of toilet flush volumes

Bin (gpf)	Flushes	Total Volume in Bin (gal)	Rel. Freq.	Cum. Freq.
0.25	19	4	0%	0%
0.50	305	206	0%	0%
0.75	930	835	1%	1%
1.00	2,955	3,382	2%	3%
1.25	11,206	15,540	9%	13%
1.50	15,877	25,749	13%	25%
1.75	14,798	27,547	12%	37%
2.00	10,893	23,073	9%	46%
2.25	9,249	21,858	8%	54%
2.50	7,055	18,429	6%	59%
2.75	6,023	17,289	5%	64%
3.00	6,506	20,273	5%	70%
3.25	5,093	17,152	4%	74%
3.50	5,329	19,300	4%	78%
3.75	5,488	21,251	4%	83%

Bin (gpf)	Flushes	Total Volume in Bin (gal)	Rel. Freq.	Cum. Freq.
4.00	4,435	18,249	4%	86%
4.25	4,197	18,318	3%	90%
4.50	2,886	13,315	2%	92%
4.75	2,811	13,675	2%	94%
5.00	1,660	8,489	1%	96%
More	5,154	33,226	4%	100%
Totals	122,869	337,160	100%	

Using the same 2.75 gpf cut-off point, if one looks at the toilet flush distribution from the REUWS study, shown in Figure 42, then 26% of all flushes (toilets) would be ULF or better devices. This would imply a change from 26% to 64% ULF or better toilets in approximately 10 years. This is equivalent to 38% of the toilets in 10 years, or 3.8% per year change-over.

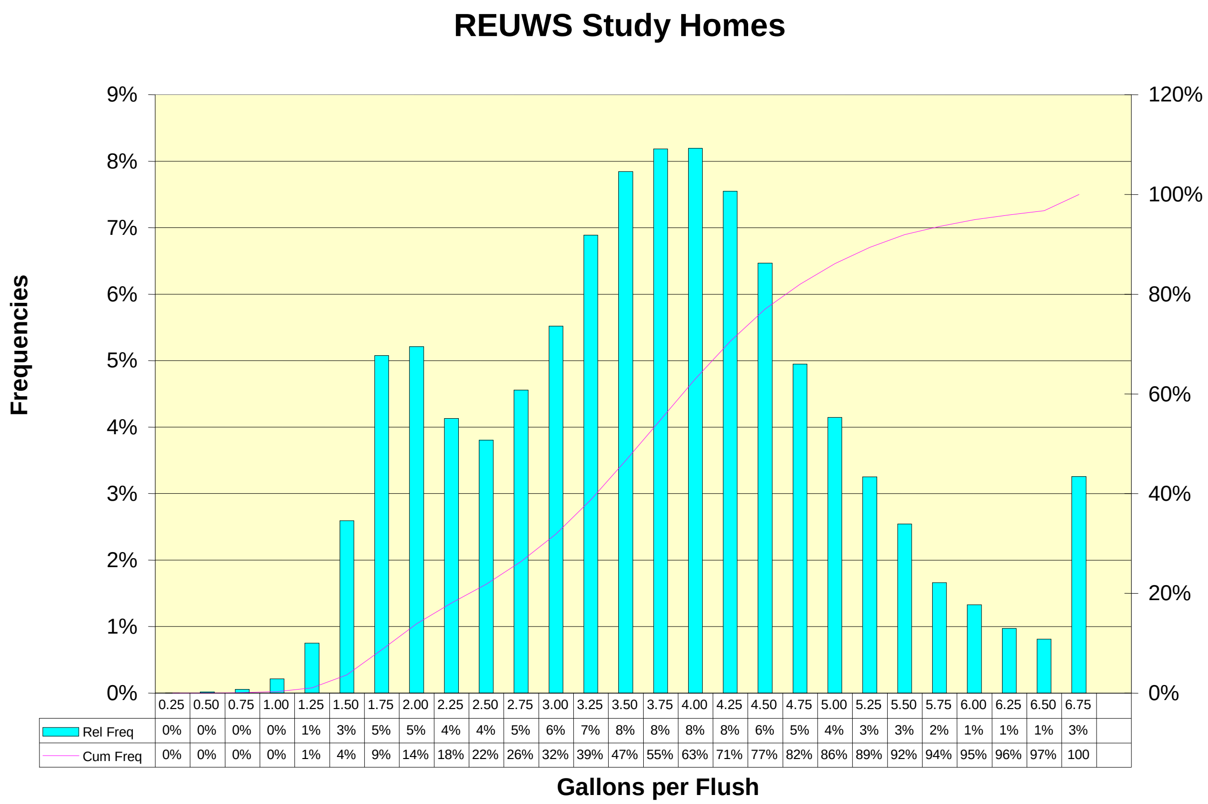
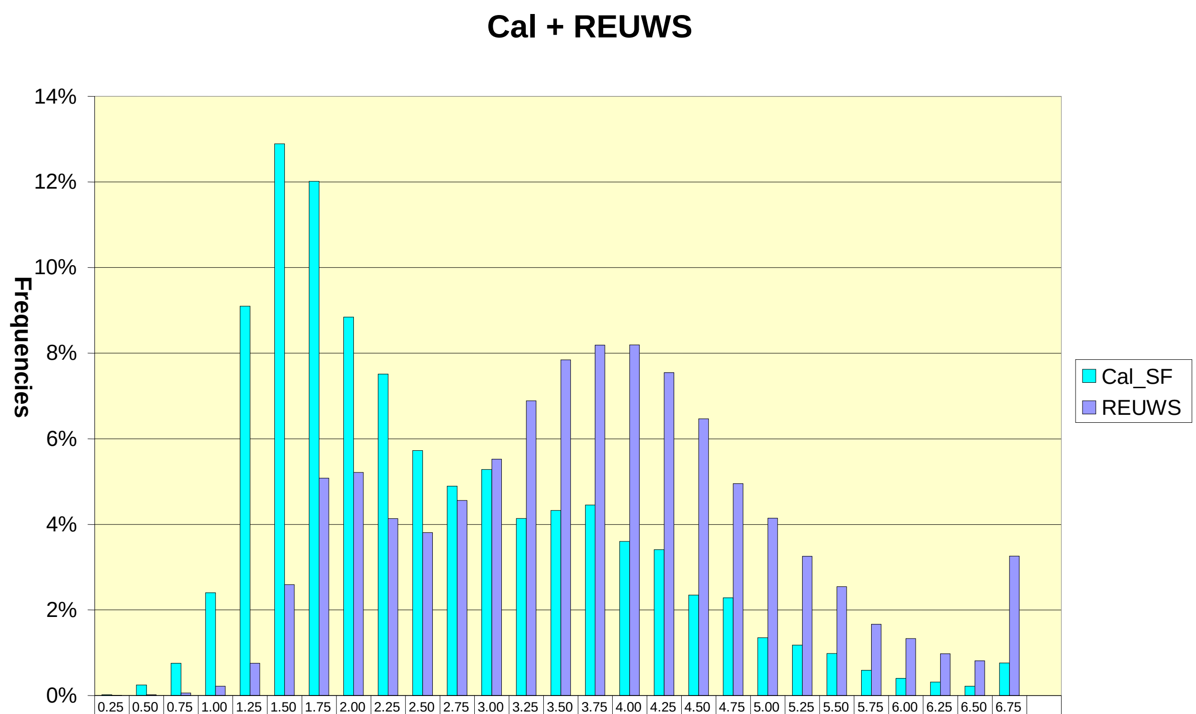


Figure 42: Histogram of toilet flushes from REUWS study group

If we line up both histograms on the same graph the change in flush volume distributions becomes even more impressive. This comparison is shown in Figure 43. In this figure the change in the number of flushes from the higher bins to the lower represent high volume toilets that have been replaced with ULF or better devices.



	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	
Cal_SF	0%	0%	1%	2%	9%	13%	12%	9%	8%	6%	5%	5%	4%	4%	4%	4%	3%	2%	2%	1%	1%	1%	1%	0%	0%	0%	1%	0%
REUWS	0%	0%	0%	0%	1%	3%	5%	5%	4%	4%	5%	6%	7%	8%	8%	8%	8%	6%	5%	4%	3%	3%	2%	1%	1%	1%	3%	

Figure 43: California Single-Family Homes vs. REUWS toilet flush volume distributions

In order to estimate the percentage of efficient toilets in the California SF sample, the most useful comparison would be against a distribution of flushes from a group of homes which were known to contain only ULF toilets. Fortunately, such a data set is available from the EPA New Home Study. In this study, only homes built after 2001 were included that provide us with a flush volume distribution from only ULF toilets[43]. The comparison of the California SF homes to the EPA New Homes is shown in Figure 44.

If one assumes that the flush distribution for the New Homes represents a true distribution of flush volumes for ULF toilets, then by subtracting the relative frequency in each of the bins at 3.0 gpf or greater for the New Homes from the California Study Homes, we can get an estimate of the percent of non-ULF toilets in the California distribution. This difference comes out to ~30%, which implies that 70% of the toilets in the sample are ULF or better. This approach gives a higher estimate of ULF or better toilet penetration, since in the estimates based on a hard dividing line between efficient and high volume devices none of the flushes above the line are counted as efficient. When the estimate is based on the actual distribution of ULF or better toilets, then a percentage of the flushes above the cut-off are counted in the efficient category based on the empirical data from the New Home study group.

[43] These homes contained predominantly 1.6 gpf toilets based on current building codes to meet the 1992 EP Act. There may have been a few HET toilets, but not a significant number.

Figure 44 also shows that in a population known to be equipped exclusively with ULF toilets, the largest percentage of flushes are between 2.0 and 2.25 gallons. This bin accounts for 25% of all of the flushes. On a cumulative basis, however, 48% of all of the flushes are greater than 2.0 gallons. The fact that such a large percentage of flushes are greater than 2.0 gallons per flush is noteworthy, since if all toilets had been performing as designed one would expect few if any of the flushes would be greater than 2.0 gpf.

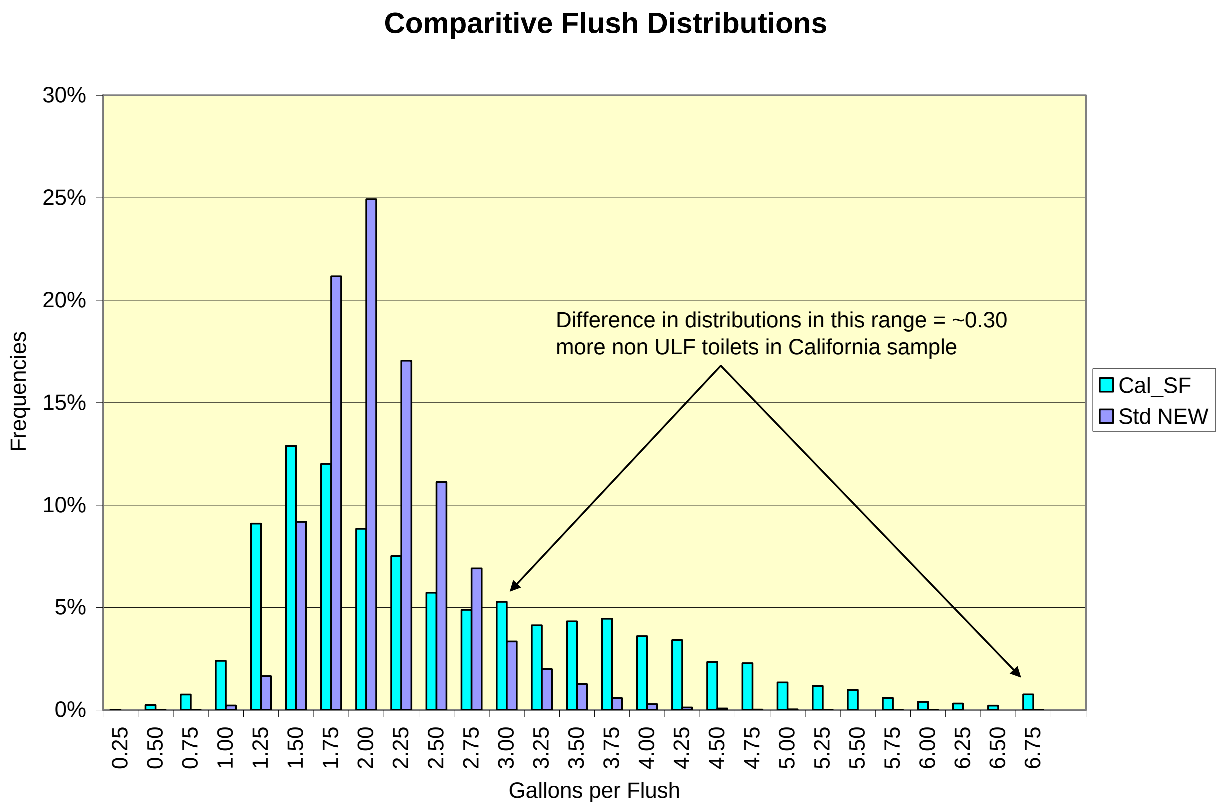
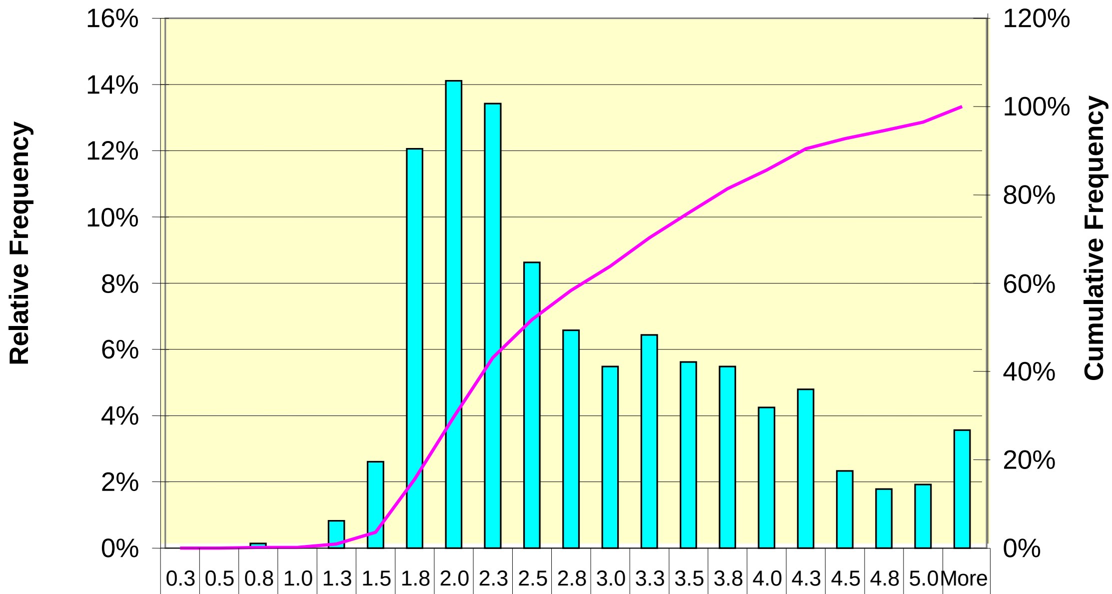


Figure 44: Comparison of California SF Homes to New Homes

From the perspective of the efficiency of household water use, which is the main topic of this research project, it is important to consider household efficiency levels as well as penetration rates of high-efficiency toilets. From this perspective what is important is the percentage of households that are meeting specific efficiency benchmarks for toilet flushing, irrespective of the type of toilet installed. The fact that such a high percentage of ULF toilets are flushing at more than 2.0 gpf is significant in this discussion.

Figure 45 shows the distribution of the average toilet flush volumes in the 732 study homes. The average flush volumes were determined by taking the total volume of water used for toilet flushing in the home over the logging period, and dividing this volume by the number of flushes counted in the home. Hence, the value represents the average of all of the toilets in the home. Figure 45 indicates that 30% of all homes in the group have average flush volumes of 2.0 gpf or less. Note that this does not imply that only 30% of the toilets in the population are ULF or better since, as discussed above the flush distribution data and survey data show that between 64% and 72% of all toilet flushes appear to be caused by ULF or better-rated devices. The question is: why, with such a high percentage of ULF-type toilets in the population, do so few of the homes have average flush volumes of 2.0 gpf or less?



	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.0	4.3	4.5	4.8	5.0	More
R Freq%	0%	0%	0%	0%	1%	3%	12%	14%	13%	9%	7%	5%	6%	6%	5%	4%	5%	2%	2%	2%	4%
Cum %	0%	0%	0%	0%	1%	4%	16%	30%	43%	52%	58%	64%	70%	76%	81%	86%	90%	93%	95%	96%	100%

Figure 45: Histogram of average household flush volumes (N=732)

Even though the data appear different on the surface, there is actually no contradiction between the penetration rates of individual toilets shown in Figure 41 and the percentage of households meeting the efficiency benchmark of 2.0 gallons per average flush. The reason for this is that there is a much wider diversity of the types of toilets found in the homes, and the fact that so many ULF-type toilets are flushing at 2.0 gpf or more.

The fact that houses contain mixtures of toilets is important for understanding how toilet replacements impact household toilet use. For a house to meet the efficiency metric established for this study, all of the toilets in the home must be flushing at or near the ULF standard (~1.6 gpf). Homes with one ULF and one high volume toilet will not meet the criterion. They will be flushing at an average of ~2.5 gpf. In a group of 100 homes with two toilets per home: if as suggested by the data, 30% have two ULF toilets and 60 % have one ULF toilet, and 10% have no ULF toilets this would require 120 out of 200 toilets, or 60% of all of the toilets be ULF models. So, a household saturation of 30% implies a fixture saturation of ~60%, which is precisely what these data show.

In order to examine the mixture of toilets within individual homes a toilet uniformity factor was calculated for each home in the study. This factor was the ratio of flushes less than 2.2 gallons to the total number of flushes recorded for the home. The distribution of these factors for study homes is shown in Figure 46. The Y axis of this graph represents the percent of homes having the percent of their total flushes at 2.2 gal or less shown on the X axis. The data on the left end of the graph represent homes with few sub-2.2 gallon flushes and the data on the right side represent homes with a high percentage of sub-2.2 gallon flushes.

The graph shows that 25% of the homes had less than 5% of the flushes recorded at less than 2.2 gallons. These homes are most likely not equipped with any ULF toilets, or if they have a ULF they never use it, or they may have one or more malfunctioning ULF toilets. On the other side of this equation this shows that 75% of the homes appear to have at least one ULF toilet. The 25% of homes with no ULF toilets represent opportunities for substantial conservation.

On the right side the graph the data show that there are 11% of the homes where 95-100 percent of the flushes were less than 2.2 gallons. These are homes that are in all likelihood fully equipped with all ULF toilets or better. As one moves toward the center of the graph the data represent homes with more even mixes of ULF or better and high volume toilets. This type of distribution makes a lot of sense for a population of existing homes that are gradually being retrofit with higher efficiency toilets.

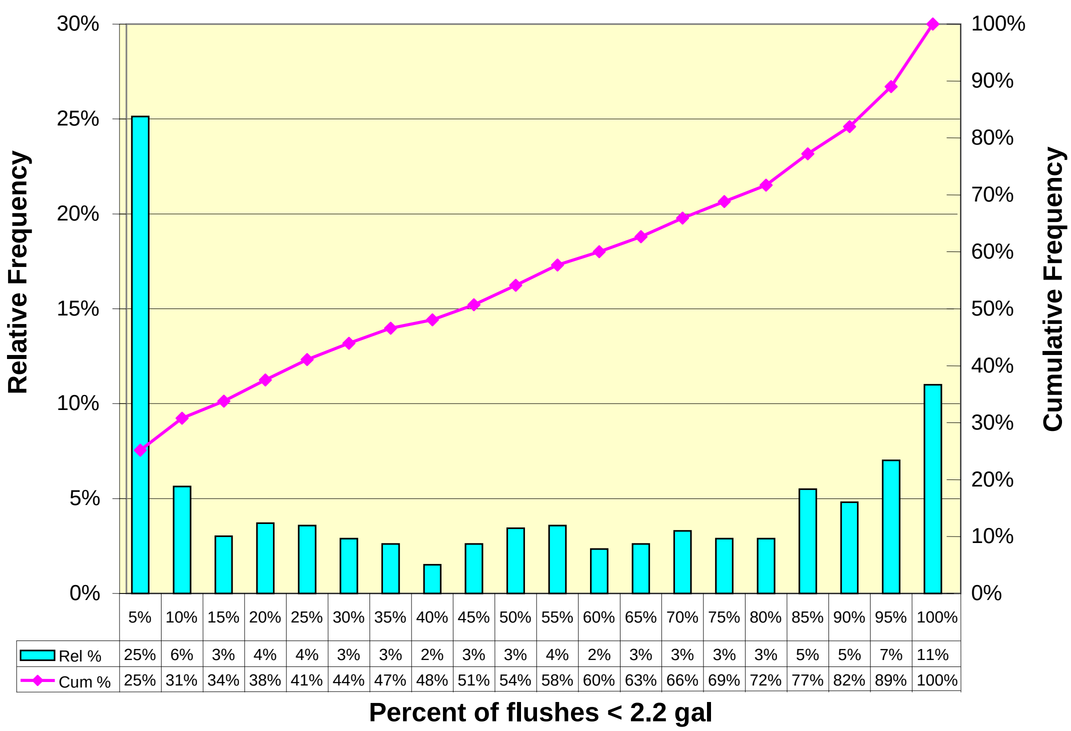


Figure 46: Percent of houses with varying -percentages of ULF flushes

Clothes Washer Use

Table 40 shows the statistics for clothes washer use in the northern sites. There were a total of 7,935 loads of clothes registered during the logging. This worked out to an average of 0.96 loads per house per day. The average load used 36.0 gallons of water and the median load volume was 37.0 gallons. A total of 29% of the loads were less than 30 gallons.

Table 40: Clothes washer statistics

Parameter	Value
Total number of loads in database	7,935
Average loads per household per day	0.96
Average gallons per load	36.0
Median gallons per load	37.0
% of loads < 30 gal	29%

The distribution of load volumes from the data is shown in Figure 47. At the time of the REUWS only around 1% of the clothes washers used less than 30 gal, so the current data represents a major advance, but the data also show that there is still significant potential for savings in clothes washer use. One can also use Figure 47 to determine the effect of using different criteria for high-efficiency houses. For example, if the limit were set to 25 gpl, only 20% of the houses would fall into the high-efficiency definition. We know that during the study period there were many clothes washers that use 25 gpl or less. These machines would have water factors of seven or less, where the water factor equals the volume per load per cubic foot of capacity.

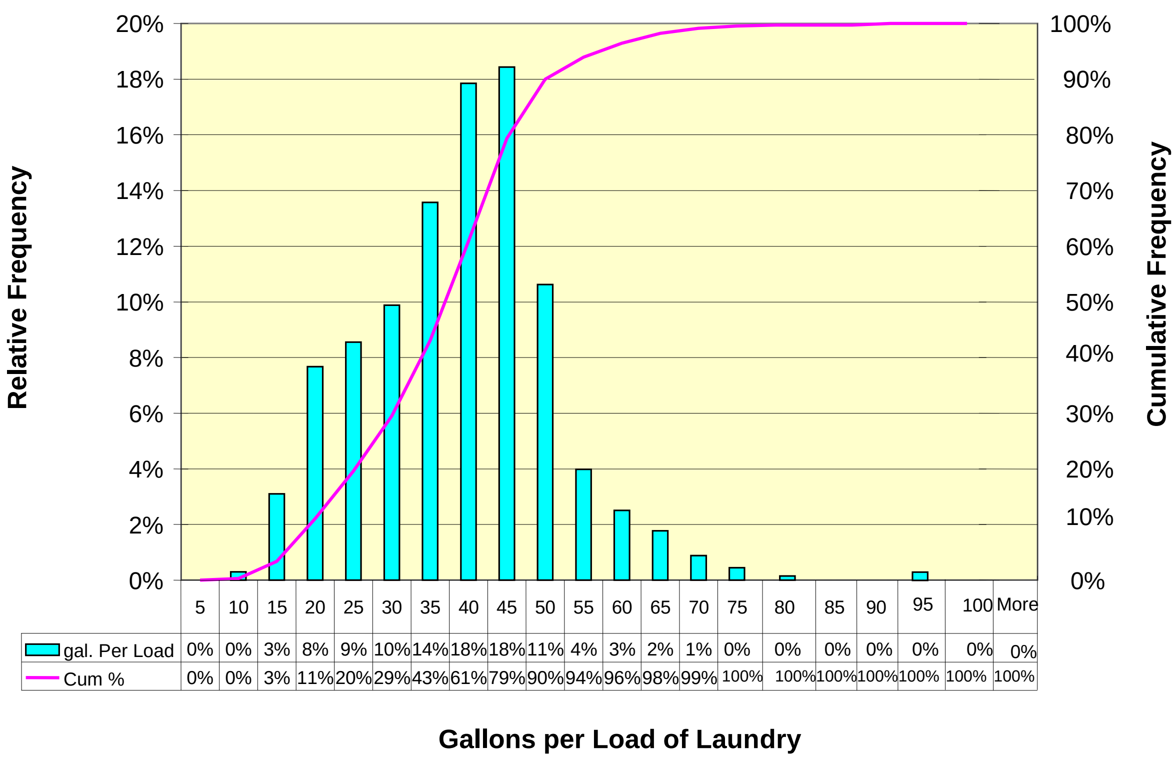


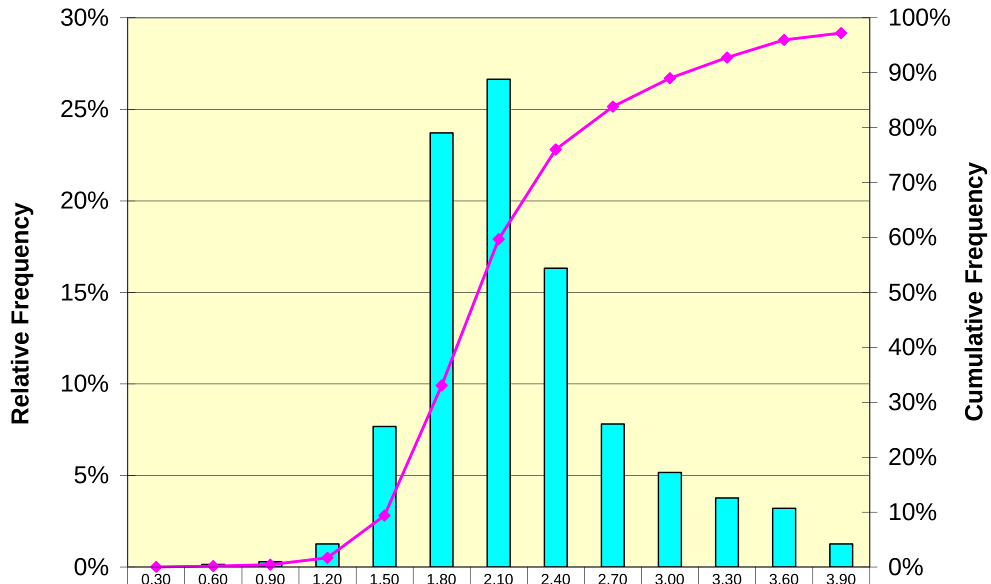
Figure 47: Distribution of clothes washer volumes

Shower Use

As shown in Table 41, there were a total of 17,334 showers identified in the site flow traces. The average flow rate of these showers was 2.14 gpm, and the median flow rate was 1.99 gpm. The average shower volume was 18.2 gallons. The distribution of individual shower flow rates, shown in Figure 48, indicates that the nearly 80% of all showers are flowing at 2.5 gpm or less. These data indicate that the market is close to saturated with respect to 2.5 gpm showerheads. The distribution of shower volumes, shown in Figure 49, shows a fairly normal distribution with the mean use of 18.2 gallons per shower.

Table 41: Shower statistics

Parameter	Value
Total number of showers in database	17334
Average number of showers per day per household	1.97
Average gallons per shower	18.18
Average shower duration (minutes)	8.7
Median shower duration (minutes)	8.3
Average shower GPM	2.14
Median shower GPM	1.99
Percent at 2.5 GPM or less	79%



	0.30	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	3.30	3.60	3.90
gal. Per Load	0%	0%	0%	1%	8%	24%	27%	16%	8%	5%	4%	3%	1%
Cum %	0%	0%	0%	2%	9%	33%	60%	76%	84%	89%	93%	96%	97%

Figure 48: Distribution of shower flow rates

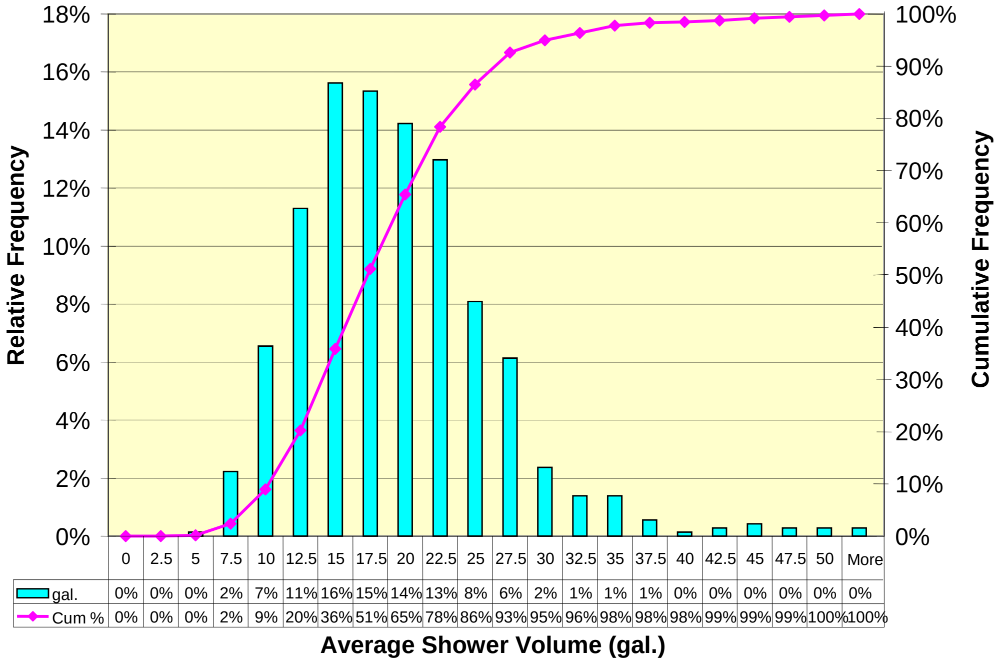


Figure 49: Distribution of shower volumes

Leakage and Continuous Uses

In evaluating the leakage data it should be kept in mind that leakage is a category like faucet use, and that it contains events that don't fit in other categories and appear to be unintentional leakage. In some cases, however, events may give the appearance of leakage, even though they are not leaks. The case of the constantly running reverse osmosis system was discussed above, for example. So, technically, leaks should be thought of as a group of events that include true water leaking from the system, as well as other events that give the appearance of leakage. The statistical modeling section describes the factors, such as automatic irrigation systems and swimming pools and home water treatment systems that are related to increased leakage rates.

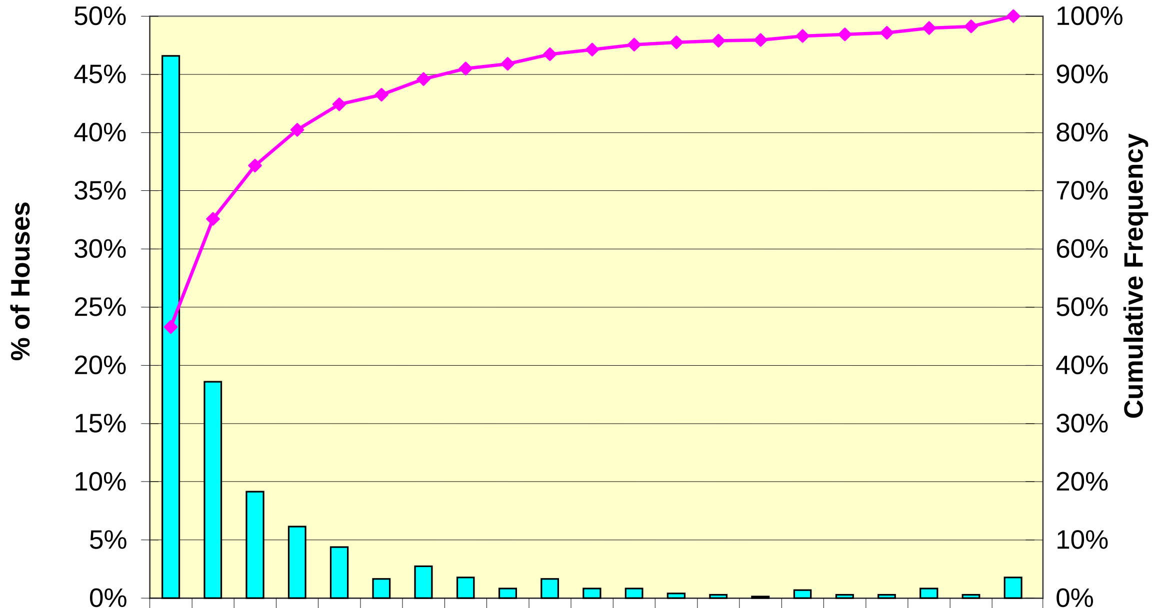
The leakage patterns from this group of homes show the same heavily-skewed distribution that leaks in all other end use studies have shown. The majority of homes were found to "leak" at low rates. During the 9021 logged days in the study, the average daily leakage rate was 30.8 gallons, but the median leakage was only 11.5 gallons. The distribution of the number of homes leaking at various rates, shown in Figure 50, indicates that 14% of the homes are leaking at more than 50 gpd, and that 7% of homes "leak" over 100 gpd. It is likely that due to the transitory nature of leaks that the list of high "leak" homes is slowly changing over time as old leaks are repaired and new leaks develop elsewhere.

The homes with leakage rates of 10 gpd or less make up 45% of the sample. These are from short duration leaks which would probably never show up in an audit, and which might be due to things like how people operate faucets. Leakage at 10 gpd or less is probably unavoidable.

Homes with old or inaccurate meters, which do not pick up very low flows, may have their leakage rates understated.

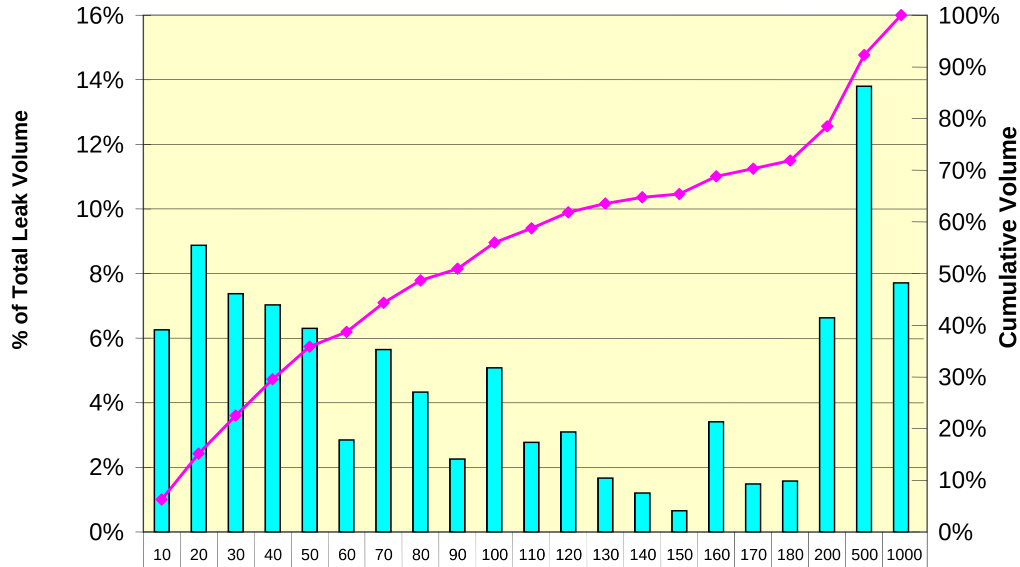
Table 42: Statistics on leakage

Parameter	Value
Total number of days in database	9,021
Average leakage, gpd	30.8
Median leakage, gpd	11.5
Max leakage in set, gpd	687
% houses w/ leakage > 50 gpd	14%
% of house w/ leakage > 100 gpd	7%



	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	More
Rel %	47%	19%	9%	6%	4%	2%	3%	2%	1%	2%	1%	1%	0%	0%	0%	1%	0%	0%	1%	0%	2%
Cum %	47%	65%	74%	80%	85%	86%	89%	91%	92%	93%	94%	95%	95%	96%	96%	97%	97%	97%	98%	98%	100%

Figure 50: Percent of homes by leakage rate



	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	200	500	1000
% of Vol	6.3	8.9	7.4	7.0	6.3	2.8	5.6	4.3	2.3	5.1	2.8	3.1	1.7	1.2	0.7	3.4	1.5	1.6	6.6	13.8	7.7
Cum %	6.3	15.1	22.5	29.5	35.8	38.7	44.3	48.7	50.9	56.0	58.8	61.9	63.5	64.7	65.4	68.8	70.3	71.9	78.5	92.3	100

Leakage Rate (gphd)

Figure 51: Percent of total "leak" volume by leakage rate

When one looks at Figure 50, the impact of the homes with high leakage rates seems small. These homes represent a very minor percent of all of the homes. The situation is drastically altered when the percent of total "leak" volume is plotted against the leakage rates. Figure 51 shows that when the percentage of the total "leak" volume in the study homes is plotted against the leakage rates, the homes in the upper bins take on a significance that far exceeds their numbers. Although only 7% of all homes were found to be leaking at more than 100 gpd, these homes accounted for 44% of the leakage volume.

As discussed in Chapter 5, large, long-duration leaks may be due to real leakage - (broken valves, - leaky pipes, etc.)- or they may be due to a "legitimate" water use that gives the appearance of leaks. We used regression models for leakage to test the impact of a number of factors that might contribute to leaks, or have water use characteristics that give the appearance of leaks. For example, swimming pools and automatic irrigation system both tested positive for leakage. Both of these types of system are subject to real leaks, but they may also use water in a way that looks like a leak, in some cases. We don't believe that either of these systems can explain more than a very few of the continuous leaks observed.

A swimming pool might require four inches of make-up water during the hottest week of the year. This is equivalent to 2.5 gallons per square foot of pool surface. For a 500 sf pool this would require 1250 gallons of water per week or 180 gpd. At a flow rate as low as 1.0 gpm this would require three hours of flow, and would not result in a continuous 24-hour-per-day flow.

Irrigation systems normally have very well-defined operating intervals and start times. Even drip systems normally operate on a regular schedule for intervals of less than an hour. No irrigation system should ever require 24-hour operation. A leaky zone valve, however, can easily explain a continuous flow of water through the system.

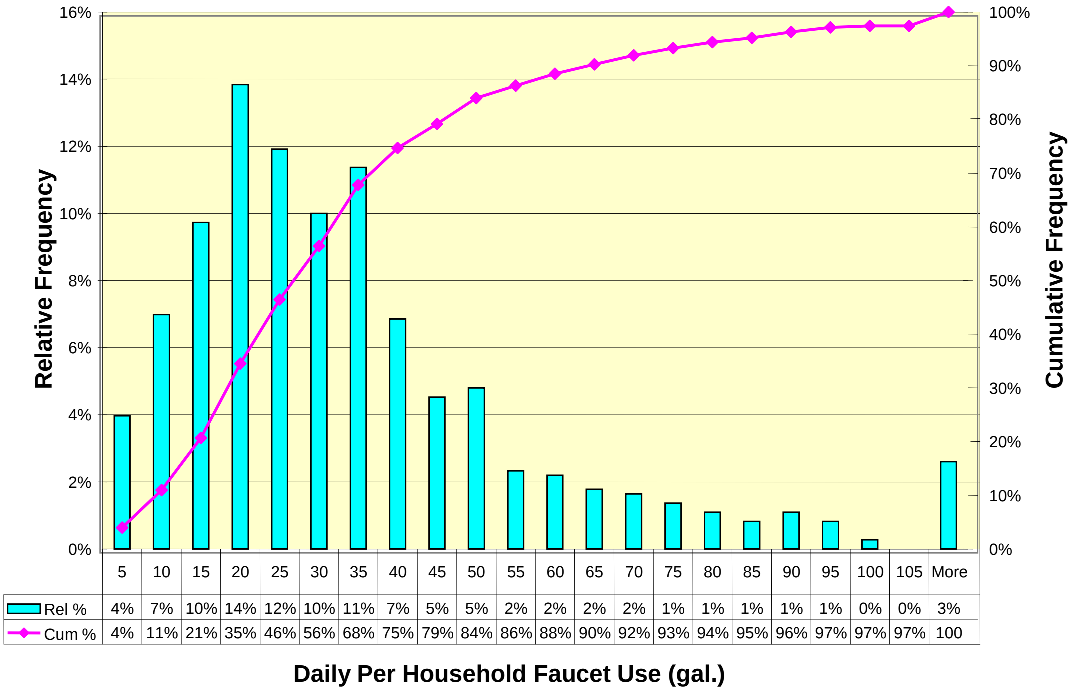
The only case where a continuous flow could be explained would be if a household was attempting to treat all of the water used for indoor purposes with an RO system, but very few homes in the study had these types of systems, and of the ones that did, we do not know precisely how they are operated. It is unlikely, however, that enough homes are practicing this type of total indoor treatment to sway the results.

Faucet Use

While faucet use is not as heavily skewed as leakage, it does resemble the leakage pattern in shape. Faucet use tends to be a category that collects miscellaneous uses that do not clearly fall into the other categories. Ice machines and normally operating pool fillers will get categorized as faucets, unless they have very distinctive flow patterns. The types of activities requiring faucet use -are very diverse and difficult to determine without intrusive investigations into the home. The survey information from the study should throw some light on the factors that affect faucet use. The basic statistics of faucet use are shown in Table 43.

Table 43: Faucet statistics

Parameter	Value
Total number of days in database	9021
Total number of faucet events	538,484
Average faucet events per day	57.4
Median number of faucet events	42.9
Average duration of faucet event	37 sec
Average peak flow of faucet events	1.1 gpm
Average volume of faucet events	0.6 gal
Average faucet use,	33.0 gphd
Median faucet use,	27.0 gphd
Max faucet use in set	220 gphd
% houses w/ faucet use > 50 gphd	16%
% of house w/ faucet > 100 gphd	3%



	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	More
Rel %	4%	7%	10%	14%	12%	10%	11%	7%	5%	5%	2%	2%	2%	2%	1%	1%	1%	1%	1%	0%	0%	3%
Cum %	4%	11%	21%	35%	46%	56%	68%	75%	79%	84%	86%	88%	90%	92%	93%	94%	95%	96%	97%	97%	97%	100

Figure 52: Distribution of daily faucet use (gphd)

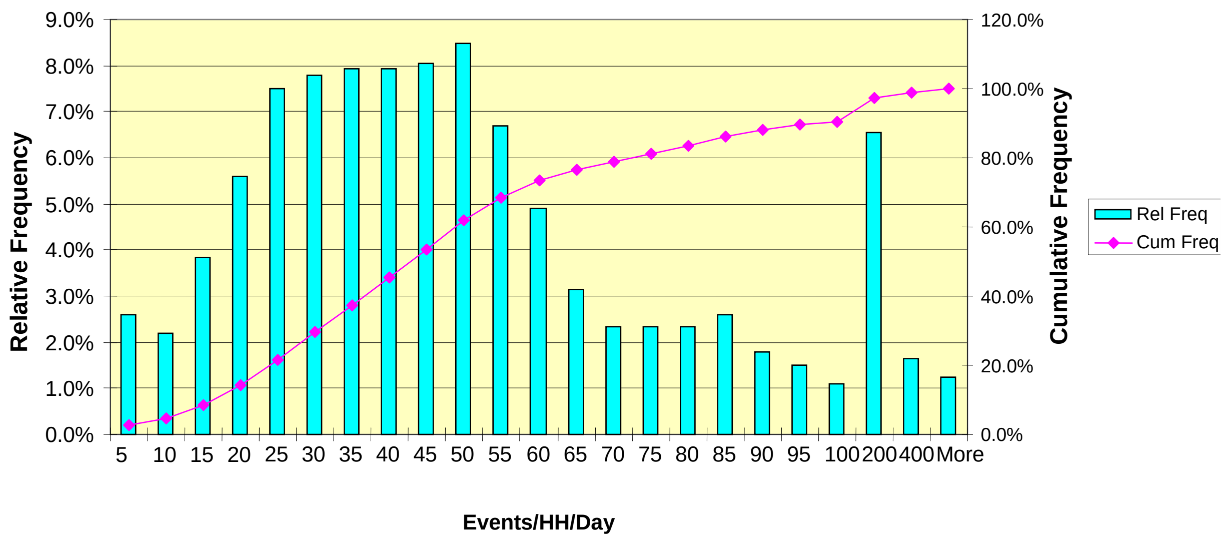


Figure 53: Distribution of number of faucet events per household

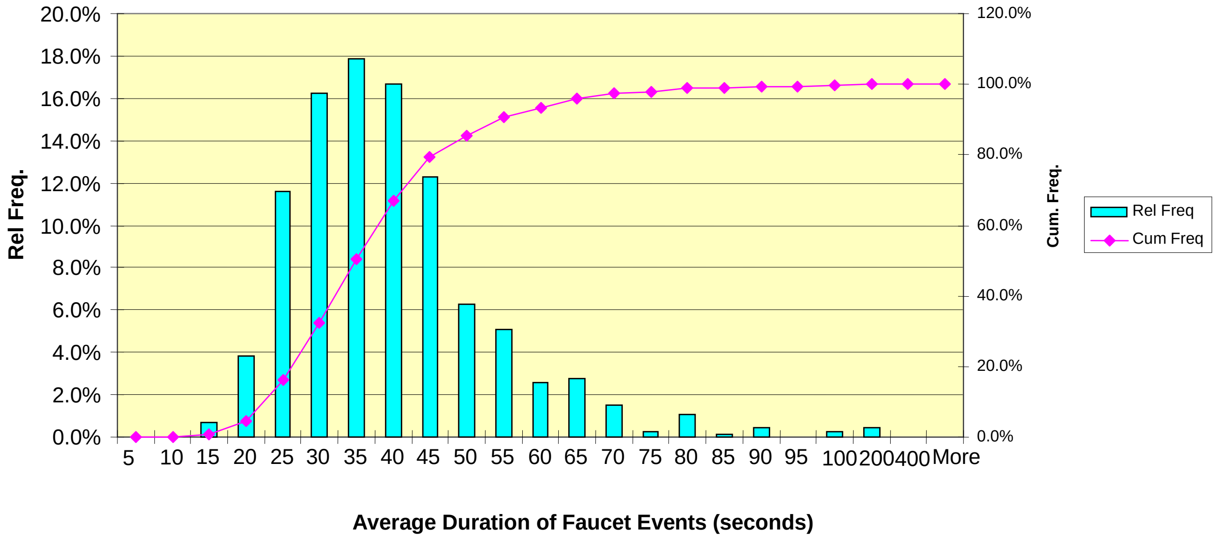


Figure 54: Average duration of faucet events (sec)

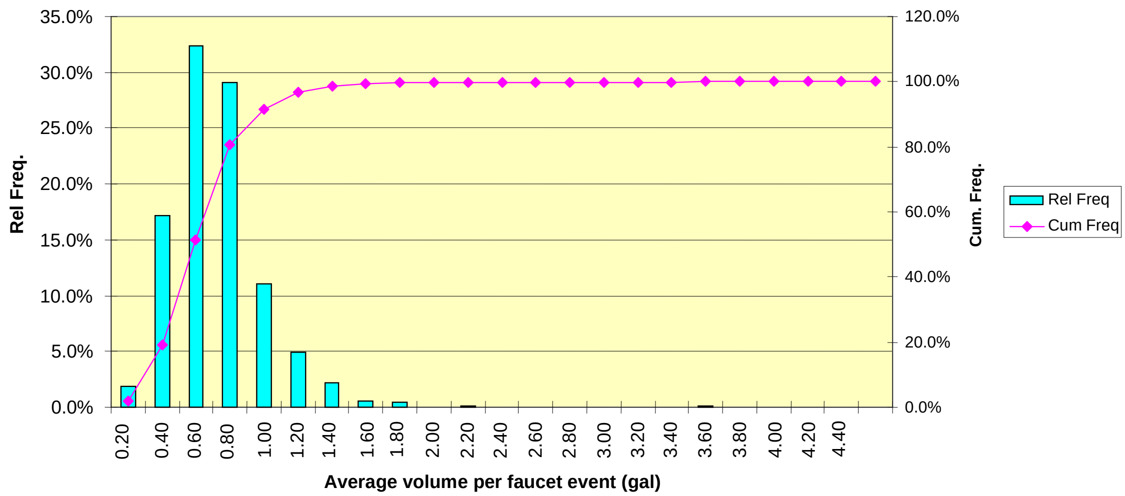


Figure 55: Average volume per faucet events (gal)

Percentages of Homes Meeting Efficiency Criteria

One of the main goals of this project was to determine the percentage of homes that are equipped with the types of efficiency fixtures and appliances encouraged by the Best Management Practices.

One thing that the data loggers cannot tell, however, is the make and model of the fixtures and appliances present in the homes. This information needs to come from either survey responses or in-home audits. Consequently, the efficiency evaluations in this study are performance-based. They show the water use level for the household. While the amount of water that a device uses is indicative of its efficiency level, it is always possible for a highly efficient device to be out of adjustment, or for a low efficiency device (like a toilet) to have been modified to perform at a higher level. There are many instances of toilets rated as ULF devices flushing at more than 1.6 gpf. These toilets, if they flush at more than 2.2 gallons, would not be counted as efficient devices in our analysis even though they are physically present. On the other hand, older toilets with dams or displacement devices may be flushing at less than 2.2 gpf, and these would be counted as ULF devices.

In order to qualify as efficient each home had to meet the criteria for each device shown in Table 44. A careful reader will notice that the criteria used for household toilet use, 2.0 gpf, is slightly lower than that allowed for individual toilet flushes, which was set at 2.2 gpf. This was done intentionally because we wanted to allow a greater degree of variability for the individual flushes than for the overall average flush volumes.

The results of the household efficiency analyses for the combined sites are shown in Figure 56. In the case of clothes washers, where there is normally only one washer per home, 30% is a good estimate of the actual penetration rate for high-efficiency clothes washers. In the case of showers, there may be old showerheads in the group that have gradually fallen back to the 2.5 gpm flow rate due to degradation or mineralization. In the case of toilets, where there are typically two or more toilets per home, and each home will have its own mixture of standard and ULF or better devices, it would require a higher percentage of individual toilets to achieve a given level of household efficiency. The data in this study suggest that 60% or more of the individual toilets are ULF or better devices, but due to the mixing of ULF and high volume toilets in the homes and the wide variation in actual toilet flush volumes, only 30% of the households have average flush volumes (for all recorded flushes) of 2.0 gpf or better.

Table 44: Metrics used for efficiency determination

Device	Efficiency Criteria
Toilets	Ave gallons per flush < 2.0 gpf
Showers	Ave shower flow rate < 2.5 gpm
Clothes washers	Ave load uses < 30 gal

In the case of clothes washers, a load volume of 30 gallons per load would be equivalent to a water factor of 8.6 gal/cf for a 3.5 cubic foot machine. In 2005 these represented high-efficiency machines. Current clothes washer water factors for the best efficiency machines are 4.5 or better, which would equate to less than 16 gallons per load.

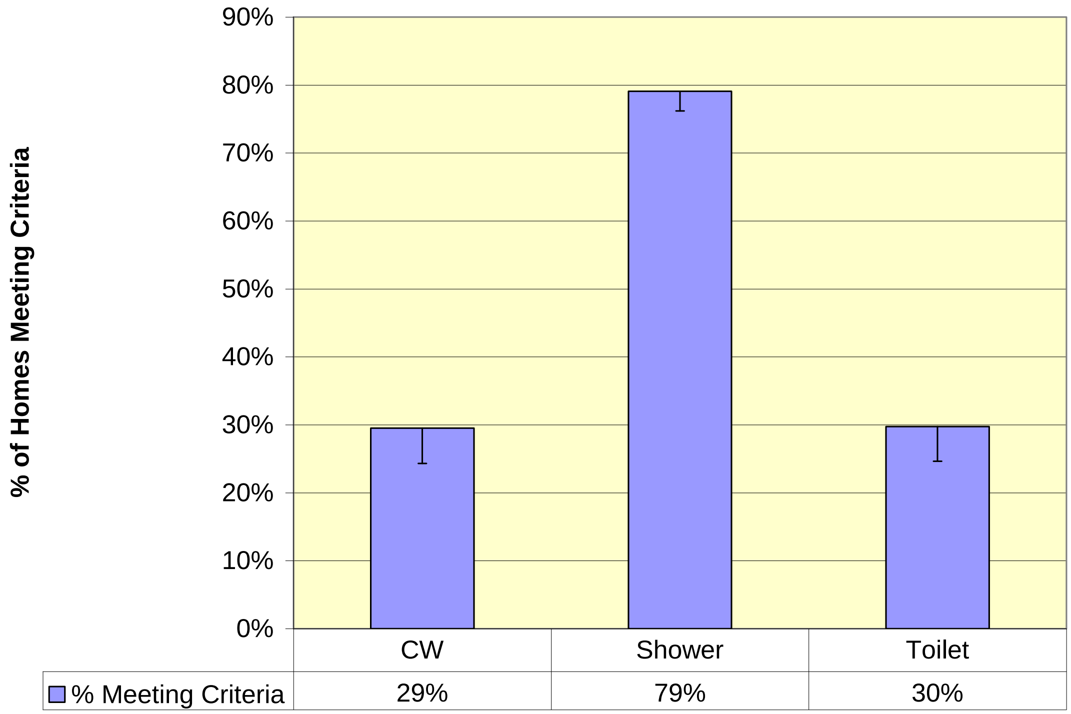


Figure 56: Percentages of homes meeting efficiency criteria for toilets, showers and clothes washers

Outdoor Use

There were a total of 734 homes for which valid flow trace data were obtained, which we included in the indoor analyses. Of these a total of 639, or 87%, appeared to be irrigating. Evidence of irrigation came from analysis of aerial photography on 612[44] lots for which aerials could be obtained and 25 lots in the remaining 120 for which aerials could not be obtained, but for which the annual water use was too high to be for indoor uses only. The following analyses are based on the sample for which aerial photos were available, and are thought to be representative of the irrigators in the group. All of the data reported in this section includes the revised irrigated areas resulting from the re-analysis of new aerial photos from the IRWD and EBMUD service areas done in January 2011. It should be kept in mind that when estimating means for the population it is necessary to apply a correction factor since these customers make up only 87% of the entire population. The same is true for each study site. For example, the average outdoor use in the EBMUD irrigating homes was 60 kgal, but since only 76% of the homes in the population appeared to be irrigating, the average outdoor use for the population would be closer to 46 kgal, which compares well with the seasonal use shown in Table 34 of 47 kgal (129 gpd x 365).

Table 45: Outdoor use in irrigating homes

Group	Average Annual Outdoor Use (kgal)	Number
All logged homes	82.0	734 (100%)
Homes that were irrigating	92.4	639 (87%)
Homes with aerials	92.6	614 (84%)

The procedure used for analysis of the outdoor use was described in detail in Chapter 5. The major parameters that were used for inputs in that analysis were:

- Annual outdoor water use (kgal)
- Lot size/irrigated area of lot (sf)
- Landscape coefficient (weighted average of crop coefficients for landscape)
- Irrigation efficiencies
- Net ETo

Outputs used for the analysis were:

- Theoretical irrigation demand
- Actual irrigation application
- Excess (deficit) use

[44] Reduced from 614 after area reviews by IRWD and EBMUD.

Lot Size

The statistics for lot size are shown in Table 46, and the distribution of lot sizes is shown in Figure 57. Lot sizes are skewed to the right side, with the average lot size being significantly larger than the median.

Table 46: Lot size statistics

Parameter	Lot Size (sf)
Average	9219 ± 985
Median	6855
Maximum	226,670

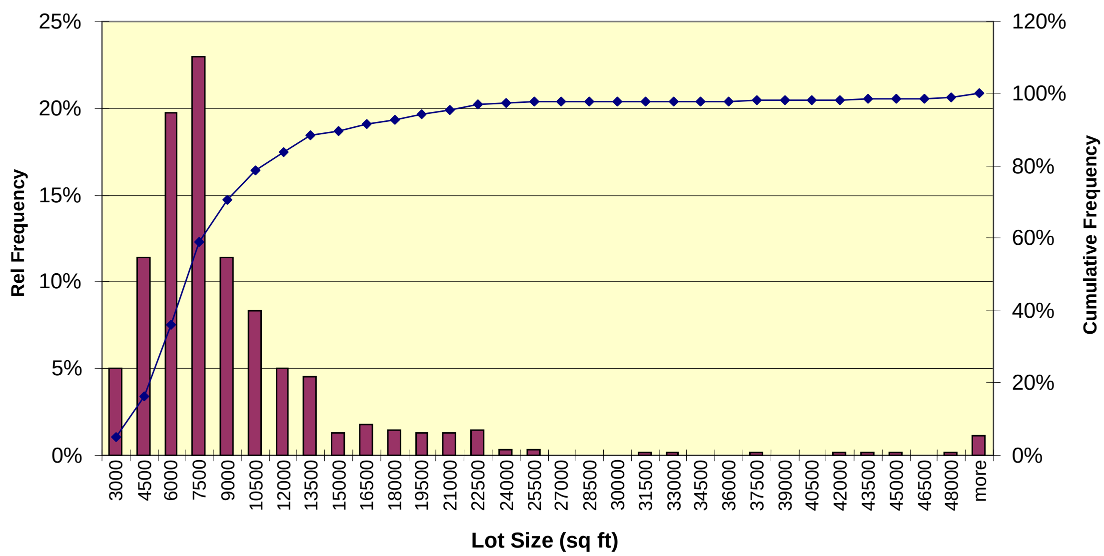


Figure 57: Distribution of lot sizes in California Single-Family Water Use Study group

Annual Outdoor Use Volumes

The average annual outdoor water use is shown in Table 47. This value ranged from a low of 17 kgal per account to a high of 226 kgal per account. The average outdoor use for all of the sites was 92.7 kgal per year. These estimates are based on the data logging results and are not the same as the estimates generated from analysis of the billing data, which were based on seasonal and non-seasonal use. Normally, data logging gives a lower estimate of indoor use and a higher estimate of outdoor use than billing records. This is because there is usually some outdoor use occurring in the winter months, which is included in the non-seasonal billing estimate. If this is used as a proxy for indoor use, it will somewhat overstate the indoor use and understate the outdoor use.

- In this study group the average non-seasonal use determined from billing data was 75 kgal/year, and the average outdoor use estimated from data logging was 93.6 kgal/year.

The distribution of outdoor use follows a log normal pattern as shown in Figure 58. This figure presents the percent of all customers that are using various volumes of water for outdoor purposes. When based on the numbers of customers, the large users appear of little significance. When presented on the basis of the percent of the total outdoor water use for which each consumption bin accounts, the situation appears different.

As shown Figure 59, the large users account for a percent of the total volume of outdoor use out of proportion to their numbers. For example, only 33% of the customers use more than 100 kgal per year for outdoor uses, but these customers account for 62% of the total outdoor use.

Table 47: Outdoor water use statistics for irrigating homes

Parameter	Outdoor Water Use (kgal)
Average	93.6 ± 7.06
Median	67.9
Maximum	644

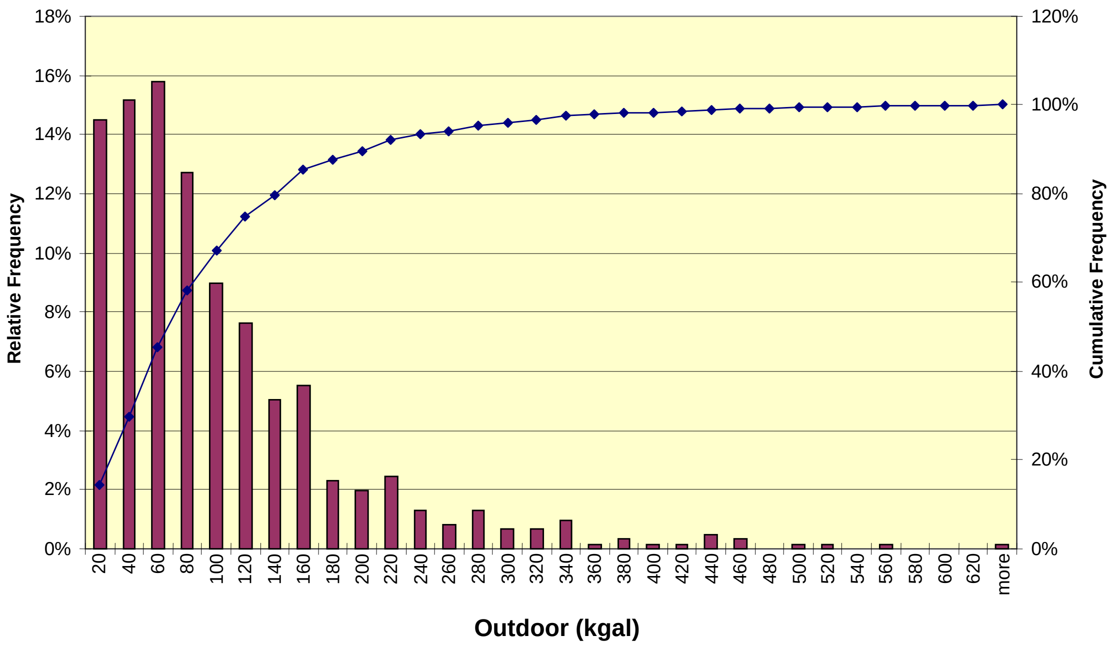


Figure 58: Percent of homes by annual outdoor use volume

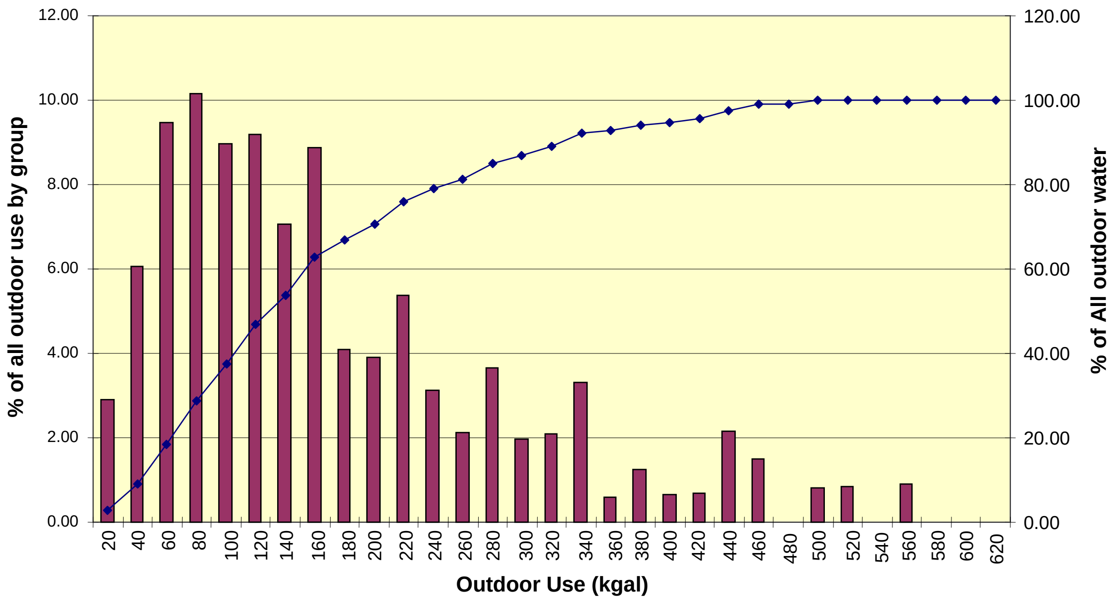


Figure 59: Percent of total annual outdoor use by household use volume

Irrigated Area

The irrigated areas in this report have been reviewed by the agencies, and in some cases updated using newer aerials as was the case for IRWD and EBMUD. In the case of IRWD the revised areas are larger than the original analysis, and in the case of EBMUD the revisions led to decreases in the estimates. The key factors that led to the revisions lay in how parcels were classified as either non-turf or xeric plant covers as opposed to non-irrigated land. In the aerial photos it was often difficult to draw a clear distinction in these marginal lands. Modifications were also made to several lots in the Sonoma County Water Agency service area to ensure consistency in how tree canopy was measured. In all cases a combination of the aerial photos and notes from the field verification were used as guides for the determination.

The statistics for the irrigated areas for the study group are shown in Table 48. The areas are skewed to the right with the median values significantly lower than the average. The distributions of areas are shown in Figure 60, which shows the percentage of the homes with larger areas dropping off geometrically with increasing areas. As shown in Figure 61, there was a correlation between irrigated area and total lot size demonstrated by the data. This is useful because it is much easier to obtain lot size information than irrigated area information, and having a relationship to predict irrigated area makes it possible to do projections for populations more easily. The distribution of irrigated areas in the study homes is shown in Figure 60.

Table 48: Irrigated areas

Parameter	Irrigated areas (sf)
Average	3370± 232
Median	2648
Maximum	31,504

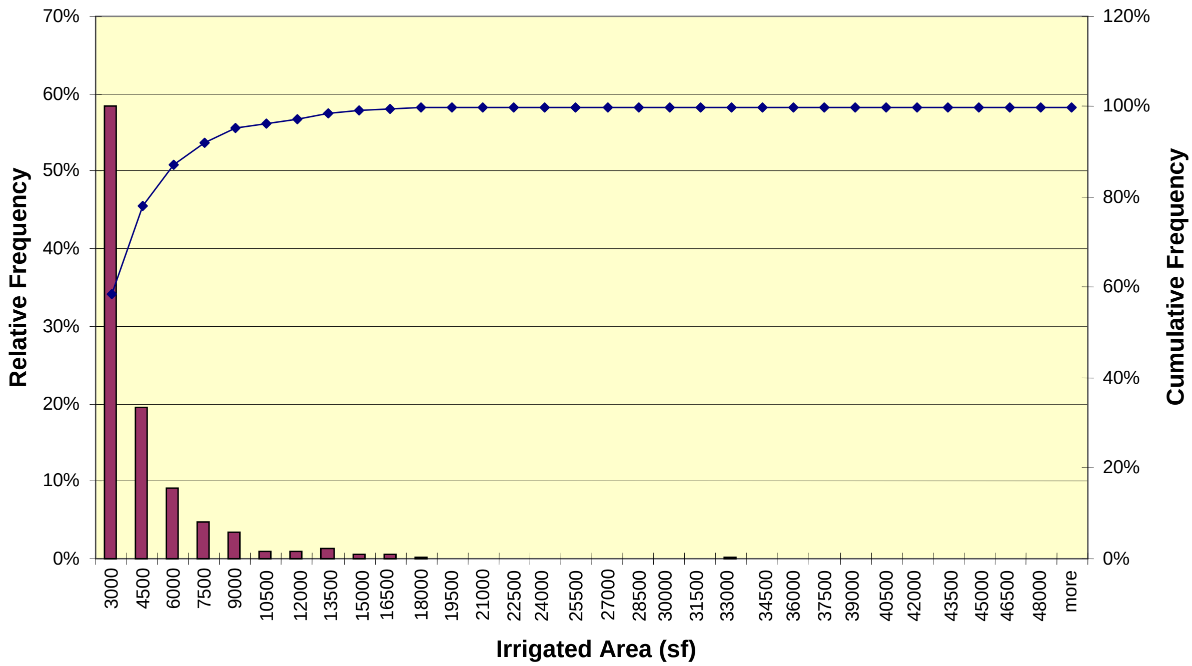


Figure 60: Distribution of irrigated areas

Figure 61 shows the relationship between irrigated area and lot size for the study homes. Logically, one would expect that the best fit line between lot size and irrigated area would pass through the origin, since lots with no area would also have no irrigated area. In fact, the best fit line does not pass through the origin, but crosses the irrigated area axis at a positive value when the total lot size is zero, and this line provides a higher R^2 value than one that does pass through the origin. The reason for this is that the large lots with little irrigated area on the right end of the diagram skew the results. The smallest lot in the study group, located in Davis, had a total area of 1263 sf and an irrigated area of 651 sf. Use of the relationship for lot sizes smaller than this is pushing it beyond its reasonable range. The relationship shown in this figure would be useful for making predictions of irrigated area on a population of single-family homes for planning purposes. Based on the amount of scatter in the data, however, it would not be a good predictor for individual lots or small groups of lots.

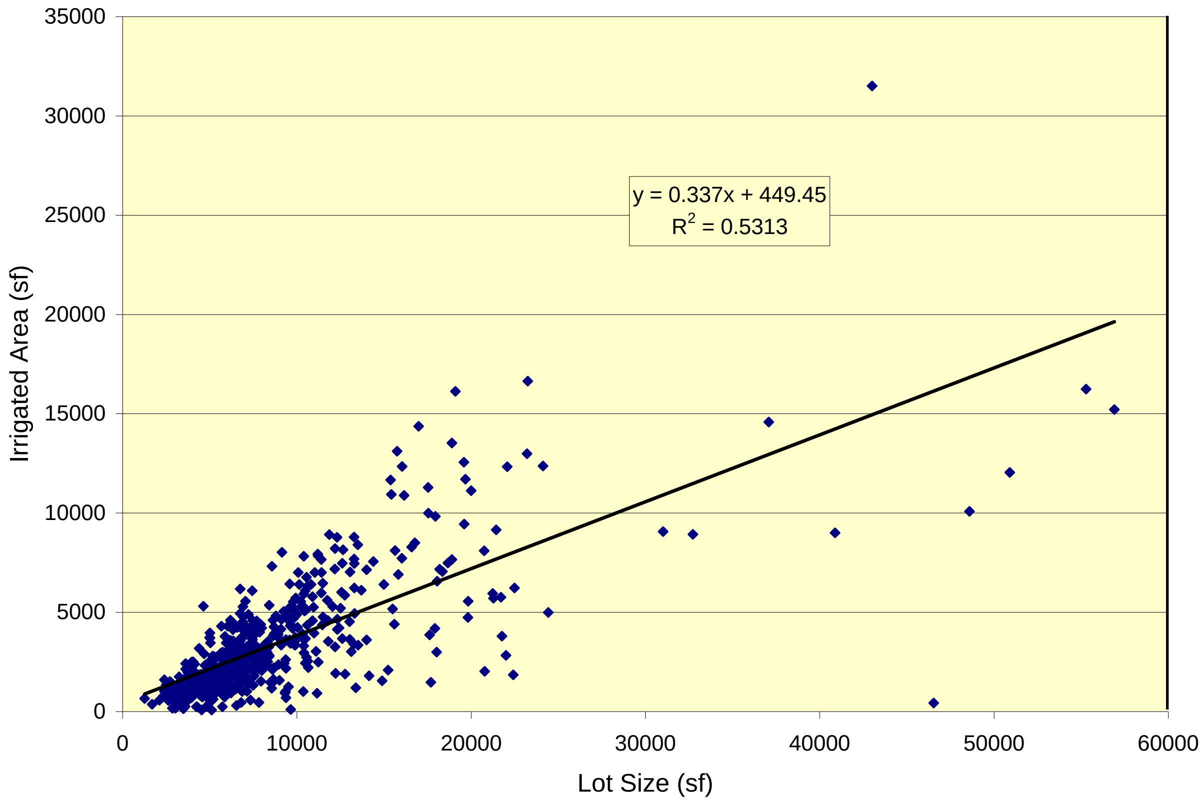


Figure 61: Irrigated area versus lot size

Our experience with determining irrigated area in this study shows that it is more complicated than one would first think. Many aerial photos are poorly suited to irrigated area determination. Photos are often taken during early spring before leaves are out, and these do not show irrigation well. Photos are often of low resolution, which makes it difficult to detect details that would help. It is optimal to take photos with infrared wavelengths, which greatly help to identify the areas that are being irrigated. In most urban areas it is appropriate to give lots areas that are covered with vegetation some level of crop coefficient, which results in a water requirement being generated. In some areas, though, lots include historic (legacy) forests or grasslands that are not part of the irrigated landscape. Defining these, and making sure that only areas with legitimate irrigation requirements are included in the TIR calculations is a challenge, even with ground verification.

Irrigation Application Rates

The volume of water applied, divided by the irrigated area, yields a value of gallons per square foot, which can be converted to inches based on the relationship that 0.623 inches of water equals 1 gpsf, which represents the average application rate for the landscape. When this was done for each of the irrigating homes, the actual application rates were determined, and the average application rate for each site was calculated. Two of the ten sites were found to be applying less than the Net ETo and eight were applying more, on average. Overall, the sites were applying more than the Net ETo during the study year.

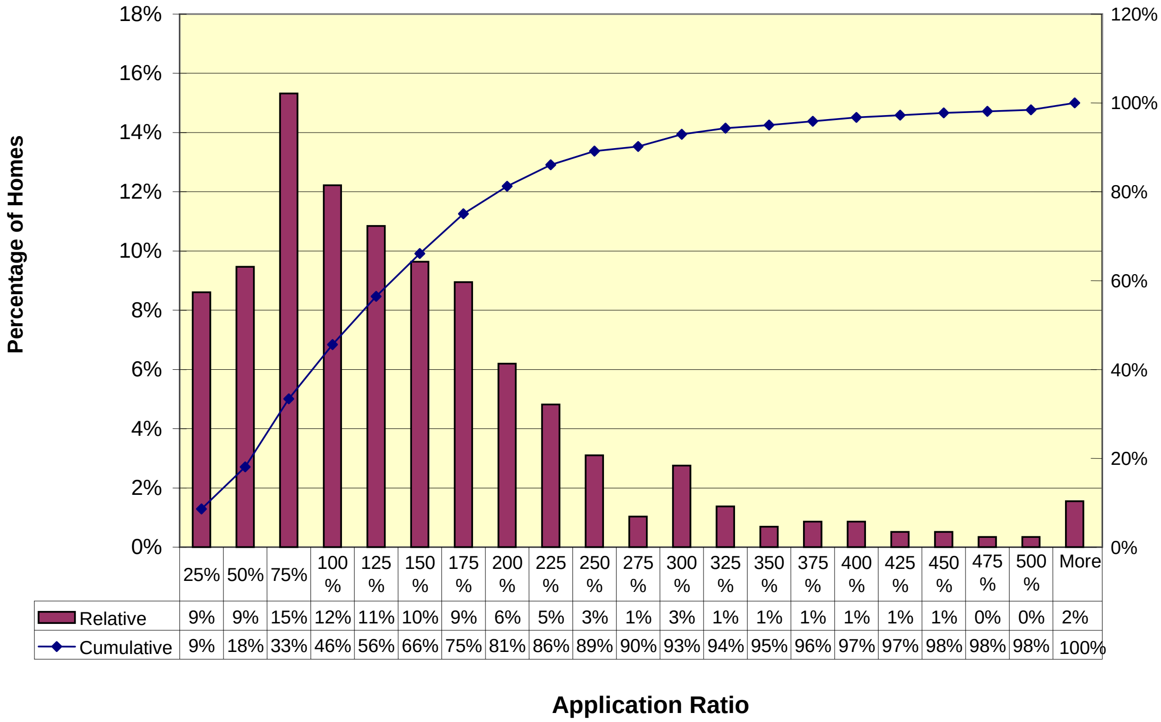
The data on application rates provides information about depths of applications, but it does not tell how much actual irrigation water is being used since small lots may be applying at high rates, but since their areas are small the volumes of water are small also.

Irrigation Application Ratios

As discussed in CHAPTER 5 the theoretical irrigation requirement is related to the ETo, the irrigated area, the crop coefficients of the plantings and the irrigation efficiencies. When all are considered the theoretical irrigation requirement for each lot can be estimated in either gallons or inches. The ratio of the actual irrigation application to the theoretical irrigation requirement is referred to as the application ratio. When this is greater than one there is excess irrigation occurring, and when it is less than one there is deficit irrigation.

The application ratios are key parameters in assessing irrigation use because they indicate at a glance whether a given site is over- or under-irrigating. They do not however, tell anything about volumes of excess use because these depend on the irrigated areas and the volumes of the theoretical irrigation requirements. To elaborate on this point, the overall average application ratio is 1.36, but that does not mean that the volume of outdoor use represents 136% of the overall TIR. The reason for this is that the irrigation volume is the product of the application ratio times TIR for each lot. The group contains small lots with high application ratios but small volumes of excess irrigation and large lots with smaller application ratios but very large volumes of excess use.

Another key fact is the distribution of excess irrigation. Figure 62 shows the distribution of application ratios in the study homes. This shows a typical log normal distribution with around 2% outliers at the top end. The fact that 46% of the homes are not over-irrigating is a very important fact to keep in mind when designing irrigation conservation programs, such as weather-based irrigation controllers, or improved irrigation scheduling. Customers who are deficit irrigating need to be approached differently than customers that are over-irrigating, and programs need to target them appropriately.



	25%	50%	75%	100 %	125 %	150 %	175 %	200 %	225 %	250 %	275 %	300 %	325 %	350 %	375 %	400 %	425 %	450 %	475 %	500 %	More
Relative	9%	9%	15%	12%	11%	10%	9%	6%	5%	3%	1%	3%	1%	1%	1%	1%	1%	1%	0%	0%	2%
Cumulative	9%	18%	33%	46%	56%	66%	75%	81%	86%	89%	90%	93%	94%	95%	96%	97%	97%	98%	98%	98%	100%

Figure 62: Distribution of application ratios in study homes

Percentage of Lots With Over-Irrigation

Approximately 44% of the lots on which irrigation was occurring were over-irrigating. This is equivalent to 38% of all of the logged lots because only 87% of the lots in the study group appeared to be irrigating. As pointed out in the following section, most of the excess use is occurring on a small percentage of the lots. The gross percentages of customers who are over-irrigating does not tell us about the volumes of over-irrigation since even very small amounts of over-irrigation are enough to put a lot into the over-irrigation category. The fact that just over half of the combined sites are applying more than their theoretical irrigation requirements shows that over-irrigation is not a universal problem in single-family landscapes.

Excess Irrigation Volumes

In any system there are some customers who are irrigating in excess of the requirements and some that are deficit irrigating. Excess irrigation is the difference between the actual volume of water applied to the landscape and the theoretical irrigation requirement. From the perspective of water conservation, this is a key parameter because it is a measure of potential actual volume of water savings from improved irrigation management. If excess irrigation could be eliminated without simultaneously eliminating deficits, then outdoor savings could be maximized.

If we look all of the irrigating homes and compare their average outdoor use to the average theoretical requirement we see that the two values are close to each other. The average annual outdoor use for the group as a whole is 92.7 kgal. The average theoretical irrigation requirement for the group is 89.9 kgal. So, taken as a whole, there is only 2.8 kgal of excess use per lot occurring in the group. Another way of looking at this is that the under-irrigation in the less-than-TIR group just about balances the over-irrigation in the more-than-TIR group. If all irrigators were brought into compliance with their theoretical requirements then the data indicate that the net result would be little change in overall use.

The fact that the difference between the average outdoor use and the average theoretical irrigation requirement is small does not mean that there is no potential for irrigation savings. The savings potential is there, but it exists only on the lots of customers who are over-irrigating. From the perspective of water conservation, the customers who are deficit irrigating need to be set aside, and attention needs to be targeted to the over-irrigators.

If we assume that the people who are under-irrigating are doing so because that is how they like their landscapes, then the goal would be to discourage over-irrigation without simultaneously encouraging the under-irrigators to increase their outdoor applications. If this is done we can estimate the savings potential on just the lots where over-irrigation is occurring. The excess use is calculated as the actual application (kgal) minus the theoretical requirement (kgal), but the value was set to zero on lots that were deficit irrigating. When defined in this manner, excess irrigation captures the potential savings in irrigation use by eliminating over-irrigation use while allowing the under-irrigation to proceed.

Figure 63 shows the distribution of the number of accounts in various excess use bins. When viewed strictly in terms of numbers of accounts, the heavy users seem relatively unimportant. When one looks at the percent of the total volume of excess irrigation use for each consumption bin then the impact of the higher users becomes much more dramatic. For example, Figure 63 shows that 0-20 kgal group makes up 62.5% of all accounts, but we see in Figure 64 that this group accounts for only 17.8% of the total volume of excess use. The homes that are using more than 60 kgal of excess irrigation water make up only 18% of all irrigators, but they account for 62% of the total excess volume.

The excess use statistics shown in Table 49 show that the average excess use on the lots that are irrigating is approximately 30 kgal per year. Since only 87% of the lots were irrigators, the average excess use for all single-family accounts is estimated at 26.2 kgal per year. Approximately 62% of this excess use is occurring on 18% of the irrigating lots or 15% of all lots.

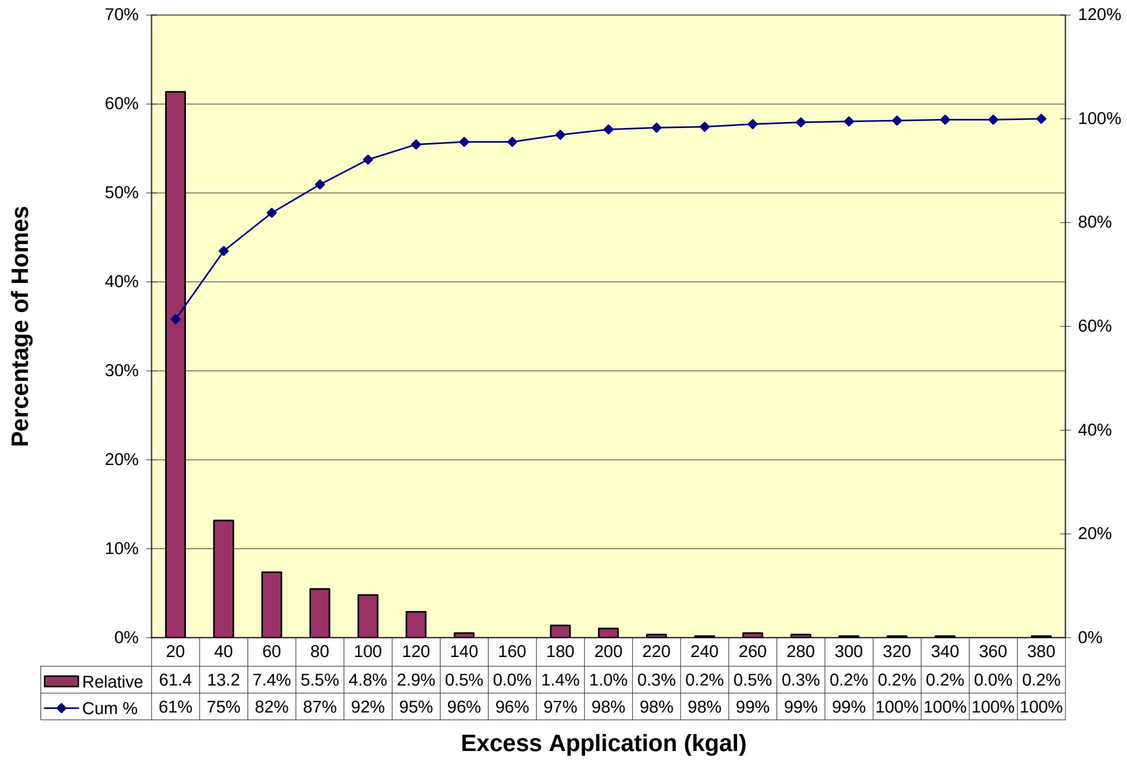


Figure 63: Distribution of excess irrigation by number of accounts

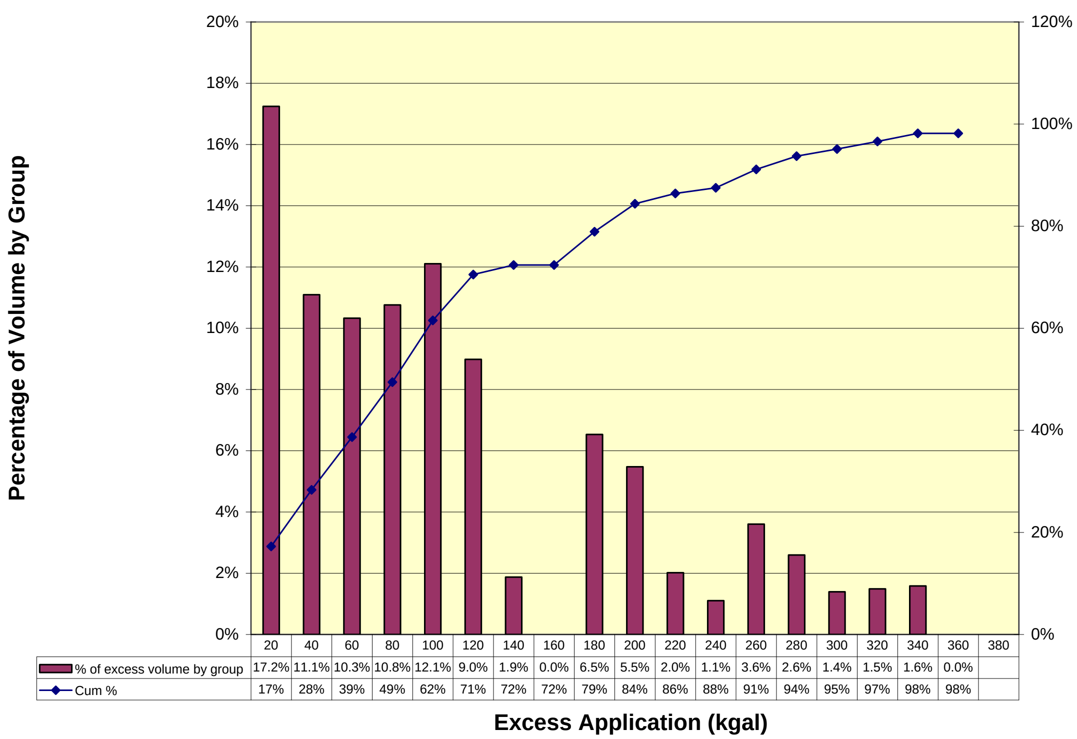


Figure 64: Percent of excess volume attributed to excess use bin

Table 49: Excess use parameters

Irrigation Parameter	Value
Number of lots analyzed from aerials	614
Net over application	6.7 kgal
Average excess use on irrigating lots (87%)	29.6± 4.13 kgal
Average excess use on all lots	25.6 kgal
Median excess	2.4 kgal
Minimum excess	0 kgal
Maximum excess	364 kgal

In interpreting the excess use statistics the average excess use was determined by taking the sum of the excess use for each lot with negative values for deficit irrigators set to zero. This means that this is the total of just the excess uses, and represents the average savings per lot if the excess use could be eliminated while the deficit irrigation was allowed to continue. If one simply takes the average of the net application including both positive and negative values then the average savings drops to 6.8 kgal per lot.

Diurnal Use

The time of day at which water uses occurs is important for demand forecasting both for water and energy. These diurnal use patterns were analyzed using the water event database for the entire study group. The total volume of water used for each use category was summed from the event database by the hour of day that the use began. Irrigation use was determined for both summer and winter so that the difference in seasonal use patterns could be quantified. The results are presented in the following tables and graphs.

Figure 65 shows the percentage of total winter and summer household use occurring during each hour of the day. It is noteworthy that the lowest daytime demands in single-family residences tend to occur during the peak energy demand period from noon until 6:00 pm. The following graphs show, however, that there is still a considerable amount of daytime irrigation use in these homes. If people would refrain from irrigating during the noon to 6:00 pm period it would reduce peak electric period water use.

Figure 66 shows the percent of the water use for each category occurring by hour of day. This shows the sequence of when demands for various single-family end uses come onto the system. In this graph the relative demands are not to scale relative to each other since each is based on the hourly percent for the individual end use. It is interesting to note that most single-family residential demands are outside of the periods of peak electrical demand. Most irrigation demands occur between 3:00 and 6:00 am. These data are presented in tabular form in Table 50.

The percent of total household water use associated with each end use is shown in Figure 67 for the winter (October through April) period and Figure 68 for the summer (May through September) period. In these graphs the magnitudes of the demands are shown in scale relative to each other, as percentages of total household use. The hourly data are presented in tabular form in Table 51and Table 52.

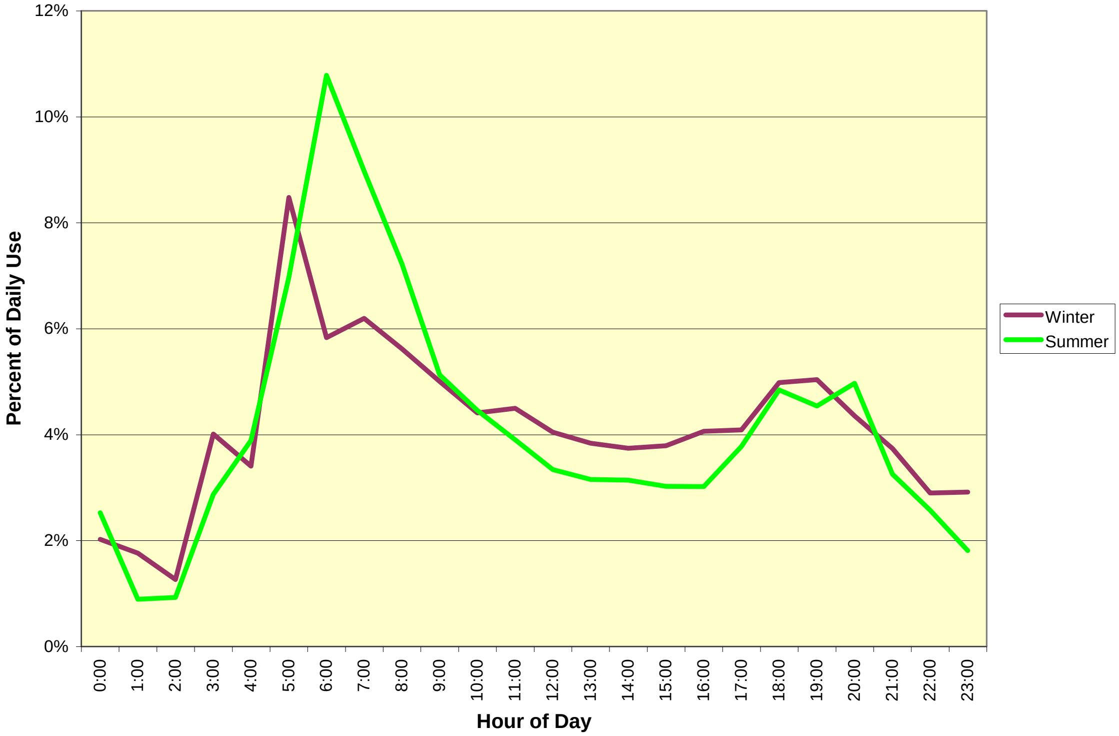


Figure 65: Diurnal use patterns for total household use, winter and summer

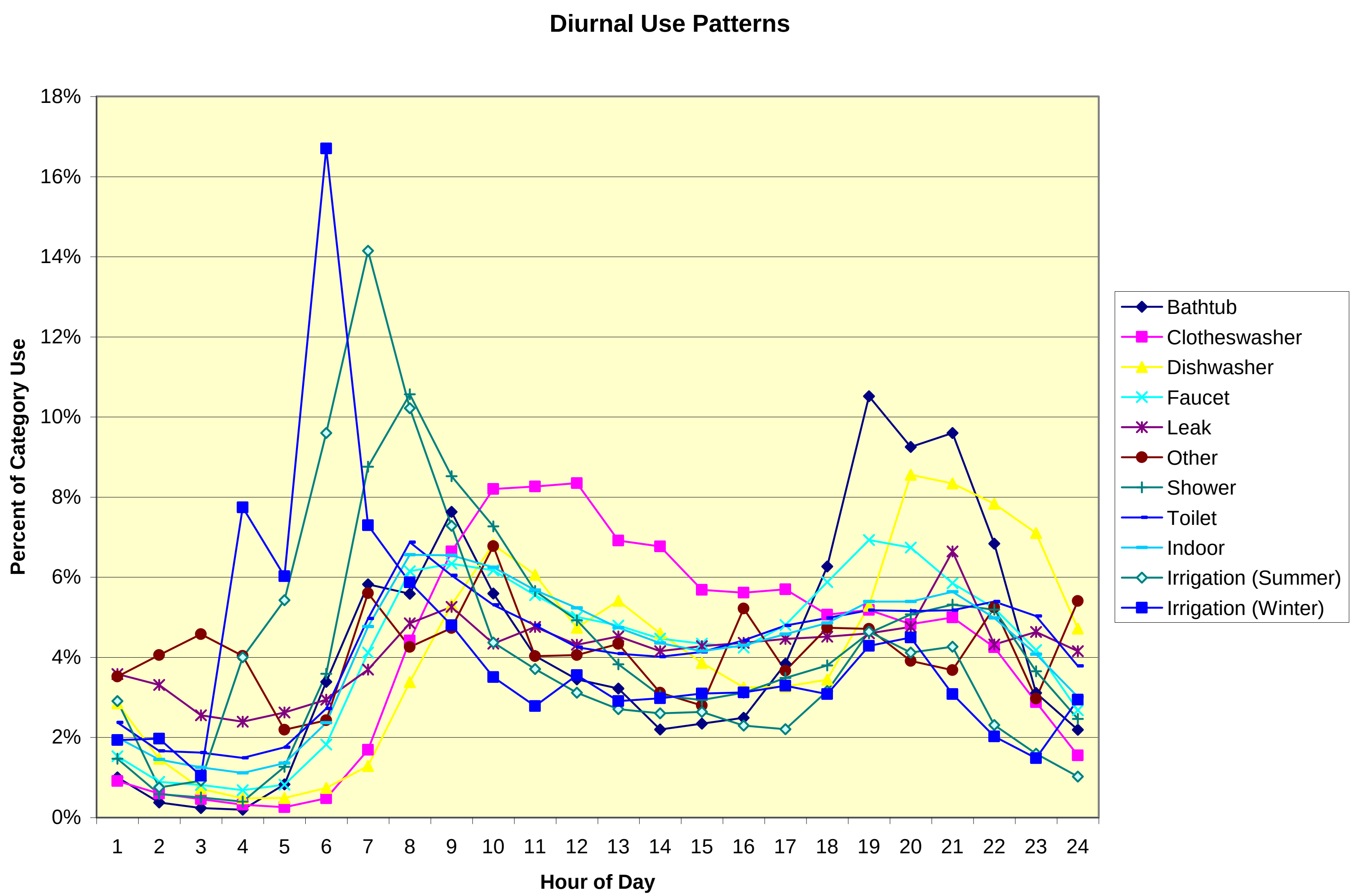


Figure 66: Percent of use by category on hourly basis

Table 50: Percent of category water use by hour of day

Hour of Day	Bath	Clothes Washer	Dish washer	Faucet	Leak	Other	Shower	Toilet	Indoor	Irrigation (Summer)	Irrigation (Winter)
0:00	1%	1%	3%	2%	4%	4%	1%	2%	2%	3%	2%
1:00	0%	1%	1%	1%	3%	4%	1%	2%	1%	1%	2%
2:00	0%	0%	1%	1%	3%	5%	0%	2%	1%	1%	1%
3:00	0%	0%	0%	1%	2%	4%	0%	1%	1%	4%	8%
4:00	1%	0%	0%	1%	3%	2%	1%	2%	1%	5%	6%
5:00	3%	0%	1%	2%	3%	2%	4%	3%	2%	10%	17%
6:00	6%	2%	1%	4%	4%	6%	9%	5%	5%	14%	7%
7:00	6%	4%	3%	6%	5%	4%	11%	7%	7%	10%	6%
8:00	8%	7%	5%	6%	5%	5%	9%	6%	7%	7%	5%
9:00	6%	8%	7%	6%	4%	7%	7%	5%	6%	4%	4%
10:00	4%	8%	6%	6%	5%	4%	6%	5%	6%	4%	3%
11:00	3%	8%	5%	5%	4%	4%	5%	4%	5%	3%	4%
12:00	3%	7%	5%	5%	5%	4%	4%	4%	5%	3%	3%
13:00	2%	7%	5%	4%	4%	3%	3%	4%	4%	3%	3%
14:00	2%	6%	4%	4%	4%	3%	3%	4%	4%	3%	3%
15:00	2%	6%	3%	4%	4%	5%	3%	4%	4%	2%	3%
16:00	4%	6%	3%	5%	4%	4%	3%	5%	5%	2%	3%
17:00	6%	5%	3%	6%	5%	5%	4%	5%	5%	3%	3%
18:00	11%	5%	5%	7%	5%	5%	5%	5%	5%	5%	4%
19:00	9%	5%	9%	7%	5%	4%	5%	5%	5%	4%	4%
20:00	10%	5%	8%	6%	7%	4%	5%	5%	6%	4%	3%
21:00	7%	4%	8%	5%	4%	5%	5%	5%	5%	2%	2%
22:00	3%	3%	7%	4%	5%	3%	4%	5%	4%	2%	1%
23:00	2%	2%	5%	3%	4%	5%	2%	4%	3%	1%	3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

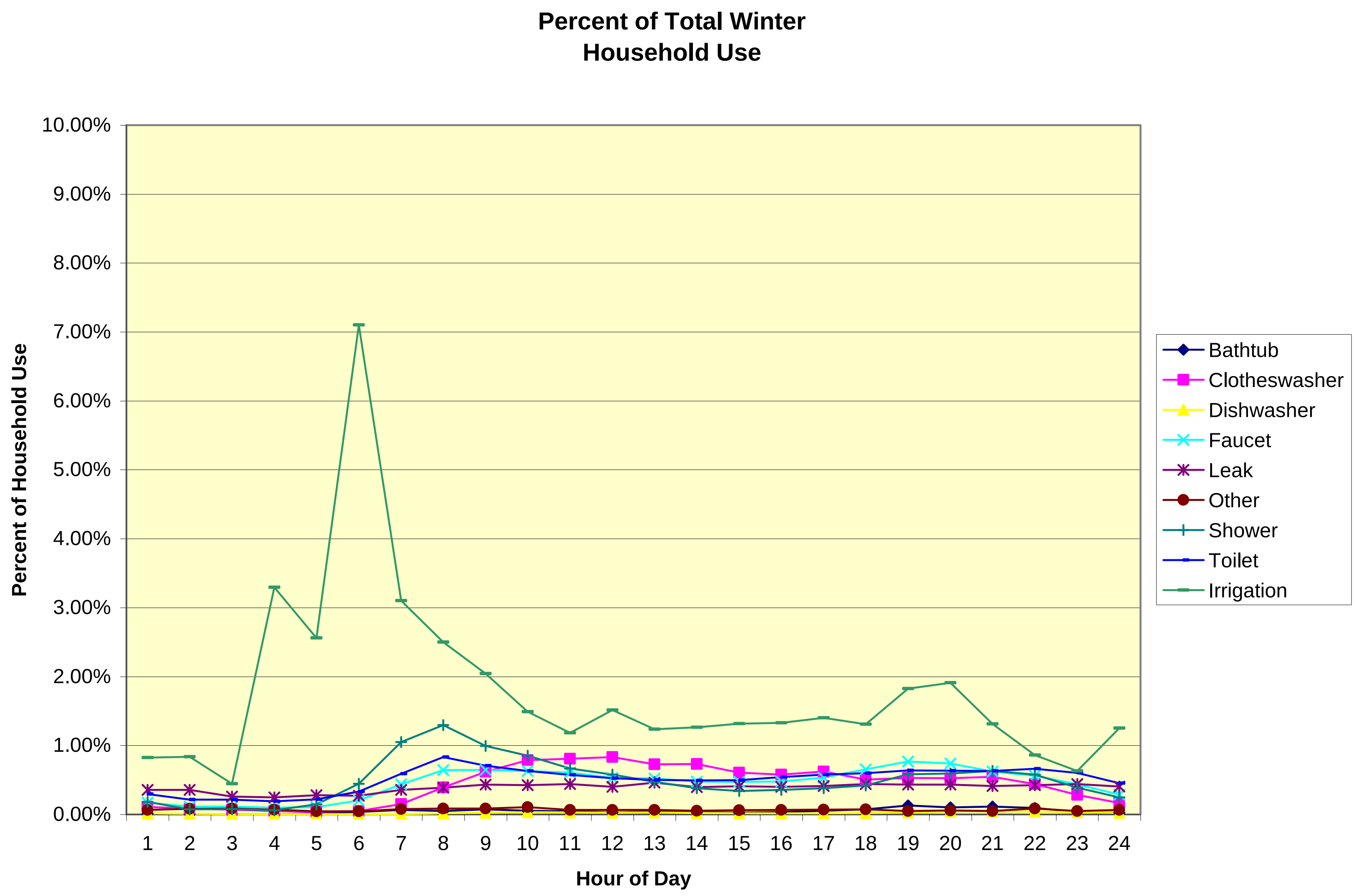


Figure 67: Percent of total winter household use by category

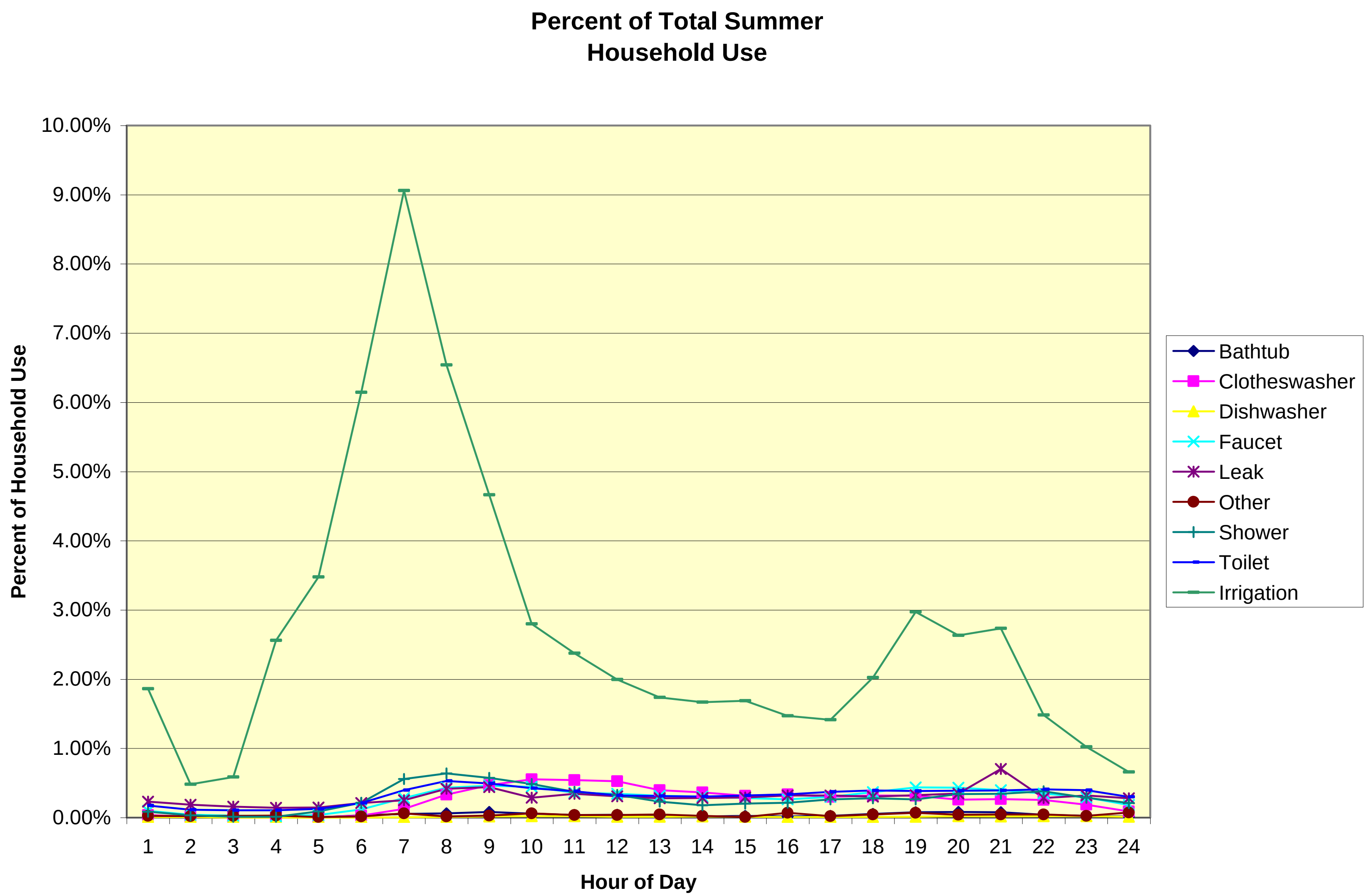


Figure 68: Percent of total summer household use by category

Table 51: Percent of total winter household use by category

Hour of Day	Bath	Clothes Washer	Dish washer	Faucet	Leak	Other	Shower	Toilet	Irrigation
0:00	0.01%	0.11%	0.01%	0.17%	0.36%	0.06%	0.18%	0.29%	0.82%
1:00	0.01%	0.08%	0.01%	0.11%	0.35%	0.08%	0.07%	0.21%	0.84%
2:00	0.00%	0.07%	0.00%	0.11%	0.26%	0.09%	0.08%	0.21%	0.44%
3:00	0.00%	0.05%	0.00%	0.10%	0.25%	0.07%	0.06%	0.19%	3.29%
4:00	0.01%	0.04%	0.00%	0.10%	0.28%	0.04%	0.14%	0.22%	2.56%
5:00	0.04%	0.05%	0.00%	0.20%	0.27%	0.04%	0.44%	0.33%	7.10%
6:00	0.06%	0.15%	0.01%	0.43%	0.36%	0.08%	1.05%	0.59%	3.10%
7:00	0.05%	0.39%	0.02%	0.64%	0.39%	0.09%	1.29%	0.83%	2.50%
8:00	0.07%	0.62%	0.03%	0.65%	0.43%	0.09%	0.99%	0.71%	2.04%
9:00	0.05%	0.79%	0.03%	0.63%	0.42%	0.11%	0.85%	0.63%	1.49%
10:00	0.04%	0.81%	0.03%	0.61%	0.44%	0.07%	0.67%	0.57%	1.18%
11:00	0.03%	0.83%	0.03%	0.53%	0.40%	0.07%	0.58%	0.52%	1.51%
12:00	0.04%	0.73%	0.03%	0.52%	0.46%	0.06%	0.47%	0.50%	1.24%
13:00	0.03%	0.73%	0.02%	0.48%	0.40%	0.05%	0.38%	0.49%	1.27%
14:00	0.02%	0.61%	0.02%	0.47%	0.41%	0.06%	0.34%	0.50%	1.32%
15:00	0.03%	0.58%	0.02%	0.48%	0.40%	0.06%	0.36%	0.54%	1.33%
16:00	0.05%	0.62%	0.02%	0.53%	0.41%	0.07%	0.38%	0.58%	1.40%
17:00	0.07%	0.51%	0.02%	0.65%	0.44%	0.07%	0.42%	0.60%	1.31%
18:00	0.13%	0.53%	0.03%	0.77%	0.43%	0.05%	0.58%	0.64%	1.82%
19:00	0.10%	0.52%	0.05%	0.74%	0.43%	0.06%	0.59%	0.63%	1.91%
20:00	0.11%	0.54%	0.05%	0.62%	0.41%	0.05%	0.63%	0.63%	1.31%
21:00	0.09%	0.44%	0.04%	0.56%	0.42%	0.09%	0.58%	0.66%	0.86%
22:00	0.04%	0.28%	0.03%	0.44%	0.44%	0.05%	0.39%	0.60%	0.63%
23:00	0.03%	0.16%	0.03%	0.29%	0.40%	0.06%	0.25%	0.45%	1.25%
Total	1%	10.23%	0.51%	10.83%	9.27%	1.60%	11.77%	12.14%	42.52%

Table 52: Percent of total summer household use by category

Hour of Day	Bathtub	Clothes Washer	Dishwasher	Faucet	Leak	Other	Shower	Toilet	Irrigation
0:00	0.01%	0.04%	0.01%	0.10%	0.23%	0.02%	0.09%	0.17%	2%
1:00	0.00%	0.01%	0.00%	0.04%	0.18%	0.02%	0.03%	0.11%	0.48%
2:00	0.00%	0.00%	0.00%	0.03%	0.16%	0.03%	0.01%	0.11%	0.59%
3:00	0.00%	0.00%	0.00%	0.02%	0.14%	0.03%	0.01%	0.10%	2.56%
4:00	0.00%	0.00%	0.00%	0.04%	0.15%	0.01%	0.09%	0.13%	3.47%
5:00	0.03%	0.03%	0.00%	0.12%	0.21%	0.02%	0.21%	0.21%	6.14%
6:00	0.05%	0.13%	0.00%	0.28%	0.25%	0.06%	0.56%	0.39%	9.06%
7:00	0.06%	0.33%	0.01%	0.43%	0.41%	0.02%	0.64%	0.53%	6.54%
8:00	0.08%	0.47%	0.02%	0.46%	0.44%	0.03%	0.57%	0.49%	4.66%
9:00	0.06%	0.55%	0.02%	0.45%	0.29%	0.06%	0.48%	0.42%	2.80%
10:00	0.04%	0.54%	0.02%	0.36%	0.34%	0.03%	0.37%	0.38%	2.38%
11:00	0.04%	0.53%	0.01%	0.34%	0.31%	0.03%	0.33%	0.32%	1.99%
12:00	0.02%	0.40%	0.01%	0.31%	0.28%	0.04%	0.23%	0.31%	1.73%
13:00	0.01%	0.36%	0.02%	0.30%	0.28%	0.03%	0.18%	0.30%	1.67%
14:00	0.02%	0.31%	0.01%	0.28%	0.29%	0.01%	0.20%	0.32%	1.69%
15:00	0.02%	0.33%	0.01%	0.26%	0.32%	0.07%	0.22%	0.33%	1.47%
16:00	0.02%	0.30%	0.01%	0.30%	0.32%	0.02%	0.26%	0.37%	1.41%
17:00	0.05%	0.32%	0.01%	0.37%	0.30%	0.04%	0.28%	0.39%	2.02%
18:00	0.08%	0.31%	0.01%	0.44%	0.32%	0.07%	0.26%	0.38%	2.97%
19:00	0.08%	0.26%	0.02%	0.43%	0.35%	0.04%	0.34%	0.39%	2.63%
20:00	0.08%	0.26%	0.02%	0.39%	0.70%	0.05%	0.34%	0.39%	2.73%
21:00	0.04%	0.25%	0.02%	0.35%	0.28%	0.04%	0.38%	0.41%	1.48%
22:00	0.02%	0.19%	0.02%	0.29%	0.32%	0.03%	0.29%	0.40%	1.02%
23:00	0.02%	0.09%	0.01%	0.18%	0.28%	0.07%	0.21%	0.30%	0.66%
Total	0.85%	6.02%	0.26%	6.57%	7.16%	0.87%	6.58%	7.66%	64.02%

Double Blind Analysis Results

As mentioned in CHAPTER 5, a set of 20 randomly selected flow traces were sent to an independent consultant, Mr. Bill Gauley, of Veritec Consulting Inc. Mr. Gauley then analyzed the traces using the Trace Wizard software and returned the results to Aquacraft. The entire analysis process was double-blind: neither analyst knew the results of the other until the analyses were complete. The results were then compared. The results of this analysis are shown in Table 53 for the key analysis parameters. The overall volume of the logged flows agreed within .002%. The end use analyses agreed the best for the toilet uses. The estimates of total volume of water used for toilets, total number of flushes recorded during the logging period and the average gallons per flush for each home agreed within 1% of each other. For clothes washers the count of loads agreed within 1.2%, and the gallons per load and total gallons used for clothes washers agreed within 5%. The greatest variability occurred for the shower category, for which the total volume of water used for showers agreed within 8.7% and the average flow rates for showers agreed to within 5.9%.

Table 53: Results of independent flow trace analyses

End Use Category	**Aquacraft**	**Veritec**	**Difference**	**Difference as % of Aquacraft Estimate**
	Mean	Mean		
Logged Volume (gal)	3160.36	3160.41	-0.050	-0.002%
Toilet Vol. in Trace (gal)	463.29	465.98	-2.694	-0.581%
Toilet Gal. per Flush (gpf)	2.657	2.662	-0.005	-0.191%
Toilet Flush Count	163.25	165.25	-2.000	-1.225%
CW Vol. in Trace (gal)	286.30	291.39	-5.088	-1.777%
CW load count	7.70	7.35	0.350	4.545%
CW gal. per load (gpl)	37.51	39.04	-1.525	-4.065%
Shower Total Volume (gal)	343.26	313.35	29.908	8.713%
Shower Flow Rate (gpm)	2.13	2.26	-0.126	-5.882%

CHAPTER 8 – SURVEY RESULTS

Utility Survey Results

As part of the survey process each utility was asked to fill out a survey describing their water conservation efforts and programs. The survey results were intended to provide information on the responses among the participating agencies to the requirements of the California Memorandum of Understanding and the agreed upon Best Management Practices. The responses from the utility survey have been supplemented with additional information from the agency websites and urban water management plans in order to examine patterns and variations in how the BMPs have been implemented among the participating agencies in this study.

An agency's implementation of and participation in various conservation measures is important in assessing the impact of these measures on both current and future water demand. All agencies participating in this study are signatories to the California Urban Water Conservation Council Memorandum of Understanding Regarding Urban Water Conservation in California (MOU). Developed in 1991, the MOU serves as a tool to assist agencies with providing a reliable, long-term water supply. Increasing demands from urban development, drought, agriculture, and environmental uses results in an increasing need for water suppliers to find ways to protect this valuable resource. The two primary purposes of the MOU are:[45]

[T]o expedite implementation of reasonable water conservation measures in urban areas; and …to establish assumptions for use in calculating estimates of reliable future water conservation savings resulting from proven and reasonable conservation measures. Estimates of reliable savings are the water conservation savings which can be achieved with a high degree of confidence in a given service area. The signatories have agreed upon the initial assumptions to be used in calculating estimates of reliable savings.

"The urban water conservation practices included in this MOU (referred to as "Best Management Practices" or "BMPs") are intended to reduce long-term urban demands from what they would have been without implementation of these practices and are in addition to programs which may be instituted during occasional water supply shortages."[46] Signatories to the MOU consist of wholesale and retail water suppliers, public non-profit advocacy organizations, and other interested parties; the CUWCC is responsible for monitoring the implementation of the MOU. How and to what extent each agency has implemented various conservation measures is affected by factors such as their customer base, climate, economic feasibility, and the extent to which these measures have already been implemented.

[45] http://www.cuwcc.org/WorkArea/showcontent.aspx?id=12976. Memorandum of Understanding Regarding Urban Water Conservation in California. As Amended September 16, 2009. Section 2. Purposes. 2.1. Accessed February 4, 2010.

[46] Ibid.

Included in the development, implementation, and reporting requirements is:

A list of Best Management Practices identified by the signatories
A schedule of BMP implementation
The level of activity or water savings necessary to achieve full implementation of BMPs
Reporting requirements documenting the implementation of BMPs
The criteria for determining the progress of implementing the BMPs
Assumptions used in estimating reliable savings from implementation of the BMPs and estimates of reliable savings
Alternative water savings measures promoting new initiatives in water conservation that will provide savings equal to or greater than those achieved by implementing the BMPs.

Originally there were 16 BMPs. In 1997, they were revised to 14 BMPs for implementation by the signatories to the MOU, as shown in Table 54. The new categories for the BMPs following the 2007 revision are shown in the right column.

Table 54: BMPs from the CUWCC MOU

BMP Number	BMP	BMP Category
1	Water Survey Programs for SF and MF Residential Customers	Programmatic: Residential
2	Residential Plumbing Retrofit	Programmatic: Residential
3	System Water Audits, “leak” Detection and Repair	Foundational: Utility Operations – Water Loss Control
4	Metering with Commodity Rates for All New Connections and Retrofit of Existing Connections	Foundational: Utility Operations – Metering
5	Large Landscape Conservation Programs and Incentives	Programmatic: Landscape
6	High-Efficiency Clothes Washing Machine Financial Incentive Programs	Programmatic: Residential
7	Public Information Programs	Foundational: Education – Public Information Programs
8	School Education Programs	Foundational: Education – School Education Programs
9	Conservation Programs for Commercial, Industrial, and Institutional (CII) Accounts	Foundational: Commercial, Industrial, and Institutional
10	Wholesale Agency Assistance Programs	Foundational: Utility Operations
11	Retail Conservation Pricing	Foundational: Utility Operations – Pricing
12	Conservation Coordinator	Foundational: Utility Operations – Operations
13	Water Waste Prohibition	Foundational: Utility Operations – Operations
14	Residential ULFT Replacement Programs	Programmatic: Residential

Each agency was asked to complete a survey indicating their utility's implementation of the BMPs and their participation in various conservation measures. The utility questionnaire is provided in APPENDIX A: Utility Water Conservation Program Questionnaire. The survey was designed as a tool that would assist with comparing the extent to which various conservation measures have been implemented, and to examine possible impacts on customers' water use related to BMP implementation.

The BMPs provide utilities with a variety of indoor and outdoor conservation measures. Indoor BMPs included toilet and clothes washer rebates, indoor surveys, and distribution of low flow showerheads and faucet aerators; outdoor measures include irrigation surveys, watering schedules, irrigation controller rebates and other financial incentives aimed at large landscape conversions. BMPs could be implemented through distribution, direct installation, retrofit on resale, rebates, or some combination of each. Table 55 shows the various residential indoor and outdoor measures utilized by the participating water agencies and the way(s) in which they were implemented.

BMP 1 required agencies to provide free residential water audits (surveys) to their customers. Surveys are designed to provide customers with tools and recommendations for reducing their water consumption. Although not indicated by the utility survey responses, some agencies target their surveys to their high water use customers. Surveys are often used in conjunction with shower and faucet distribution and/or replacement. All agencies, except Rincon del Diablo and Sweetwater, have a direct installation or free distribution program for showerheads; North Marin WD requires an upgrade to high-efficiency fixtures on resale as well. Most of the utilities also provide free distribution of faucet aerators and North Marin WD requires an upgrade of faucet aerators at the time of resale.

Water for toilet flushing has long been the single highest residential indoor use. Considerable effort has been made to replace old, inefficient toilets with ultra-low flow toilets (ULFTs). With the exception of the City of Davis[47] and Redwood City (which combined a distribution program with direct installation) all participating agencies provided rebates for purchase of ULFTs. In addition to rebates, the City of Petaluma had a direct installation program for ULFTs. Recently some agencies have stopped offering rebates for ULFT model toilets in favor of HET models, which have an average flush volume of 1.28 gpf or less. Clothes washers are second only to toilets in their indoor water use, and all but EBMUD provided their customers with rebates as an incentive to replace their clothes washer with a more efficient model. EBMUD had a distribution program of clothes washers that satisfied BMP 6.

Studies have shown that water use for automatic dishwashers is less than 2% of residential indoor use.[48] None of the participating agencies provided rebates or other incentives to replace dishwashers.

[47] The City of Davis provided toilet rebates until 2001. They were discontinued at this time because it was believed that the request for rebates was less than the natural replacement rate of toilets and because there was concern about free ridership.

[48] Mayer, P.M. and DeOreo, W.B. Residential End Uses of Water. AWWARF. 1999.

Although some utilities are studying the efficacy of hot water recirculation or "on demand" hot water, none of them were providing rebates or other incentives for these systems at the time of this study.

Outdoor audits are provided by all participating agencies – often in conjunction with indoor audits. These audits usually include an assessment of the irrigation system, including leaks and malfunctions, and irrigation scheduling recommendations. Weather-based irrigation controllers can be used as a tool to automate irrigation scheduling and most of the participating agencies provide rebates for these controllers. Davis, Petaluma, and Rincon del Diablo provide direct installation programs for weather-based controllers; Sweetwater and North Marin WD have a distribution program.

About half of the utilities actively promote xeriscape with training programs, demonstration gardens, landscape and irrigation training workshops, and literature. IRWD, Las Virgenes MWD, and Otay provide financial incentives through rebates for the installation of xeriscape, "Cash for Grass Programs" and the use of artificial turf.

Table 55: Survey responses of participating water agencies

Codes for type of installation program
0= none
1= direct (or yes)
2= distribution
3= rebate or owner install
4= upgrade on sale

	Residential Indoor								Residential Outdoor			
Water Agency	Toilet replacements	Showerhead replacement	Faucet aerators	Dishwashers	Clothes Washers	Audits	Hot Water Recirc.	Other Res. Indoor?	Controller replacement	Rotating water days	Xeriscape	Irrigation audits
City of Davis Public Works	0	1,2	0	0	3	1	0	0	1	0	0	1
City of Petaluma	1,3	1	1	0	3	1	0	0	1,3	0	0	1
City of Redwood City	1,2	1,2	1,2	0	3	1	0		0	0	0	1
City of San Diego Water Dept.	3	2	2	0	3	1	0	0	3	0	0	1
City of Santa Rosa	3	2	2	0	3	1	0	1	3	0	1	1
East Bay Municipal Utility District	3	2	2	0	2	1	0	1	3	0	1	1
Helix Water District	3	2	0	0	3	1	0	0	3	0	0	1
Irvine Ranch Water District	3	2	2	0	3	1	0	0	3	0	3	1
Las Virgenes Municipal Water District	3	2	0	0	3	1	0	0	3	0	3	1
Los Angeles Dept. of Water and Power	1,4	1,4	1	0	3	1	0	1	0	0	0	1
North Marin Water District	2,3,4	2,4	2,4	0	3	1	0	1	2,3	0	1	1
Otay Water District	3	2	0	0	3	1	0	0	3	1	3	1
Rincon Del Diablo MWD	3	0	2	0	3	1	0	1	1,3	0	0	1
San Francisco PUC	3	1, 2	1, 2	0	3	1	0	0	0	0	0	1
Sweetwater Authority	3	0	0	0	3	1	0	0	2,3	0	0	1

BMP 11 is intended "to reinforce the need for Water Agencies to establish a strong connection between volume-related system costs and volumetric commodity rates."[49] Rates are intended to send a price signal that encourages water conservation, reflects the cost of delivering water, and creates financial stability for the utility. Metering is a necessary element of measuring the volumetric delivery of water to customers and can be used in conjunction with connection fees, service charges, and fees for special services such as fire protection.

The volumetric rate structures that may satisfy the BMP requirement of conservation pricing are:

Uniform rate (all water purchased at the same rate)
Seasonal rates (reflects the seasonal variability for the cost of water deliveries)
Increasing block rate (rates increase at certain breakpoints)
Water budget rates (also known as allocation-based rates). Allocation based on a variety of parameters as defined by the utility.

Table 56 shows that during the study period all participating agencies were metering their customers. Table 57 provides the codes used to identify the water rate billing structure for each utility. The most common volumetric unit of measurement is CCF[50] and most customers are billed bi-monthly. Only Santa Rosa, IRWD, and Otay send customers a monthly bill. Otay is the only agency that bills their customer in kgal (1,000 gallons). An increasing block rate is the most common rate structure; the number of blocks ranges from 2 to 5. During the study period, Otay and San Francisco[51] used a uniform rate structure. The uniform rate for San Francisco customers with a conservation affidavit is 33% less than customers without the affidavit. Both Los Angeles Department of Power and Water and IRWD have an allocation-based billing system with two tiers and five tiers respectively. More detailed information about each utility's rates can be found in CHAPTER 4.

[49] http://www.cuwcc.org/WorkArea/showcontent.aspx?id=12976. Memorandum of Understanding Regarding Urban Water Conservation in California. Exhibit 1. As Amended September 16, 2009. 1.4 Retail Conservation Pricing (formerly BMP 11) Part I – Retail Water Service Rates. A. Implementation. Accessed February 11, 2010.

[50] A CCF is one hundred cubic feet or 748 gallons.

[51] Although San Francisco PUC has a uniform rate structure, customers who have implemented conservation measures such as retrofitting their plumbing fixtures, and filed an affidavit to that effect, are charged 50% less than those that have not.

Table 56: Residential billing and metering information during study period

Water Agency	Metering of SF Customers	Units of Billing	Billing Period	Single-Family Rate Structure	Number of Billing Tiers
City of Davis Public Works	Yes	CCF	bi-monthly	2	2
City of Petaluma	Yes	CCF	bi-monthly	2	4
City of Redwood City	Yes	CCF	bi-monthly	2	5
City of San Diego Water Dept.	Yes	CCF	bi-monthly	2	3
City of Santa Rosa	Yes	CCF	monthly	1	NA
East Bay Municipal Utilities District	Yes	CCF	bi-monthly	2	3
Helix Water District	Yes	CCF	bi-monthly	2	3
Irvine Ranch Water District	Yes	CCF	monthly	3	5
Las Virgenes Municipal Water District	Yes	CCF	bi-monthly	2	5
Los Angeles Dept. of Water and Power	Yes	CCF	bi-monthly	3	2
North Marin Water Dist.	Yes	CCF	bi-monthly	2	3
Otay Water District	Yes	CCF	monthly	2	4
Rincon del Diablo MWD	Yes	kgal	bi-monthly	2	2
San Francisco PUC	Yes	CCF	bi-monthly	1	NA
Sweetwater Authority	Yes	CCF	bi-monthly	2	5

Table 57: Codes used for Table 56

Codes to describe water rate structure
0= Flat rate (charges are not based on amount used)
1= Uniform Rate (all water purchased at same rate)
2= Increasing block rate (rates jump at breakpoints)
3= Water Budget Rates (jump points based on budget)
4= Decreasing block rate
5= Other (please provide description)

Table 58: System Measures

Water Agency	System Measures						
	"leak" detection	System Audits	Tiered Billing Systems	Water Budgets	Revolving Loans	Water Recycling	Public Education Programs
City of Davis Public Works	1	1	1	0	0	1	1
City of Petaluma	1	1	1	1	1	1	1
City of Redwood City	0	1	1	1	0	1	1
City of San Diego Water Dept.	0	0	1	0	0	1	1
City of Santa Rosa	1	1	1	1	0	1	1
East Bay Municipal Utilities District	1	1	1	1	0	1	1
Helix Water District	0	1	1	1	0	0	1
Irvine Ranch Water District	1	1	1	1	0	1	1
Las Virgenes Municipal Water District	1	1	1	1	0	1	1
Los Angeles Dept. of Water and Power^	1	1	1	1	0	1	1
North Marin Water Dist.	1	1	1	1	0	1	1
Otay Water District	1	1	1	1	0	1	1
Rincon Del Diablo MWD	1	1	1	1	1	1	1
San Francisco PUC	1	1	1	0	0	1	1
Sweetwater Authority	1	1	1	0	0	0	1

^Los Angeles Dept. of Water and Power did not respond to the survey. Codes for types of installation were obtained from LADWP's 2005 Urban Water Management Plan.

Customer Survey Results

All homes that were data-logged for the study were surveyed with regard to their water use. An initial survey was delivered to homes at the same time as data logging was set to commence. For those that did not respond, reminder letters were sent a month after the original letter was dropped off. For those that had not responded to the original attempt or the follow-up, a shortened survey was sent. The follow-up survey concentrated on variables deemed essential to potential modeling, including persons per household, and the stock of water using appliances.

The survey response rate to the original distribution was relatively high, with a response rate to the initial survey for all survey sites of 48%, and similar return rates across study sites. Table 59 shows the response rate to the initial mailing, the shortened follow-up survey, and to both combined for each of the participating utilities. The follow-up survey increased the response rate for all regions combined from 48% to 55%. The Los Angeles study area was left out of the calculation of the initial and combined response rates because the Los Angeles Department of Water and Power made sure that all Los Angeles homes that were data logged also returned a filled-out survey, assuring a 100% response for that study site.

Table 59: Survey response rates

Water Agency	Initial Surveys Sent Out	Initial Surveys Returned	Initial Survey Response Rate	Follow-up Survey Returns	Combined Surveys Returned	Combined Response Rate
Davis	64	31	48%	5	36	56%
SCWA	70	37	53%	7	44	63%
San Francisco	60	32	53%	2	34	57%
East Bay MUD	120	70	58%	0	70	58%
Redwood City	60	35	58%	2	37	62%
Northern California	374	205	55%	16	221	59%
Las Virgenes MWD	69	32	46%	0	32	46%
Los Angeles DWP (a)	117	117	100%	0	117	100%
IRWD	116	50	43%	14	64	55%
City of San Diego	86	40	47%	6	46	53%
San Diego County WA	68	16	24%	13	29	43%
Southern California (b)	339	138	41%	33	171	50%
All Study Sites (b)	713	343	48%	49	392	55%

(a) Los Angeles required all participants to respond to the survey.
(b) Response rate does not include Los Angeles, where 100% response was assured.

The full survey was a five-page questionnaire with 57 multiple part questions. The survey questions covered demographic information about the respondents, housing characteristics, indoor and outdoor water using fixtures and appliances, landscape watering habits, and a multi-part question about customers' water bill awareness and response to water costs. The shortened follow-up version of the survey was a two-page questionnaire with 12 multiple part questions. The shortened survey had a few questions on each topic covered in the longer survey, except water bill awareness. For the questions selected for the follow-up survey, the same question was used from the original survey. The surveys are shown in Appendices A and B.

Respondent Demographics

Survey respondents were asked to report the number of adults, teenagers, older children, younger children, and toddlers or infants living full-time at the address. Across the ten study sites, the average household size was 2.95 people. Average household size ranged from 2.67 in Sonoma County WA to 3.5 in San Francisco. Table 60 shows the breakout of persons per household according to age groups.

Table 60: Comparison of persons per household across study sites

Water Agency	Adults (age 18+)	Teenagers (age 13-17)	Older Children (age 6 - 12)	Younger Children (age 3 - 5)	Infants or Toddlers (under age 3)	Mean Household Size
Davis	2.11	0.43	0.26	0.06	0.06	2.91
SCWA	2.05	0.14	0.29	0.05	0.14	2.67
San Francisco	2.94	0.12	0.12	0.12	0.21	3.50
East Bay MUD	2.31	0.27	0.27	0.07	0.09	3.01
Redwood City	1.94	0.23	0.43	0.17	0.09	2.86
Northern California	2.27	0.24	0.27	0.09	0.11	2.98
Las Virgenes MWD	2.22	0.28	0.13	0.06	0.06	2.75
Los Angeles	2.30	0.22	0.22	0.12	0.10	2.97
IRWD	2.37	0.35	0.32	0.10	0.10	3.24
City of San Diego	2.32	0.18	0.11	0.07	0.05	2.73
San Diego County WA	2.25	0.11	0.18	0.07	0.07	2.68
Southern California	2.30	0.24	0.21	0.10	0.08	2.94
All Study Sites	2.29	0.24	0.24	0.09	0.10	2.96

Respondents were asked to identify their household income by choosing from 18 income brackets, spanning $10,000 at a time in the lower income brackets and up to $25,000 at a time in the higher income brackets. The responses are shown in Table 61, grouped into four categories: less than $50,000, between $50,000 and $100,000, between $100,000 and $200,000, and greater than $200,000. For all respondents, the highest percentage of respondents was in the $50,000 to $100,000 category. Las Virgenes MWD had the highest percentage of respondents in the greater than $200,000 category at 41%, while Sonoma County had no residents in this category. IRWD had the lowest percentage of respondents in the less than $50,000 category at 4%, and Los Angeles had the highest percentage in this category at 17%.

Table 61: Comparison of household income across study sites

Water Agency	Less than $50,000	$50,000 to $99,999	$100,000 to $199,999	> than $200,000
Davis	7%	24%	55%	10%
SCWA	15%	47%	26%	0%
San Francisco	8%	31%	23%	19%
East Bay MUD	7%	44%	20%	15%
Redwood City	7%	18%	43%	29%
Northern California	9%	35%	31%	14%
Las Virgenes MWD	5%	32%	23%	41%
Los Angeles	17%	26%	29%	10%
IRWD	4%	27%	35%	29%
City of San Diego	8%	33%	42%	6%
San Diego County WA	8%	44%	16%	8%
Southern California	11%	30%	30%	16%
All Study Sites	10%	32%	31%	15%

For all respondents, 83% completed at least some college, with 30% percent completing a master’s or doctoral degree. Davis had the highest level of college and graduate school completion, at 100% and 83% respectively. Los Angeles had the lowest level of college and graduate school completion, with 78% and 25% respectively. Table 62 shows an accounting of educational attainment by study site.

Table 62: Comparison of education attainment across study sites

Water Agency	At least high school	At least some college	Graduate school
Davis	100%	100%	83%
SCWA	97%	82%	24%
San Francisco	97%	76%	17%
East Bay MUD	97%	79%	35%
Redwood City	97%	81%	29%
Northern California	97%	83%	37%
Las Virgenes MWD	100%	94%	29%
Los Angeles	89%	78%	25%

Water Agency	At least high school	At least some college	Graduate school
IRWD	100%	86%	30%
City of San Diego	97%	87%	18%
San Diego County WA	100%	73%	13%
Southern California	94%	82%	25%
All Study Sites	96%	83%	30%

Respondents to the survey were overwhelmingly home owners, as opposed to renters. Ninety-two percent of respondents owned the homes they occupied, while only 8% of those surveyed were renters.

Home Characteristics

Survey respondents were asked about when their homes were built. As shown in Table 63, for homes from all survey locations, 76% of all homes were built before 1980, 17% were built between 1980 and 1994, and 7% were built between 2000 and 2006. Las Virgenes MWD (56%), IRWD (48%), and San Diego County (50%) contained the lowest percentage of houses built before 1980. Los Angeles contained the highest percentage of houses built before 1980, with 95%. The decade with the highest percent of homes built across all responding homes was the 1950s, with 20% of the total.

Table 63: Comparison of year home built across study sites

Water Agency	Built before 1980	Built 1980-1994	Built 1995-2006
Davis	74%	10%	16%
SCWA	66%	29%	6%
San Francisco	84%	10%	6%
East Bay MUD	73%	21%	6%
Redwood City	85%	12%	3%
Northern California	76%	17%	7%
Las Virgenes MWD	56%	44%	0%
Los Angeles	95%	3%	2%
IRWD	48%	26%	26%
City of San Diego	79%	15%	5%
San Diego County WA	50%	38%	13%
Southern California	75%	17%	8%
All Study Sites	76%	17%	7%

The number of bedrooms in a house can generally be used as an indicator of house size. Table 64 shows the percentage of respondents in a study site that indicated their homes had a certain number of bedrooms. The median number of bedrooms per house of all study sites was 3. Eighty three percent of the homes had 3 or more bedrooms, and 39% of all homes had 4 or more bedrooms. Las Virgenes MWD had the highest percentage of homes with 4 or more bedrooms (75%). San Francisco had the lowest percentage of homes with 4 or more bedrooms (13%).

Table 64: Number of bedrooms by percentage of respondent homes

Water Agency	Number of Bedrooms					
	1	2	3	4	5	6+
Davis	0%	6%	45%	42%	6%	0%
SCWA	0%	8%	67%	25%	0%	0%
San Francisco	13%	39%	35%	13%	0%	0%
East Bay MUD	0%	21%	40%	31%	4%	3%
Redwood City	0%	36%	42%	9%	9%	3%
Northern California	2%	22%	45%	25%	4%	2%
Las Virgenes MWD	0%	0%	25%	44%	25%	6%
Los Angeles	0%	20%	51%	19%	9%	2%
IRWD	0%	6%	34%	48%	12%	0%
City of San Diego	0%	10%	38%	33%	13%	5%
San Diego County WA	0%	6%	56%	31%	6%	0%
Southern California	0%	12%	43%	31%	12%	2%
All Study Sites	1%	16%	44%	28%	8%	2%

Table 65 shows reported home value for each study site. Respondents were asked to show the value of their home using 17 home value categories. Median home values were highest in Redwood City and Las Virgenes MWD, where the median home value was between $900,000 and $999,999. The lowest median home value in this study was in San Diego County.

Table 65: Home values by percentage in homes reported in home value category

Water Agency	$0k to $449k	$450k to $499k	$500k to $599k	$600k to $699k	$700k to $799k	$800k to $899k	$900k to $999k	$1,000k to $1,499k	$1,500k +
Davis	24%	18%	21%	18%	12%	3%	3%	3%	4%
SCWA	12%	8%	36%	19%	17%	6%	3%	0%	0%
San Francisco	4%	0%	15%	26%	11%	19%	7%	11%	7%
East Bay MUD	4%	15%	19%	6%	20%	11%	7%	13%	6%
Redwood City	0%	0%	3%	6%	16%	13%	23%	26%	13%
Northern California	8%	9%	19%	14%	16%	10%	8%	10%	5%
Las Virgenes MWD	0%	0%	3%	10%	10%	14%	21%	24%	17%
Los Angeles	20%	8%	11%	12%	10%	17%	3%	13%	6%
IRWD	2%	0%	0%	19%	21%	17%	4%	21%	17%

Water Agency	$0k to $449k	$450k to $499k	$500k to $599k	$600k to $699k	$700k to $799k	$800k to $899k	$900k to $999k	$1,000k to $1,499k	$1,500k +
City of San Diego	25%	8%	19%	17%	11%	6%	6%	8%	0%
San Diego County	38%	21%	25%	0%	4%	8%	4%	0%	0%
Southern California	16%	6%	10%	13%	12%	14%	6%	14%	8%
All Study Sites	15%	14%	13%	14%	12%	7%	10%	13%	7%

Indoor Water Fixtures

The survey asked respondents several questions about the water-using appliances they have in their homes. As shown in Table 66, across all respondents, the average number of toilets per household was 2.4, with a range of 2.0 (San Francisco) to 3.2 (Las Virgenes MWD). Overall, households reported an average of 1.6 (out of 2.4) ultra-low-flush toilets (ULFTs or better). The City of San Diego reported the highest average number of ULFTs per household at 2.0, while Davis and East Bay MUD reported the lowest average number per household at 1.1. Up to 17% of respondents in any one location reported not knowing whether they had ULFTs. (The survey stated that toilets manufactured after 1993 were generally ULFTs.)

Showers with tubs were reported to be more common (an average of 1.3 per household), than either showers only (average of 1.0 per household) or tub only (average of 0.4 per household). Households reported an average of 1.3 low-flow showerheads. Up to 18% of respondents reported not knowing whether their showerheads were low-flow. Areas with newer homes generally reported having more showers and low-flow showerheads.

Table 66: Mean numbers of toilets, showers, and tubs

Water Agency	Toilets	Ultra-low-flush Toilets	Tub With Shower	Tub Only	Shower Only	Number of Low-flow Showerheads
Davis	2.3	1.1	1.1	0.4	1.0	1.2
SCWA	2.3	1.5	1.2	0.2	0.9	1.3
San Francisco	2.0	1.3	1.4	0.4	0.8	1.2
East Bay MUD	2.1	1.1	1.3	0.5	0.8	1.0
Redwood City	2.2	1.4	1.2	0.5	1.0	1.1
Northern California	2.2	1.3	1.2	0.4	0.9	1.1
Las Virgenes MWD	3.2	1.9	1.3	0.7	1.7	1.7
Los Angeles	2.3	1.8	1.2	0.4	1.1	1.3
IRWD	3.0	1.4	1.8	0.5	1.0	1.4

Water Agency	Toilets	Ultra-low-flush Toilets	Tub With Shower	Tub Only	Shower Only	Number of Low-flow Showerheads
City of San Diego	2.5	2.0	1.2	0.4	1.0	1.4
San Diego County WA	2.6	1.6	1.6	0.4	0.8	1.4
Southern California	2.6	1.8	1.3	0.5	1.1	1.4
All Study Sites	2.4	1.6	1.3	0.4	1.0	1.3

Survey responses about the presence of other water using appliances are shown in Table 67. Top-loading clothes washing machines were found in 75.7% of homes while 27.6% percent of homes reported owning front-loading clothes washing machines[52]. Davis had the highest penetration rate for front-loading clothes washers: 61% owned top-loading washers and 44% owned front-loading washers. Clothes washers (of any type) had the highest penetration rate of any water-using appliance owned by survey respondents (98.7% for either a top-loader or a front-loader).

While 81% of all respondents reported owning a dishwasher, percentages reported by individual service areas varied widely: only 51% of respondents from San Francisco owned a dishwasher, compared to 100% of respondents from Las Virgenes MWD. In general, study sites with older homes had lower penetration rates for dishwashers than study sites with homes built more recently.

Households also were asked whether they had installed whole-house water treatment systems. The percent of households reporting using a whole-house treatment system ranged from 47% in Davis to 0% in Redwood City. Overall, 12% of total households responding to the survey reported whole-house water treatment system use. Whole house systems include devices such as simple filters, carbon filters, water softeners and reverse osmosis systems. Some of these use essentially no water, some use water only during regeneration and some use water whenever water is being treated.

Table 67: Percent of respondents indicating presence of various water using devices

Water Agency	Garbage Disposal	Top-loading Washer	Front-loading Washer	Dish Washing Machine	Whirlpool Bathtub	Indoor Hot Tub or Spa	Fountain Indoor	Whole-house Treatment
Davis	87.1%	61.3%	44.4%	83.3%	3.8%	7.1%	3.6%	47.1%
SCWA	91.9%	94.3%	12.5%	97.3%	12.5%	3.1%	6.3%	10.3%
San Francisco	62.5%	71.9%	35.5%	58.1%	0.0%	0.0%	3.2%	3.1%
East Bay MUD	80.0%	84.3%	27.0%	77.1%	7.8%	3.1%	1.6%	1.6%
Redwood City	85.7%	73.5%	33.3%	82.9%	30.3%	5.9%	2.9%	0.0%

[52] The penetration rate is greater than 100% because 4.6% of all homes reported having both a front-loader and a top-loader.

Water Agency	Garbage Disposal	Top-loading Washer	Front-loading Washer	Dish Washing Machine	Whirlpool Bathtub	Indoor Hot Tub or Spa	Fountain Indoor	Whole-house Treatment
Northern California	81.5%	78.7%	29.5%	79.8%	10.8%	3.7%	3.2%	10.8%
Las Virgenes MWD	100.0%	68.8%	35.7%	100.0%	17.2%	0.0%	0.0%	16.7%
Los Angeles	84.6%	79.6%	32.0%	73.7%	15.7%	2.8%	2.8%	10.2%
IRWD	93.9%	77.6%	30.4%	98.0%	12.5%	6.4%	2.1%	14.8%
City of San Diego	87.5%	75.0%	30.3%	80.0%	11.1%	2.8%	2.8%	17.1%
San Diego County WA	87.5%	64.3%	46.7%	86.7%	21.4%	0.0%	0.0%	10.7%
Southern California	89.0%	76.2%	32.9%	83.6%	14.9%	3.0%	2.1%	13.1%
All Study Sites	85.6%	75.7%	27.6%	81.9%	13.1%	3.3%	2.6%	12.1%

Households reported that they knew of some leaks at the time of the survey. They survey asked whether they had a “leak” in any of the following areas: toilet, faucet, pool, irrigation system, or other leak. Respondents identified toilets and irrigation systems with the highest rates of known leaks. Overall, 6% of respondents identified toilet leaks, and the same percentage identified current irrigation systems leaks. Dripping faucets were identified by 4% of respondents, while pool system related leaks were identified by 1% of respondents, and 2% reported “other” types of leaks.

The survey included a section asking respondents whether or not they had renovated or replaced plumbing pipes, bathroom fixtures, and kitchen fixtures since 1995. Forty percent of respondents reported renovating or replacing plumbing pipes, 64% reported having renovated bathroom fixtures, and 64% also reported having renovated or replaced kitchen fixtures. In general, study sites containing fewer homes built before 1980, such as San Diego County, Las Virgenes MWD, and IRWD, consistently reported lower incidence of renovation or replacement compared with study sites containing more homes built before 1980, such as San Francisco and Los Angeles.

Respondents were asked questions regarding how fast hot water reaches certain parts of their home. When asked whether or not respondents had to wait longer for hot water to reach certain parts of their home, almost two thirds, 63%, answered “yes.” Among those reporting longer waits for hot water, 62% reported waiting longer for hot water in the master bathroom, and approximately 40% reported longer waits in the kitchen and other bathrooms.

Sixty percent of respondents described their longest wait for hot water as “almost no time at all,” or “not very long.” Forty percent described their longest wait for hot water as “pretty long,” or “very long.” Study sites with more homes built before the 1980s, such as San Francisco and Los Angeles were more likely to report waiting times of “almost no time at all,” or “not very long,” while study sites with fewer homes built before the 1980s, such as Redwood City, Las Virgenes MWD, and IRWD, were more likely to report waiting times of "pretty long," or "very long."

Respondents were asked if the wait for hot water bothered them at all. Approximately 52% of survey respondents were not bothered by the wait for hot water, 30% were bothered a little bit, and 18% were bothered very much.

The survey also asked about whether households had installed remedies to shorten the wait time for hot water. Overall 10% of households had installed a remedy. Rates of those reporting installing a remedy ranged from 23% in Las Virgenes MWD to 3% in Davis and Sonoma County WA. A recirculating pump was the most popular remedy, with 71% of those reporting a type of remedy identifying a recirculating pump.

Swimming Pools and Hot Tubs

The survey asked respondents whether or not their houses had swimming pools and outdoor hot tubs. Almost one fifth (19%), of all survey respondents reported owning a hot tub. The percentages were almost identical when respondents were asked about whether or not they owned swimming pools: 18% of all respondents reported owning a swimming pool. In general, respondents from Southern California study sites were more likely to have an outdoor pool or hot tub than respondents from study sites in Northern California. Figure 69 shows swimming pool and hot tub saturation rates across each study area, as well as Northern and Southern California regions, and saturation rates across all study areas.

Outdoor pool owners were asked about their use of pool covers. Overall, pool cover use remains nearly constant year-round. From month to month, between 60% and 75% of outdoor pool owners cover their pools. Some study sites show seasonal variability in pool cover usage. Outdoor pool owners surveyed in Las Virgenes MWD and Redwood City do not use pool covers in cooler months (primarily from November to April). Also, in San Diego County, where only two outdoor pool owners responded, no pool owners reported using pool covers from May to August.

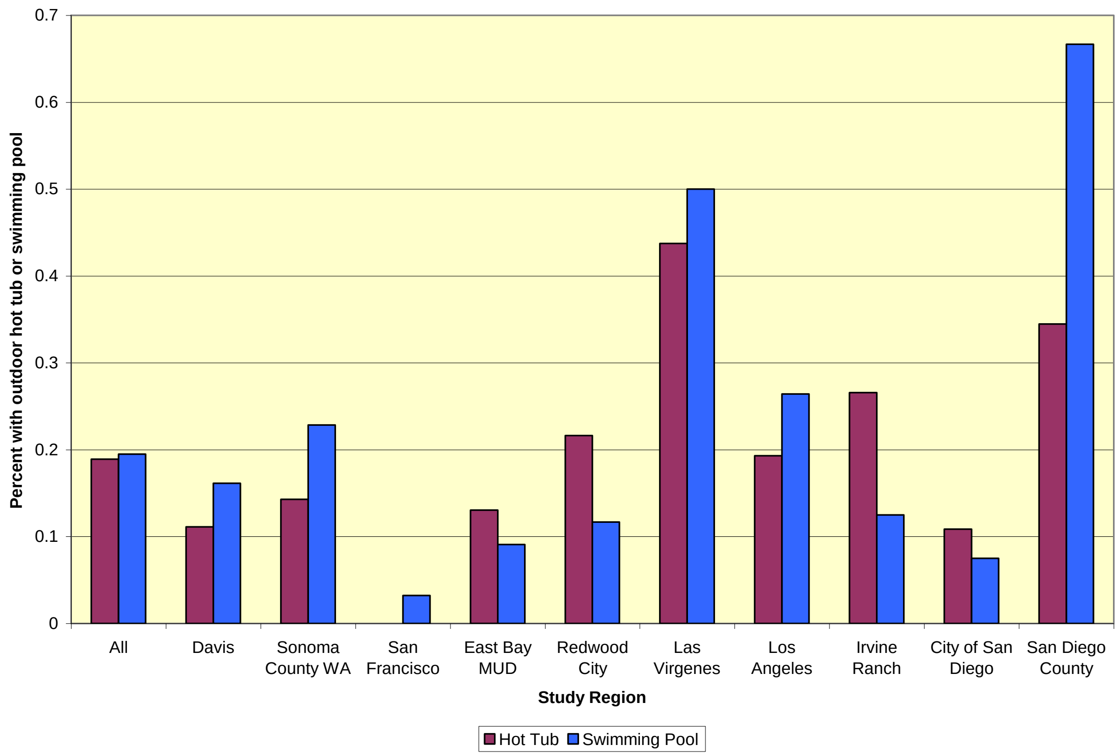


Figure 69: Percentage of respondents with outdoor hot tub or swimming pool

Landscape Watering

The survey gathered information on each household's outdoor landscape and related water use. Ninety-six percent of respondents water their outdoor landscape; the other four percent do not. Nearly half of respondents (43%) reported using a contractor for some part of outdoor landscape maintenance.

Respondents were asked to describe how much of their outdoor landscape is made up of turf. Table 68 shows how outdoor landscape coverage varied across the study sites, as well as overall. In general, respondents' outdoor landscapes in Southern California were composed of more turf than outdoor landscapes in Northern California.

The median frequency for watering turf during the summer months (June-August) was three times per week. Across all regions, 70% of respondents watered their turf during the summer three or more days per week. In the Northern California study sites, 64% of respondents watered their turf three or more days per week in the summer, compared to 74% of respondents in Southern California study sites. Figure 70 shows the percent of respondents in each study area that watered their turf three times a week or more.

Table 68: Percentage of outdoor landscape reported to be turf

Water Agency	100%	Half or more	About 20% to 50%	About 10% to 20%	About 5% to 10%	Less than 5%	None
Davis	0%	38%	19%	19%	0%	5%	19%
SCWA	0%	33%	11%	11%	0%	0%	44%
San Francisco	0%	20%	7%	0%	7%	7%	60%
East Bay MUD	3%	19%	28%	17%	0%	3%	31%
Redwood City	5%	30%	30%	20%	0%	5%	10%
Northern California	2%	27%	21%	15%	1%	4%	31%
Las Virgenes MWD	0%	54%	29%	13%	4%	0%	0%
Los Angeles	7%	40%	24%	10%	10%	1%	8%
IRWD	5%	32%	32%	16%	5%	3%	5%
City of San Diego	7%	19%	26%	4%	11%	4%	30%
San Diego County WA	0%	20%	40%	20%	0%	10%	10%
Southern California	5%	36%	28%	11%	8%	2%	10%
All Study Sites	4%	33%	25%	12%	5%	3%	17%

Seventy-two percent of respondents manually watered some part of their outdoor landscape. The most common mode of manual watering was hand-held garden hose, which was used by 82% of the manual irrigation respondents. Approximately one quarter of respondents reported manually watering their outdoor landscape using a hose with a sprinkler, 11% using an in-ground sprinkler system with no timer, 9% drip irrigation or bubbler system, and 7% a soaker hose.

Forty percent of all respondents reported manually watering between 50% and 100% of their outdoor landscape. Thirty-eight percent reported manually watering between 5% and 50% of their outdoor landscape, while slightly more than one-fifth of respondents, 22%, reported manually watering only 5% or less of their outdoor landscape. Manually watering a majority of outdoor landscape (50%-100%) was more common among Northern California study sites (50%), and was less common among respondents from Southern California study sites (31%).

Over two-thirds of respondents reported having an in-ground sprinkler system, with 87% of those systems having an automatic timer. Only 4% of the in-ground sprinkler systems were said to run a weather-based irrigation controller (WBIC) or “smart” controller. Thirteen percent of respondents with in-ground sprinkler systems did not know whether or not their system had a WBIC or similar controller.

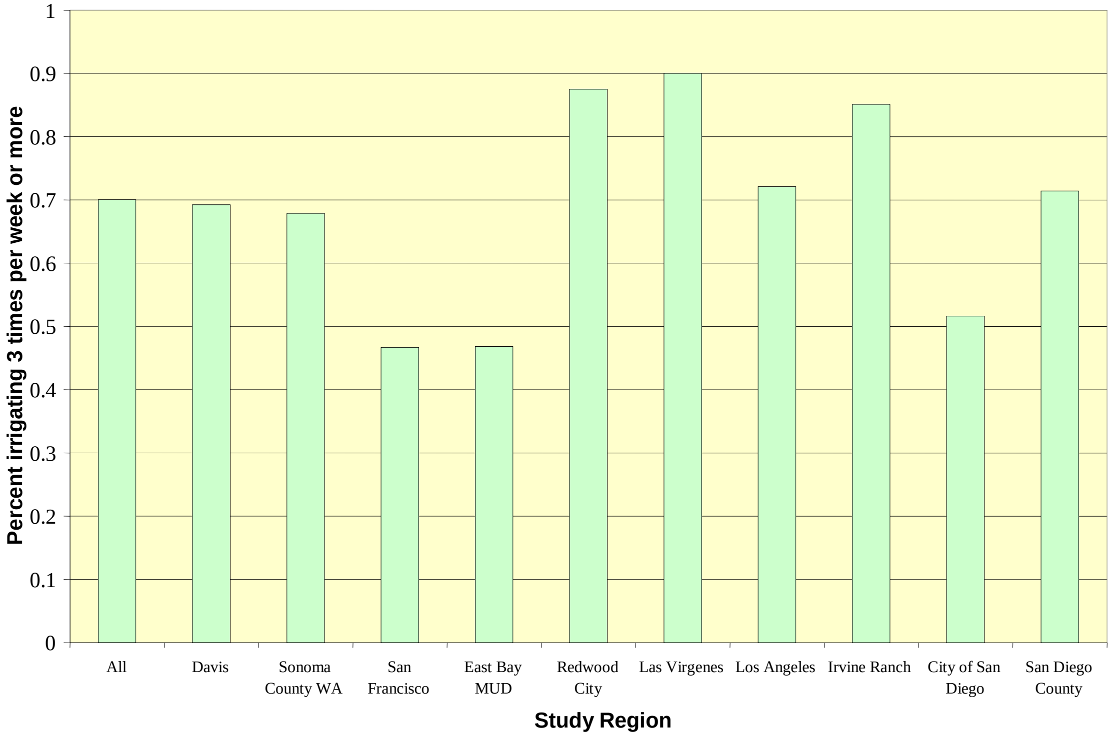


Figure 70: Percentage of respondents irrigating three times per week or more

Water Bill Awareness

To begin, respondents were asked to what degree they agreed or disagreed with the statement; “Without looking at past bills, I know about how much my average (typical) household water bill was (in dollars) last year.” Just over 25% of respondents either “somewhat agreed” or “strongly agreed” with the statement regarding past water bill amounts, and approximately 70% of respondents either “somewhat disagreed” or “strongly disagreed.”

Next, the survey asked the extent to which respondents agreed or disagreed with the following statement regarding knowledge of typical water use: “Without looking at past bills, I know about how much water my household used in an average (typical) billing period last year.” Nearly 45% of respondents chose “strongly agree” or “somewhat agree,” and approximately 52% either “somewhat disagreed” or “strongly disagreed.”

Thus California respondents were more likely to remember water use amounts from past bills (45%) than dollar amounts from past bills (25%). This is the reverse of the result for the same questions asked of households in Florida, where 78% agreed they knew the approximate dollar amount of their average bill, but only 38% of homes agreed they knew the approximate number of gallons of usage (Whitcomb, 2005). This result may indicate that California respondents are more likely to be able to interpret the details of their water bill and understand how their water use fits into water use blocks for inclining block rates designed to encourage water conservation.

Respondents were then posed the statement; “The cost of water is an important factor for me when deciding how much water to use indoors.” Only 36% of survey respondents either “strongly agreed” or “somewhat agreed” with that statement, compared to over 60% who “somewhat disagreed” or “strongly disagreed.” For the Davis study site, responses were reversed, with 65% of respondents either “strongly agreeing” or “somewhat agreeing” versus 29% choosing “somewhat disagree” or “strongly disagree.” For comparison, 65% of homes surveyed in Florida either strongly agreed or somewhat agreed that the cost of water was an important factor in deciding how much water to use indoors (Whitcomb, 2005).

The next statement related to determinants of respondents outdoor water use: “The cost of water is an important factor for me when deciding how much water to use outdoors.” Only 26% of respondents “strongly agreed” or “somewhat agreed,” while approximately 70% either “somewhat disagreed” or “strongly disagreed.” Again, respondents from Davis differed from other study sites, with almost half of the respondents reporting that they “strongly agree” or “somewhat agree” and 45% either “somewhat disagree” or “strongly disagree.” For comparison, 72% of homes surveyed in Florida either strongly agreed or somewhat agreed that the cost of water was an important factor in deciding how much water to use outdoors.

The next statement related to respondents’ motivations for conserving water: “I conserve water mainly for environmental reasons.” Across all study sites, only 16% “strongly agreed” or “somewhat agreed,” compared to over 80% who “somewhat disagreed” or “strongly disagreed.” For comparison, 67% of homes surveyed in Florida reported that they conserved water mainly for environmental reasons (Whitcomb, 2005).

The last statement posed to respondents was related to water use and the cost of wastewater service: “I take into account the cost of wastewater (sewer) service when deciding how much water to use.” Thirty-nine percent of respondents “strongly agreed” or “somewhat agreed” with the statement, and forty-three percent “somewhat disagreed” or “strongly disagreed.” Respondents who are charged a flat rate for wastewater/sewer services were instructed to mark “not applicable,” which 17% of respondents did. In Davis and IRWD, a majority of respondents (58% and 62%, respectively) either “somewhat agreed” or “strongly agreed” that wastewater rates influence their water use. For comparison, 50% of homes in Florida reported taking into account the cost of wastewater in deciding how much water to use.

CHAPTER 9 – MODELS OF WATER USE

Having analyzed both the indoor and outdoor water use patterns and survey information from several hundred single-family homes across California, the next step was to perform regression analyses on the results in order to determine which factors were most important in explaining water use in the homes. Models were built for total indoor water use (gphd), outdoor water use (kgal/year) and individual models were also built for the important end uses because variables that might not show up as significant for whole house indoor use may be significant for individual end uses.

Using the SPSS package, a series of models were tested. The list of 61 variables used in this analysis is shown in Table 69. The variables were divided into four groups. The first group consisted of dependent variables, namely the daily and annual water use that we seek to explain in this analysis. The second group contained the variables that were thought to be best for the indoor analyses. The third group contained the variables for the outdoor analyses, and the fourth group contained questions about the attitudes and knowledge of the customers that were to be tested as to their relevance for both indoor and outdoor models.

There were two types of independent variables in the modeling system: continuous variables that could assume any real positive value, and flag or conditional variables that were used to test the impact of a specific state or conditions on the water use. Flag variables assume the values of 0 or 1. Note that there were no geographical variables, such as the water agency or region of the state in which the customer resided. Geographical variables were excluded because the original work plan called for pooling all of the results into a single data set for modeling purposes. By pooling the data the underlying factors such as the number of residents, types of fixtures and appliances, income, irrigated area, ET, etc., that have a real impact on water use could be identified and analyzed using the full range that they assumed in the sample.

The modeling approach was a two step process. First models were developed using the continuous variables that best explained indoor and outdoor water use. Next the impact of the conditional variables was tested as to whether their inclusion reduced the variance of the basic model. In this case, variance is the total error of the model in predicting water use. If a conditional variable reduced the variance in a statistically significant degree then that condition was deemed important in explaining water use.

Table 69: Variables used for modeling single-family water use

Var Name	Type	Description
Annual_Kgal	dependent	annual use kgal
Outdoor Kgal	dependent	best estimate of annual outdoor use
Indoor_Kgal	dependent	best estimate of annual indoor use
Indoor_GPD	dependent	gpd for all indoor uses
Toilet_GPD	dependent	gpd for toilet use
CW_GPD	dependent	gpd for clothes washer use
Shower_GPD	dependent	gpd for showers
DW_GPD	dependent	gpd for dishwashers
Leak_GPD	dependent	gpd for leaks
Faucet_GPD	dependent	gpd for faucets
Bath_GPD	dependent	gpd for baths
Other_GPD	dependent	gpd for other
CW_GPL	continuous	gallons per load for clothes washers
Toilet_GPF	continuous	gallons per flush for toilets
CW_HE	flag	set if cw gpl < 30
Toilt_HE	flag	set if toilet gpf < 2.0
Res_No	continuous	number of residents in home
Youth	flag	flag for presence of non-adults in home
AtHome	flag	flag for at least one adult at home that is not employed outside home
OwnHome	flag	flag for ownership of home
Pay4Wtr	flag	flag if homeowner pays his own water bill
AveRate	continuous	Average water rate for customer
MaxRate	continuous	maximum rate charged for water
Bedrooms	continuous	number of bedrooms in home
HouseAge	continuous	year that house was built
Bathrms	continuous	number of bathrooms in the home
Pool	flag	does house have a pool
Fount_out	flag	does house have an outdoor fountain
Fount_in	flag	set if house has an indoor fountain or water feature
Income_Hi	flag	set flag if household income is => $120,000
Income_Low	flag	set if income is =< $30000
Garb	flag	set if house has a garbage disposal
CW	flag	set if house has a clothes washer
CW Front	flag	set if house has a front loading CW
DW	flag	set if house has a dishwasher
Spa_In	flag	set if house has an indoor spa or jacuzzi tub
Spa_out	flag	set is house has an outdoor spa or hot tub
Swamp	flag	set if house has a swamp cooler
Treat	flag	set if house has a whole-house water treatment system
ULF	flag	set if owners report having at least 1 ULF toilet
Hydra	flag	set if there is at least one multi headed shower in the home
Leak	flag	set if homeowner reports knowing of a leak in the home
Wait	flag	set if homeowner reports a very long wait for hot water
Lot_area	continuous	lot size
Irr_area	continuous	total irrigated area
Turf_area	continuous	total turf area
Nonturf_area	continuous	total non-turf area
NetETo	continuous	net Eto for site
AppliedWater	dependent	water applied to landscape (inches)
TIR	continuous	theoretical irrigation demand (Inches)
AppRatio	dependent	Application ratio (Applied water/tir)
LndscpRatio	continuous	landscape ratio (TIR/RefRequirement)
ExcessUse	dependent	excess water use (kgal)
ContractWtr	flag	Is the contractor responsible for watering your lawn
Sprinklers	flag	do they have an inground irrigation system
Override	flag	does the system have a rain or other shut off device
KnowBill	flag	Know how much my average water bill was last year (4)
KnowVol	flag	Know average volume of water used last year
CostImp	flag	The cost of water is important
Enviro	flag	I conserve water for environmental reasons
CostAccount	flag	I take cost into account when deciding how much water to use

Indoor Models

Regression analyses were done for both total indoor use and for several key individual end uses. This section describes the model results for the indoor uses.

Overall Indoor Use

A total of eight continuous variables were tested for significance in predicting overall indoor water use. In this model the dependent variable was daily indoor household water use (gphd) determined from the flow trace analysis. The independent variables were obtained from the survey results. Both linear and log-log models were tested and the log-log model was found to give a better fit to the data. In addition, the log-log model also captures the fact that indoor water use is not linearly related to the key variable (the number of residents in the home), so a log-log model was selected for the indoor model. Table 70 shows the variables tested for the indoor model and the significance, measured by the respective p values, determined for each.

Table 70: Continuous variables tested for indoor model

Variable	p-value
Number of residents in home	0.00
Household income	0.76
House Age	0.70
Home_value	0.39
Number of Bedrooms	0.60
Number of Bathrooms	0.46
Indoor SQFT	0.36

As can be seen in Table 70 the only continuous variable that was found to be statistically significant in predicting indoor use was the number of residents in the home. All of the others had significance p values greater than 0.10, which means that there is a greater than 10% chance that their impact was simply random.

The model that resulted from the analysis of indoor water use versus the number of residents in the home is shown in Equation 9-1. The R2 value for the model was 0.40, which implies that the model explains roughly 40% of the variability in observed water use.

Equation 9-1: Model for indoor water use

$$Indoor\_Use = 72.675 \times Res\_No^{0.728} + 6.50$$

Where:

Indoor_use = gallons per day of indoor water use
Res_no = number of residents living in the home
6.50 = bias correction factor

This model describes household water use patterns in the single-family homes in this study, based on their current demographics and physical characteristics. If one examines the descriptive statistics for the homes, described in this report in terms of percent of homes with high-efficiency fixtures and appliances, income, employment, etc. then the indoor model describes a population of homes meeting those parameters.

To the extent that various groups of homes vary in their characteristics from the homes included in this study it was necessary to test for certain conditional variables. In order to see how the various physical and demographic parameters affect the predicted water use a series of conditional variables were tested in order to determine how they affected the predicted indoor water use in homes.

Table 71 shows a list of the conditional variables tested for their impacts on indoor water use. The table shows the variable names, the description of what the variable means, the change in the mean indoor use associated with the variable, the probability that the observed change in means in simply due to chance, the total number of homes for which the variable was available, and the total number of positive responses for the variable. The variables that proved useful for the predictive model have been bolded.

Table 71: Conditional variables tested for indoor model

Variable Name	Description of Variable	Change in Mean Daily Use (GPD)	p-value	Total No. of Responses	Total Positive Responses
significant_leak	Trace analysis showed leakage greater than 100 gpd.	222.90	0.000	451	25
Youth	Is at least one of the residents of the home not an adult?	-41.62	0.000	451	170
Toilet_HE	Does the flow trace analysis show average gpf to be less than 2.0?	-21.98	0.026	448	129
Survey_ULF	Did the survey indicate at least one ULF toilet in the home? (note: this is not additive with Toilet_HE)	-20.54	0.065	369	262
CW_HE	Did the flow trace analysis show average gallons per load to be less than 30?	-16.72	0.083	426	136
Hydra	Did the survey indicate at least one multi-headed shower head present in the	25.91	0.154	451	30

Variable Name	Description of Variable	Change in Mean Daily Use (GPD)	p-value	Total No. of Responses	Total Positive Responses
	home?				
Income_Hi	Was the household income above $120,000?	-13.63	0.168	377	140
CW_Front	Did the survey response indicate that the home has a front loading clothes washer?	-11.98	0.283	360	110
Pay4Wtr	Do the residents pay for their own water?	-48.06	0.322	445	441
Spa_out	Is there an outdoor spa or hot tub at the home?	-9.93	0.381	447	91
Spa_in	Is there an indoor spa at the home?	-23.82	0.386	374	13
OwnHome	Do the residents own the home?	-14.36	0.393	446	411
Survey Dishwasher	Is there a dish washer present?	-9.51	0.451	406	349
Survey Cooler	Is there a swamp cooler?	27.75	0.456	410	7
Survey Garbage Disposal	Is there a garbage disposal?	-10.12	0.461	406	349
Stay at home?	Is there at least one adult that is not employed outside the home?	-3.38	0.732	444	316
Survey Softener	Is there a whole house water treatment system present?	4.52	0.770	415	45
Fount_Out	Is there an outdoor fountain present?	2.66	0.844	451	58
Wait	Is there a noticeable wait for hot water somewhere in the home?	1.84	0.848	384	163
Pool	Is there a swimming pool present?	-1.28	0.913	388	77
Income_Low	Is the household income less than $30,000?	1.57	0.924	377	35

For practical purposes this model took the form shown in Table 72. This model is applied by first determining the uncorrected water use by multiplying 72.675 times the number of residents to the 0.728 power. The four correction factors are determined by multiplying the percent of the populations that are negative for the factor by the negative study residual plus the percent of the population for which they are positive times the positive residual. The total correction factor is the sum of the four separate factors.

Table 72: Working version of predictive model

Indoor Model Summary				
	Exponent	Constant	Bias Correction	
Number of Residents	0.728	72.675		
Bias correction	6.5			
	Study Pct. Neg.	Study Pct. Pos.	Study Residual (-)	Study Residual (+)
Significant leak	93%	6.55%	-12.356	210.541
HE Clothes washer	71%	29.50%	10.012	-6.708
HE Toilet	70%	29.73%	7.747	-14.235
Kids/Teens at home	64%	36.15%	15.688	-25.932

When the predictive model is used with an average number of 2.94 residents per household, which was the average number of persons per household in the study group, and with the proportion of homes meeting the four conditional criteria shaded in green, then the model predicts an average indoor household use of 175 gphd, which is the same as the observed use shown in Table 37.

Per Capita Indoor Use Relationships

At this point the research contains detailed indoor use data for a number of study sites, which were collected using the same techniques used for this study. Using each dataset, relationships were developed between indoor water use and the number of occupants in the homes. These per capita relationships are shown in Table 73 and Figure 71. It is significant to note that none of the relationships between indoor water use and number of residents are linear. This effect has been noted by other authors such as Pekelney and Chesnutt[53], and it has important implications for use of per capita data for projecting water savings or water demands. The last column of Table 73 shows the projected per capita use for a family of three based on each data set. These show that the per capita indoor use in the California Single-Family Homes Study is 13.3% lower than the per capita indoor use from the REUWS when the data are normalized for a family of three.

[53] Pekelney, D.M., T.W., Chesnutt, and D.L. Mitchell (1996). "Cost-Effective Cost-Effectiveness: QuantifyingConservation on the Cheap." In: *AWWA National Conference*, AWWA, Toronto, Canada., Pgs 6, 7 & 8.

Table 73: Comparison of per capita indoor water use

Study	Model	Description	Per capita Use for Family of three	Percent of REUWS
REUWS	$87.41 \cdot x^{0.69}$	1189 homes from REUWS set	62.18	100%
California SF Home Study	$72.67 \cdot x^{0.728}$	The 780 SF homes in this study, see Equation 9.1	53.89	87%
EPA New Home Study	$66.3 \cdot x^{0.63}$	Study of homes built after 2001	44.15	71%
EPA Post Retrofit Study	$50.21 \cdot x^{0.77}$	Study of 100 high-efficiency homes	39.0	58%

When the four equations shown above are plotted on the same graph the results are quite striking. The oldest and least efficient is the group of homes from the REUWS study. The highest efficiency homes are those from the EPA Retrofit study. The group of approximately 300 new homes selected from standard homes built after 2001 in 10 water agencies lies just above the Retrofit homes, and the homes from this study, which are a cross section of existing homes in California lies between the new homes and the REUWS homes. The potential savings in indoor use in the California homes can be estimated as the reduction in use that would occur if the homes' consumption dropped to the region of the bottom line in the figure represented by the EPA Retrofit Homes.

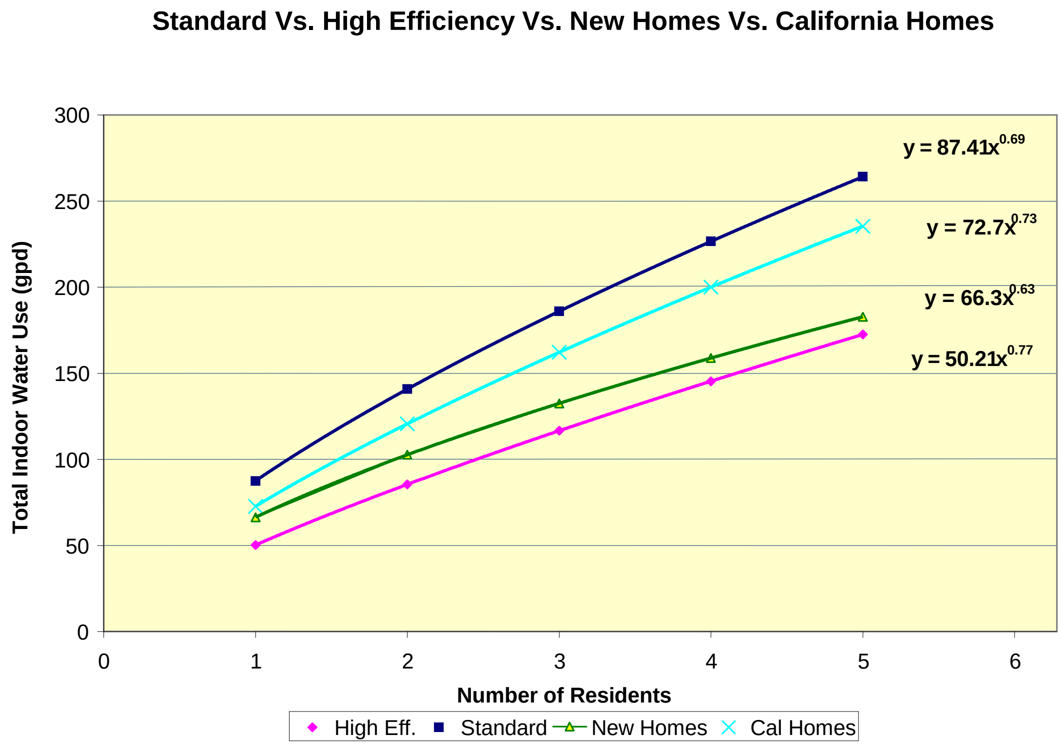


Figure 71: Comparison of per capita indoor use relationships

Individual End Uses

Individual end use models were developed for clothes washers, faucets, leaks, showers and toilets. These models helped to clarify the factors that influence these end uses, which might not have shown up as significant in models of overall indoor use. They offer several useful insights for program design, but are not intended to be used for prediction of overall household use.

Clothes washer end use analysis

The model for clothes washer use was developed similarly to the indoor use model. First a regression model was created using the continuous variables that proved significant in predicting clothes washer use. Next, a series of conditional variables were tested as to how they improved the fit of the data. Like daily indoor use, this end use follows a log-normal distribution. Several of the factors listed below correlate with higher or lower clothes washer use, but we would not say that in all cases these factors have a cause and effect relationship. For example, the two questions about knowledge of water and wastewater use and charges correlate with increased clothes washer use. This is an interesting correlation, but one would not expect that knowledge of water use and wastewater charges would necessarily lead to increased clothes washer use, unless people who pay attention to things like the cost of water are basically more compulsive about details, and this extends to the level of cleanliness of their clothes.

The following factors were associated with higher clothes washer use. All except the first two of these variables are flags:

- Number of residents
- Higher clothes washer gallons-per-load
- Having residents younger than 18. This is after correcting for the number of residents.
- Agreement with "Without looking at past bills, I know about how much water my household used in an average (typical) billing period last year" q45B
- Agreement with "I take into account the cost of wastewater (sewer) service when deciding how much water to use" q45F
- Respondents who underwent bathroom renovations and plumbing renovations. These numbers are not cumulative for respondents who have renovated both.

Factors associated with lower clothes washer use:

- Having to pay for water

Table 70 shows the continuous variables that tested positive for clothes washer use. The resulting model, shown in Equation 9-2, had an r^2 value of 0.30.

Table 74: Continuous variables found to be significant for clothes washer use

Variable	p-value
Number of residents	0.00
Clothes washer gallons per load	0.00

Equation 9-2: Clothes washer end use correction

$$CW = 1.31 \cdot Res\_No^{0.58} \cdot CW\_GPL^{0.70}$$

Where: CW = gallons per household per day used for clothes washers
Res_No = number of residents in the home
CW_GPL = capacity of clothes washer (gal/load)

This regression achieved the highest r-squared (0.30) by ignoring other physical factors: income, age of home, home value, and indoor size. The strength of a factor is measured by the difference in average clothes washer use. The mean of corrected clothes washer use is based on residuals from log-log regression.

Table 75: Conditional variables tested for impacts on clothes washer use

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Pay4Wtr	Do the residents pay for their own water?	-18.73	0.05	421	417
Survey Bathroom Renovated	Bathroom fixtures have been renovated	3.52	0.09	374	235
Survey Plumbing Renovated	Plumbing has been renovated	3.53	0.10	364	144
q45F_agree	Agreement with "I take into account the cost of wastewater (sewer) service when deciding how much water to use"	3.57	0.08	367	148
q45B_agree	Agreement with "Without looking at past bills, I know about how much water my household used"	4.19	0.04	372	164
Youth	Is at least one of the residents of the home not an adult?	4.59	0.02	426	162

Whether the clothes washer is a front-loading or top loading design did not reach significance. This is expected because the effect of clothes washer load volume is already corrected as part of regression gallons per load.

The means reported for bathroom and plumbing renovations are not cumulative. The real interpretation of the renovations findings is that kitchen renovations are not related to clothes washer use, where households with either plumbing or bathroom renovations are associated with increased use.

The data show that after correcting for the number of residents in the home, having children or teenagers present in the home is associated with a modest increase of 4.59 gpd for clothes washer use. This makes sense given the way children and teenagers get their clothes dirty at school, play or sports.

Only 1% of respondents reported that their landlord or homeowners association pays for water. This small group, however, had an average use that was 18.7 gphd less than the rest of the households. Even though the p value was only 0.05, which indicates a statistically significant value, a sample of only 1% seems too small from which to base general conclusions.

Four factors reached significance with very similar results: Two attitude questions and the presence of bathroom and plumbing renovations are each associated with an average 3.52 – 4.19 gphd higher clothes washer use. We speculated above about the possible linkages between attitudes and clothes washing. The relationship between remodels and plumbing seems a more concrete sort of effect.

Faucet end use analysis

Like daily indoor use, this end use follows a log-normal distribution.

Factors significantly associated with higher faucet use:

- Number of residents
- Number of toilet flushes
- A "leak" other than toilet, faucet, pool and irrigation leaks.

Factors significantly associated with lower faucet use:

- Modernized kitchen appliances (dishwasher and garbage disposal)
- Agreement with "Without looking at past bills, I know about how much water my household used in an average (typical) billing period last year."
- Agreement with "The cost of water is an important factor for me when deciding how much water to use indoors (e.g. for washing dishes, washing clothes, showering/bathing, etc.)"
- Agreement with "I take into account the cost of wastewater (sewer) service when deciding how much water to use."
- Household has a water softener, pool or outdoor spa. (Numbers reported do not reflect a cumulative effect)
- Household has residents under 18

The level of significance reflected here is based on corrected Trace Wizard faucet analysis using the same technique as broader indoor and outdoor models for total household use: log-log regression. This technique is used to mitigate the dominance of physical features like bathroom use and the number of people in the household over subtler features like the respondent's attitudes toward water conservation. Bathroom use is defined by the number of toilet flushes per day. This factor is not generally estimable in the population – it is reflected specifically as part of the faucet end use model and is not included in any other models.

Table 76: Faucet end use correction factors

Factor	p-value
Flushes Per Day	0.00
Residents	0.00

Equation 9-3: Faucet end use correction

$$\text{Faucet GPD} = 5.54 \cdot \text{residents}^{0.44} \cdot \text{FPD}^{0.46}$$

Where:

Faucet GPD = Average daily gallons faucet use
Flushes per day = Average daily number of toilet flushes
Residents = Full-time residents in household

This regression achieved the highest r-squared (0.29) by ignoring other physical factors: income, age of home, value of home, inside size of home, and number of bathrooms. Generally, survey responses are less complete for these ignored variables.

The strength of a factor is measured by the difference in average daily faucet use. The mean of corrected faucet use is based on residuals from log-log regression.

Table 77: Conditional variables tested for impacts on faucet use

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Survey Dishwasher	Is there a dishwasher present?	-14.17	0.00	398	330
Survey Garbage Disposal	Is there a garbage disposal?	-13.08	0.00	403	347
q45B_agree	Agreement with "Without looking at past bills, I know about how much water my household used in an average (typical) billing period last year."	-7.85	0.00	391	174
Spa_out	Is there an outdoor spa or hot tub at the home?	-7.71	0.00	444	89
q45F_agree	Agreement with "I take into account the cost of wastewater (sewer) service when deciding how much water to use."	-7.16	0.00	386	158

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
q45C_agree	Agreement with "The cost of water is an important factor for me when deciding how much water to use indoors (e.g. for washing dishes, washing clothes, showering/bathing, etc.)"	-6.34	0.01	392	143
Survey Softener	Is there a whole house water treatment system present?	-5.93	0.10	412	45
pool	Is there a swimming pool present?	-5.35	0.07	385	75
Youth	Is at least one of the residents of the home not an adult?	-4.11	0.06	448	168
Survey Other Leaks	A "leak" other than toilet, faucet, pool or irrigation leakage	28.50	0.00	389	6

Other factors, such as the number of adults not employed outside the home did not reach significance. With a larger sample, bathroom renovations may reach significance.

The survey asked the residents to say whether they had known leaks in five types of devices: toilets, faucets, pools, irrigation systems and "other leaks." There were a few homes that responded that they had other leaks. This response was associated with a significant increase in faucet use. It is possible that theses leaks gave the appearance of faucets, and that in this case some leaks -were classified as faucet use.

The results for dishwashers are interesting in that they suggest that the presence of a dishwasher relates to lower faucet use. This makes intuitive sense since dishwashers wash dishes far more efficiently than do hand washers. On average there are 0.35 dishwasher loads per day and these are linked to 14 gpd of reduced faucet use. This suggests that a dishwasher that uses 7 gallons per run or 2.4 gpd of water eliminates the use of 14 gallons of faucet use for a net reduction in 11.5 gpd in indoor use. The data do not prove this to be the case, but do suggest that dishwashers may be water conservation devices.

The same is true of garbage disposals, although the intuitive linkage is not quite as compelling. The logic here is that having a garbage disposal reduces the amount of water that is run into the kitchen sink in order to clean out food particles and keep the drain running. Again, this is an interesting finding and one that could be tested through pre-post analysis in a set of test homes.

Leaks

Like daily indoor use, household leakage follows a log-normal distribution. However, the highest "leak" rates are several orders of magnitude above the mean. Unlike other end uses in this analysis, leakage was not found to be related to any of the continuous variables in the data set so it was modeled strictly against the conditional variables.

The following conditional factors were associated with higher leakage:

- The presence of a swimming pool
- Remedy installed for hot water availability
- Having an in-ground sprinkler system
- The presence of a water treatment system
- Survey indicates any leaks were known to be present in the home

Factor associated with lower leakage:

- Manual irrigation (versus automatic irrigation)

As shown in Table 78 the strength of a factor is measured by the difference in average daily leakage and the p value being less than 0.10.

Table 78: Conditional variables tested for impacts on leakage

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Survey Manual Irrigation	Any part of the landscaping is watered manually	-4.29	0.07	393	284
survey_leaks	Any "leak" indicated	2.27	0.04	415	56
Survey Treatment	Is there a whole house water treatment system present?	7.47	0.01	425	47
SprinklerSystem	In-ground sprinkler system	8.35	0.01	733	246
Survey Toilet Leaking	Toilet is running, potentially a flapper leak	10.58	0.06	415	23

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Q10	Hot water remedy	12.11	0.05	380	42
Pool	Is there a swimming pool present?	17.51	0.09	396	78

The data show that there is a marked difference of over 12.6 gphd in mean leakage rates between homes with automatic sprinklers and homes that irrigate manually. This suggests that automatic sprinkler systems are the source of a significant amount of leakage in these homes. It is not really clear why having a water softener should relate to increases in leakage. Perhaps this is due to the fact that water softeners may create events that have the appearance of leaks. The fact that the two survey questions about leakage relate to the amount of leakage found in the trace is obvious. The relationship between a pool and leakage may be due to the fact that some pools are a source of leaks and that pool filling may appear to be leakage on the trace as pools are continuously refilled to replace evaporation and splashing losses. Again, it is not clear what the relationship is between having a hot water recirculation system and leakage. These devices operate inside the house plumbing systems and should not have an impact on the water meter.

Shower end use model

Daily shower usage showed a relationship between the number of residents in the home and the household income. Like daily indoor use, this end use follows a log-normal distribution.

Factors associated with higher shower use:

- Number of residents
- Income
- Renting
- Unspecific renovations (any bathroom, kitchen, or plumbing renovations)

Factors associated with lower shower use:

- Adults not employed outside the home. This occurs after correcting for the number of residents.
- Outdoor spa or hot tub

The level of significance reflected here is based on corrected shower gallons-per-day from Trace Wizard analysis using the same technique as broader indoor and outdoor models for total household use: log-log regression. This technique is used to mitigate the dominance of physical features like the number of people in the household over subtler features like the respondent's attitudes toward water conservation.

Table 79: Shower end use correction factors

Factor	p-value
Residents	0.00
Income	0.01

Equation 9-4: Shower end use correction

$$\text{Shower GPHD} = 3.49 \cdot \text{Residents}^{0.84} \cdot \text{Income}^{0.27}$$

Where:

Shower gphd = Average daily shower use (gallons)
Residents = Full-time residents in household
Income = Annual household income, units of $1000

The regression achieved the highest r-squared (0.29) by ignoring other physical factors: income, age of home, home value, indoor size of the home, number of bathrooms and, notably, showerhead flow rate. Showerhead flow rate is not correlated strongly with household shower water use and its absence means this model predicts no change in daily shower volume given a change in showerhead flow rate.

The lack of a relationship between shower flow rate and household water use for showering appears to be due to the fact that while there is a significant spread in flow rates of individual showers, as shown in Figure 48 and Figure 49, there is not a lot of variation in the average shower flow rate on the household level. The average shower flow rate for each of the 716 homes in the group was 2.15 ± 0.05 gpm, which implies that the variability in shower flow rates occurs within the houses rather than among them. In other words, the higher flow rate showers are spread out among many homes rather than being concentrated in a few homes, and as a consequence the impact of higher flow rate showers was lessened in significance.

It was interesting to note that the presence of multi-headed showers was not a factor in predicting greater household shower usage, while it was a factor relating to increased total indoor water use. Examining the data showed that the homes with the multi-headed showers also had larger leakage than the others. This suggests a relationship between leaks and multi-headed showers. - Whether the showers' heads are actually leaking themselves, or whether this is a coincidental finding remains to be seen.

The strength of a factor is measured by the difference in average daily shower use. The mean of corrected shower use is based on residuals from log-log regression.

Table 80: Conditional variables tested for impacts on shower use

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Spa_out	Is there an outdoor spa or hot tub at the home?	-5.52	0.06	368	72
At Home	Is there at least one adult that is not employed outside the home?	-4.51	0.08	371	256
Renovations	Any bathroom, plumbing or kitchen renovations	5.20	0.07	335	259
Renter	Survey respondent is not the homeowner	13.35	0.00	369	29

Other factors, including presence of a multi-showerhead fitting and attitudes about water conservation, did not reach the 90% significance level. The relationship between having an outdoor spa and less water used for showering seems to imply that people may spend less time in the shower if they have a spa. The fact that having someone at home during the day relates to less shower use seems counter intuitive. One would expect persons in the home during the day to shower more than people who go out to work. Perhaps people who stay at home don't shower because they don't need to, or they may go to health clubs. It is possible that generational changes affect this result as well. The survey did not include ages of residents beyond 18 years, and adults at home during the day may be related to the age of those residents. Having a positive relationship between bathroom improvements and more shower use makes sense, but it is not clear why renting rather than owning relates to more shower use. Remember, the number of residents in the home has already been taken into account.

The 29 homes occupied by renters also used more water for showering. This is a small sample so it is difficult to determine if there is a meaningful relationship between renting and shower use. Showerhead flow rates showed no relationship to renting. The distinction between shower use by renters versus homeowners is probably related to a difference in per-person daily shower duration. Average duration per renter is 9.7 minutes, versus 5.8 minutes per homeowner. But this simply begs the question as to why renters spend more time in the shower. This may just be a coincidental relationship, or it could be due to the fact that the renters under-reported the number of persons living at their addresses.

Toilet end use model

Like daily indoor use, this end use follows a log-normal distribution.

Factors associated with higher toilet use:

- High volume toilet
- Number of residents
- Indoor house size
- Agreement with "I conserve water mainly for environmental reasons."
- Adults not employed outside the home. This occurs after correcting for the number of residents.
- Bathroom renovations. This occurs after correcting for the toilet flush volume.

Factors associated with lower toilet use:

- Residents under the age of 18. This occurs after correcting for the number of residents.

The level of significance reflected here is based on corrected toilet gallons-per-day from Trace Wizard analysis using the same technique as broader indoor and outdoor models for total household use: log-log regression. This technique is used to mitigate the dominance of physical features like household size and the number of people in the household over subtler features like the respondent's attitudes toward water conservation.

It's important to note that domestic toilet statistics from flow trace analysis can provide three valuable pieces of information:

Average toilet flush (reported here as gallons per flush) is an objective measure of water efficiency. The mean of household average toilet flush volume is an appropriate measure of average toilet flush volume throughout the population.

Flushes per day can be used to estimate how busy a household is on a daily basis, and can be more appropriate than number of residents when investigating changes in water use for fixtures other than toilets. Put another way, this analysis assumes that toilet flush volume is unrelated to many demographic and habitual characteristics; conversely, flushes per day is likely related to demographic and habitual characteristics. While approachable, flushes per day is not a commonly available statistic for a population, and statistics in units of flushes per day are not practically applied to a population specifically with regard to volumetric changes in water use. Daily toilet volume is algebraically = (average toilet flush) x (flushes per day). Reported here as gallons per day, this is the most useful statistic for dimensionally evaluating change in water use. However, while average flush volume and flushes per day are assumed to be unrelated in cases where both quantities are nonzero[54], daily toilet volume is of course fundamentally dependent on both quantities.

If one knows the average flushes per day and the gallons per flush then it would be possible to perfectly predict toilet use. In fact it is impossible to know both of these parameters. The average flushes per day is related to the number of persons per home. In addition, it appears as though toilet flushing is related to the size of the home. Perhaps larger homes have more visitors and guests who contribute to the totals. The data suggest that daily volumetric household toilet use is dependent of the average flush volume of the toilets, the number of residents in the home, and the size of the home.

Table 81: Toilet end use correction factors

Factor	p-value
Residents	0.00
Gallons per flush	0.00
Indoor SQFT	0.01

Equation 9-5: Toilet end use correction

$$\text{Toilet GPD} = 0.69 \cdot \text{Residents}^{0.61} \cdot \text{Gallons per flush}^{0.86} \cdot \text{Indoor sqft}^{0.32}$$

Where:
Toilet GPD = Average daily gallons toilet use
Gallons per flush = Average toilet flush volume, probably averaged over several toilets in household
Indoor SQFT = house size (indoor) in square feet.

This regression achieved the highest r-squared (0.46) by ignoring other physical factors: income, age of home, value of home, and number of bathrooms. The fact that a relationship was seen between the number of residents, the size of the average flush and total daily toilet use makes perfect sense.

Table 82 shows the impact analysis for the conditional variables. The strength of a factor is measured by the difference in average daily toilet use. The mean of corrected toilet use is based on residuals from log-log regression. It’s important to interpret these differences independent of the toilet flush volume; for example, a difference related to bathroom fixtures occurs beyond the impact of changing toilet flush volume.

54 Theoretically, zero toilet volume gives no information about toilet flush volume nor flushes per day. Fortunately, almost all domestic use logged includes toilet use.

Table 82: Conditional variables tested for impacts on toilet use

Variable	Description	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Youth	Is at least one of the residents of the home not an adult?	-6.79	0.02	212	93
Survey Bathroom Renovated	Bathroom fixtures have been renovated	5.46	0.07	188	115
Person at Home	Is there at least one adult that is not employed outside the home?	7.06	0.02	208	137
q45E_agree	Agreement with "I conserve water mainly for environmental reasons."	9.59	0.01	186	34

It makes sense that having young people in the home reduces toilet use since youngsters tend to be at school during the day. It is also reasonable that having adults at home during the day increases the frequency of toilet flushing. It seems reasonable that having a renovated bathroom might increase its use, but if this renovation included toilet upgrades one would expect the opposite effect. It makes no sense as to why conserving water for environmental reasons should increase toilet use. This is probably a spurious finding. The presence of ULF toilets based on the survey did not reach significance. This is expected because daily toilet volume has been corrected for toilet flush volume.

Discussion of Indoor Model

In this study group the only continuous variable that was found to be statistically significant with respect to indoor water use was the number of residents in the home. The size of the home and the home value were the closest to having significance, but neither had more than an 84% chance of being significant. The Yarra Valley, Australia study, which included over 700 homes, found that the number of residents was the only significant factor in indoor use.

The indoor water use models that were derived from the data in this study show that indoor use is related to the number of persons per home, whether there are any significant leaks in the home, whether there is at least one non-adult living in the home, whether the home is equipped with ULF or better toilets and high-efficiency clothes washers.

While the individual end use models provide interesting insights into water use they are less useful for generalized predictions. Either they relate to parameters that are difficult to determine with statistical accuracy, or they rely primarily on the same major parameter, the number of persons per home.

We suggest using the overall end use model for planning purposes.

There are several interesting findings in the conditional variables. Going down the list in Table 71:

- The presence of a non-adult (teenager or child) was associates with less water use (~42 gpd) for the same total number of residents. This means that that a youth tends to account for less water use than an adult in the home, and that a home with three adults will use more water than a home with two adults and a youth. According to the models, a home with standard fixtures and appliances with three adults is expected to use 162 gphd, while a home with two adults and a youth is expected to use only 120 gphd.

- There was remarkably good agreement among the homes in which flow trace analysis showed the presence of ULF toilets and in which the survey indicated that at least one of the toilets was a ULF. This is reassuring. The fact that there were more homes with at least one ULF than homes that met the efficiency criteria shows that there may be some confusion among customers about identifying ULFs by the customers, and also that a single ULF is not enough to bring the average gallons per flush under 2.0, which was the cut-off used for our categorizing.

- Homes which meet the ULF criteria used approximately 22 gallons per day less for indoor uses than equivalent non-ULF homes.

- The presence of high-efficiency clothes washers was responsible for a reduction in indoor use of 17 gpd relative to homes with standard clothes washers.

- Together, ULF toilets and high-efficiency clothes washers account for a reduction in indoor water use of 39 gpd or 14,235 gallons per year.

- The presence of a multi-headed shower head was significant at the 85% confidence level and was associated with an increase in indoor water use of 26 gpd. This did not meet the 95% level used for the cut-off, but it is suggestive that these devices actually do increase indoor use. They were found in only 30 out of 451 respondents.

- The high income variable was also almost significant. High income households, though, tended to use less water than the mean. Perhaps this is because everyone is out working, or they belong to more recreation centers.

- None of the variables below the front loading clothes washer in Table 71 appeared as significant in explaining indoor water use. The 163 homes in which people reported having a noticeable wait for hot water did not increase the indoor water use. This is surprising and probably shows that these people simply learned to use cold water rather than waiting for the hot water to arrive.

- Homes in which the residents paid for water had a lower average indoor use, which is as one would expect. The statistical significance, however, is not sufficient for a firm conclusion.

- The presence of a spa either in or outside of the home had no impact on indoor use. Actually, spas were associated with decreases in indoor uses, which does not seem logical. Perhaps these spas were not used that much. The survey, however, shows that 85% of the people with spas reported that they are filled year round. So there are still some questions here. One would think the homes with spas would tend to use more water than equivalent homes with no spas. It may also be that spa use showed up in the analysis as outdoor use.

- Indoor use impacts could not be found for home ownership, the presence of garbage disposals, swamp coolers, dishwashers, someone at home during the day, water softeners, pools, slow hot water systems or fountains. In some cases the impacts were small in comparison to the total indoor use, or there were not enough respondents either with or without the devices to give a good comparison.

- The presence of pools did not change indoor use. This makes sense because residential pools are almost always outdoors, and also shows that pool use did not accidentally get classified as indoor use during the analysis.

- Low income households clearly did not use indoor water differently than other homes.

Predictive Indoor Models

There were two approaches for making predictions of indoor water use from the data collected in this study. The first was to use the indoor model developed for the study group and to change the parameters for the explanatory variables to reflect greater proportions of the homes falling into the high-efficiency categories. This would involve reducing the percent of homes with more than 100 gpd of leakage and increasing the percent of homes that met the toilet efficiency criteria of average flushes of 2.0 gallons or less and increasing the percent of homes meeting the high-efficiency criteria of clothes washer per load volumes of 30 gallons or less. Table 83 gives examples of what the indoor use model predicts for impacts of these changes while leaving the number of persons per household and the proportion with youngsters alone.

As can be seen from Table 83 the data from this study predict that if all of the remaining clothes washers and toilets were brought to the efficiency criteria used for this study, the average household use would drop from 175 gphd to 148 gphd. This would be an improvement, but would not reach the target of 120 gphd used as the study efficiency benchmark. In order to get closer to this target it will be necessary to limit leakage in the homes to less than 100 gphd. If this were done then the predicted average household indoor use would drop to 133 gphd, which is closer to the target, but still 11% above it.

The reason that the model derived from the study data fails to predict household water use down at levels which are known to be possible from the retrofit studies is that there are so few homes meeting these criteria in the group that the model fails to make projections in these ranges. The household efficiency criteria used for the models are based on toilet flushes that basically meet ULF, or 1.6 gpf, criteria, and clothes washer volumes of 30 gpl. Both of these are more efficient than the averages found in the population, but they are not at the best efficiency levels available. It is important to note that could be a difference between the best efficiency levels and the water savings achievable in actual applications, due to water savings degradation, as well as limits to customer acceptance of some technologies. The models do not predict savings from faucets or showers since there was not enough variability in the data to elicit these effects.

The second approach for predicting impact on indoor household water use was the performance based model based on conservation potential calculated individually for each home in the study group; as opposed to calculated from a mathematical relationship. In this approach the conservation potential for the group was determined by taking the total savings for each home for four indoor water uses: toilets, leaks, clothes washer, and faucets using a spreadsheet that compared the observed daily use to the predicted use if the conservation parameters were adhered to.

The performance model uses the number of toilet flushes per day and the number of loads of clothes per day times volumes measured by the flow trace analysis and the conservation target gallons per flush or gallons per load to calculate the projected water use for toilets and clothes washers for each home in the study group. Leakage rates are determined by assuming that we can cap the maximum allowable leakage per household at a desired level, which in this case is 25 gpd. Faucet use is estimated by assuming that devices can be found that will reduce faucet use by a set percentage (10%). These parameters are used to determine what the water use would be for each home under the targeted performance level with the other categories left unchanged. The savings for the homes are calculated using the observed study group as the baseline. This approach allows the impact of conservation features (such as 1.2 gpf toilet or 15 gpl clothes washers) to the evaluated when the regression model is not able to predict these results because so few of the data points lie within these ranges.

Table 84 shows the results if we assume that the maximum allowable clothes washer volume is 20 gallons per load, that faucet use is reduced by 10%, that leakage is limited to no more than 25 gallons per day and that toilet flushes are limited to 1.25 gallons per flush. If these limits are imposed on the data from the homes in the study group, and all other uses are left unchanged, then the average indoor household water use would drop to 120 gphd, which is the target for the benchmark savings used for this study. Basically, this table shows the performance standards that would need to be observed by the study group in order to reduce their average indoor use from 175 to 120 gphd. All of the performance targets are well within the ranges of current technologies, and are technically achievable.

Table 83: Use of indoor model for predictions of conservation impacts

No.	Sub-Group Description	Mean Residents Per Account	Mean Indoor (gphd)	% w/"leak" < 100 gphd	% w/"leak" > 100 gphd	"leak" Correction (gphd)	% with Standard Clothes Washer	% w/HE Clothes Washer	HE Clothes Washer Correction (gphd)	% without ULF	% with ULF	ULF Correction (gphd)	% without Youth	% with Youth	Youth Correction (gphd)	Total Correction (gphd)	Corrected HH Use (gphd)
1	Model Group	2.94	166	93	6.55	2.2	70.5	29.5	5.1	70	30	1.2	64	36	0.6	9.18	175
2	All houses meet the Toilet and CW Criteria	2.94	166	93	6.55	2.2	0.0	100.0	-6.7	0	100	-14.2	64	36	0.6	-18.1	148
3	Leakage over 100 gpd eliminated	2.94	166	100	0.00	-12.4	0.0	100.0	-6.7	0	100	-14.2	64	36	0.7	-32.6	133

Table 84: Performance based conservation potentials

Conservation estimation by appliance retrofit			Mean	25th %	75th %	95th %
Clothes washer						
Target GPL =	20.00					
		Clotheswasherloadsperday	0.9	0.5	1.3	2.2
		CW_GPD	30.7	15.1	44.2	80.8
		CW_Conservation_Target_gphd	17.1	9.2	24.7	40.5
		CW_Savings_gphd	13.6	2.1	19.8	42.9
Faucet						
Target Fraction=	0.90					
		Faucetevents	743.7	354.3	809.3	1788.7
		Faucetgpd	32.9	16.4	40.3	83.2
		Faucet_Cons_Target_gphd	29.6	14.7	36.3	74.8
		Faucet_Savings_gphd	3.3	1.6	4.0	8.3
Leak						
Target GPD =	25.00					
		Leakgpd	30.8	4.2	31.0	118.6
		Leak_Conservation_Target_gphd	13.3	4.2	25.0	25.0
		Leak_Savings_gphd	17.5	0.0	6.0	93.6
Toilet						
Target GPF =	1.25					
		Toilet_GPF	2.7	1.9	3.5	4.8
		FlushesPerDay	13.7	8.2	17.8	29.1
		Toiletgpd	37.4	18.8	50.0	86.2
		Toilet_Cons_Target_gphd	17.1	10.2	22.1	36.4
		Toilet_Savings_gphd	20.3	6.6	29.3	56.8
Total		Starting Average gphd	175.0			
		Indoor Savings gphd	54.7	19.2	67.8	159.6
		Ending Average gphd	120.3			

Outdoor Model

After repeated attempts with the variables available from the data sources, an outdoor water use model was selected that had the best overall fit to the data and ability to predict outdoor water use based on empirical observations. This model also relied on data that were reasonably available for planning purposes. The selected model relies on seven predictive variables as is shown in Equation 9-6.

Equation 9-6: Outdoor Use Model

$$Outdoor\_use = 1.6207 \cdot 10^{-4} \cdot NetET_o^{1.66} \cdot IrrArea^{0.682} \cdot Inc^{0.125} \cdot LRatio^{0.506} \cdot Pool \cdot Excess \cdot Sprinkler + C_f$$

Where:
Outdoor_use = kgal per year of outdoor water use
NetETo = net annual ETo in inches
IrrArea = irrigated area in units of square feet
Inc = household income in $1000s
LRatio= landscape ratio = theoretical irrigation requirement/reference requirement
Pool = 1.38 · % of homes in population with pool + % without pools
Excess = 3.13 · % of population who are over-irrigating + % who are not
Sprinkler = 1.21 · % of population with in-ground sprinkler systems + % without
C_f = error correction factor to observed mean = -9.2

This model shows the interactions between the variables and the outdoor water use based on the data obtained for the homes in the study group. The first four variables show an exponential relationship with outdoor use. In these relationships the higher the exponent the greater will be the response of outdoor use to changes in the variable. The last three variables are linear variables in which the response is directly proportional to changes in the value of the variable.

The model clearly shows that ET, irrigated area, household income, landscape ratio, the presence of a pool, whether the customer is over-irrigating and whether or not there is an in-ground sprinkler system are the best predictors of outdoor use. It is interesting to note that marginal price of water was not a predictor, but income was.

The fact that Net ETo is a good predictor of outdoor use shows that the outdoor use of the group was affected by weather and climate factors. The exponent of the ET variable is greater than 1, which shows that outdoor use increases at an increasing rate with ET. This relationship has implications on the impact of climate on water use. Irrigated area impacts outdoor use, but in a non-linear fashion, with additional increases in area having a diminishing impact on outdoor use. While household income is included in the list of explanatory variables, its exponent is only 0.125, which shows that the impact is almost linear.

The landscape ratio variable captures the impacts of different plant materials, since the landscape ratio is the ratio of the theoretical irrigation requirement to the reference irrigation requirement. The theoretical irrigation requirement is based on the crop coefficients of the plants in the landscape relative to the irrigation requirements of a reference crop (typically cool season turf).

Therefore, more xeric landscapes will have lower landscape coefficients. Although the exponent of this variable is not as high as the irrigated area it is much higher than the household income variable. Consequently, its impact on outdoor use is intermediate of the two.

Table 85 shows the workings of the outdoor model in more detail. There is a row for each of the model parameters. The second column shows the value of the coefficients for the three linear parameters and for the exponents for the four power parameters. The third column shows the value of the parameter in the study group data, and the fourth column is for the user to insert an assumed value for sensitivity analyses. In this table they are the same as the study mean values. The fifth column shows the value for each factors based on the model coefficients and the assumed values in column four. The overall outdoor use value, predicted by the observed data is 91.3 kgal per household per year. In this table the assumed values have been set to the study means, so the model is predicting the same outdoor use as was observed from the data.

Table 85: Outdoor use model details

Parameter	Coefficient or Exponent	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3802.000	275.318
Net ETo (in)	1.659	42.193	42.193	496.064
Landscape Ratio	0.506	0.960	0.960	0.980
Excess Irrigators (%)	3.130	0.505	0.505	2.076
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061
Household income ($1000)	0.125	$118.12	$118.12	1.82
Correction	-9.200			-9.200
Observed Mean Use (kgal)				91.3
Predicted Value (kgal)				91.3

If the values for the parameters are modified without going too far from their original values the model will show the predicted change in outdoor water use assuming no other changes occur. This allows us to see how sensitive the predictions are to changes in each parameter. Table 86 shows how the predicted mean outdoor use for the population is expected to vary if the value for each parameter is either increased or decreased by 10%.

If the irrigated areas of the homes were reduced by 10% the model predicts an 8% reduction in water use or 6.9 kgal per home. If Net ETo on the other hand, increases by 10% the unconstrained water demand would increase by 20% or 17.2 kgal per household. If less turf intensive landscape were installed, such that the overall landscape ratio dropped by 10%, from 0.96 to 0.86, the water demand would drop by 6% or 5.2 kgal. If the percentage of households that are over irrigating were dropped by 10%, from 50% to 40%, there would be a 12% reduction in average outdoor use, or 10.8 kgal per year. Dropping the percentage of homes with in-ground sprinkler systems would have an effect on water use, but a 10% reduction would only result in a 2% reduction in average water use. Reduction in the percent of homes with swimming pools, from 15% to 5% would result in a 4% reduction in average outdoor use, or 3.5 kgal per year. A drop in household income of 10% would correspond to a reduction in outdoor use by just 1%, or 0.8 kgal. Therefore, of the parameters listed in the table, the most effective in reducing outdoor use would focus on reducing irrigated areas, using more xeric plant material, and elimination of over-irrigation.

Table 86: Sensitivity analysis for outdoor parameters

Parameter	No Change	+10%			-10%		
	Outdoor (kgal)	%	Change (kgal)	Outdoor (kgal)	%	Change (kgal)	Outdoor (kgal)
Irrigated Area (sf)	91.3	+7%	+6.8	98.1	-8%	-6.9	84.4
Net ETo (in)	91.3	+20%	+17.2	108.5	-18%	-16.1	75.2
Landscape Ratio	91.3	+5%	+5.0	96.3	-6%	-5.2	86.1
Excess Irrigation (%)	91.3	+12%	+8.7	101	-12%	-10.8	80.5
In ground sprinklers (%)	91.3	+2%	+1.9	93.2	-2%	-1.8	89.5
Swimming pool (%)	91.3	+4%	+3.7	95.0	-4%	-3.5	87.8
HH Income ($1000)	91.3	1%	+1.2	92.5	-1%	-1.3	90.0

Predictions from Outdoor Model

Of the variables used for the outdoor model, the three most amenable to modification in order to reduce outdoor use are landscape type, the percent of homes that are over irrigating, and irrigated area. If we take the outdoor use model shown in Table 85 and change the values for these variables we can see that the model will predict significant savings in outdoor use.

If we assume an average reduction in irrigated area of 15% from the study mean, a reduction in the landscape ratio of 35% (from 0.96 to 0.62), and a reduction in the percentage of customers who are over-irrigating from 50% to 20% then the overall average outdoor use would drop from 91.3 to 40.5 kgal. This represents an annual savings of over 50 kgal of water per household, which is significantly larger than the potential savings from indoor uses. The changes used in this example are just for illustrative purposes, but they seem reasonable and probably could be achieved over time.

Table 87: Example of outdoor use with higher efficiency standards

Parameter	Coefficient	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3232.223	246.479
Net Eto (in)	1.659	42.193	42.193	496.060
Landscape Ratio	0.506	0.960	0.624	0.788
Excess Irrigators (%)	3.130	0.505	0.200	1.426
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061

Household_income ($1000)	0.125	$118.12	$118.125	1.82
Correction	-9.200			-9.200
Observed Mean Use (kgal)				91.3
Predicted Value (kgal)				40.5

Discussion of Outdoor Model

The outdoor model shows seven parameters that appear useful in predicting outdoor water use for single-family customers. Three of these: irrigated area, landscape ratio, and the percent of customers who are over-irrigating offer the best potential for making reliable reductions in outdoor use. The remaining four factors have problems of one kind or another. There would likely be considerable opposition to any movement to ban in-ground sprinkler systems, and the predicted water savings are not great enough to make it worth the effort. The same thing applies to swimming pools. Reducing household income would cause a reduction in outdoor use, but certainly that is not how most water agencies wish to reduce water use. While there is a strong relationship between ETo and water use, until ways are found to control the weather this will not be a factor that can be used.

The three ways that are open for reducing outdoor water use based on this modeling effort are to reduce the average irrigated areas on the lots, to encourage use of less water intense plant materials—i.e. reduce the landscape coefficients—and to find ways of preventing over-irrigation.

Projections of Water Savings for Study Group

The statistical analyses and models prepared to this point allow estimates to be made of potential water savings from the 730+ study homes analyzed in this project. If we look at indoor use, the data in the predictive use model shown in Table 84 indicates that if the conservation goals specified in the model were possible to achieve then the potential indoor savings is 55 gphd, and would result in indoor use dropping from the average of 175 gphd to 120 gphd, with end uses limited to those shown in Table 84. Fifty five gphd is equivalent to 20 kgal per year (26.8 ccf). These savings are known to be achievable theoretically, in small study groups. Whether it is possible to achieve them in large populations is a subject for further studies.

Outdoor savings can be achieved by eliminating excess water use where it occurs. The outdoor use statistics show that the average outdoor use in the 87% of the homes that are irrigating is 92.7 kgal per year, and that the average excess use on these lots is 27.9 kgal per year. So, without making any drastic changes to landscaping patterns, and only eliminating excess use on the homes that are over-irrigating an average savings of 28 kgal per year could be achieved. When extrapolated from the 87% who are irrigating to all of the study homes this comes to 24 kgal per year on average. If irrigated areas were reduced, and plant materials changed then savings much greater than this could be achieved, as shown in Table 87. If we assume that a modest amount of irrigation modifications could occur that would reduce irrigated areas and use more low water use plants then outdoor saving of 30 kgal per year on average seem quite reasonable. Based on an indoor savings of 20 kgal per household, and an outdoor savings of 30 kgal per household then the data from this study suggests an average household savings of 50 kgal per year is feasible.

A key thing to keep in mind is that the distribution of water savings potential are skewed, because that is the pattern with water use and excess use in particular. The savings are not going to be found uniformly across the population, but are going to be concentrated in a small number of homes. This has important implications for designing programs to actually capture the projected savings.

CHAPTER 10 – STATEWIDE IMPLICATIONS

Overview: Sources of Potable Water

California is reaching the limits of its water supply for both urban and industrial use. As a result, there is growing interest in identifying the potential to put existing water resources to more effective use. This section provides some historical background to the state's sources of potable water and produces estimates of the potential to put those sources to better use through increases in efficiency in single-family homes, using the data collected for the California Single-Family Home Water Efficiency Study.

Water development in California has followed similar patterns observed elsewhere in the United States, gradually shifting away from reliance on local supplies to increased dependence on water imported from other watersheds as local consumption exceeded the volumes provided by local precipitation. As the extent and character of European and Spanish settlements changed, water management shifted from indigenous stewardship to the development of bigger and more sophisticated systems for storing and moving water. Today, the state is dependent on a complex set of dams, aqueducts, irrigation canals, treatment plants, and pipelines spread out and traversing many hundreds of miles.

Californians have reaped extraordinary benefits from our manipulation of the waterscape—clean, safe water is delivered to millions of homes 24 hours a day at what most consider a reasonable cost, and irrigation has made the state the fifth largest producer of food crops in the world. However, this development has also come at a high cost to the natural environment. Former park ranger and author David Carle has chronicled California's water development, and notes that California has lost more species to extinction than any other state, and that most of these can be attributed to human changes to our watercourses and habitat loss.

Nearly every commentator on California water has pointed out the mismatch between where the water is and where the people are. Statewide rainfall distributions are shown in Figure 72, and population densities are shown in Figure 73. The sparsely-populated north receives up to ten feet of rainfall in an average year, while Southern California, home to over 25 million people, receives less than 15 inches (in some places substantially less than 15 inches), enough to qualify as desert by some definitions. This has led one expert to note that "the most interesting statistic about California is that 75% of the annual precipitation falls north of Sacramento, the capital city in the center of the state, while more than 75% of the demand for the state's water is south of the capital city" (Dickinson undated).

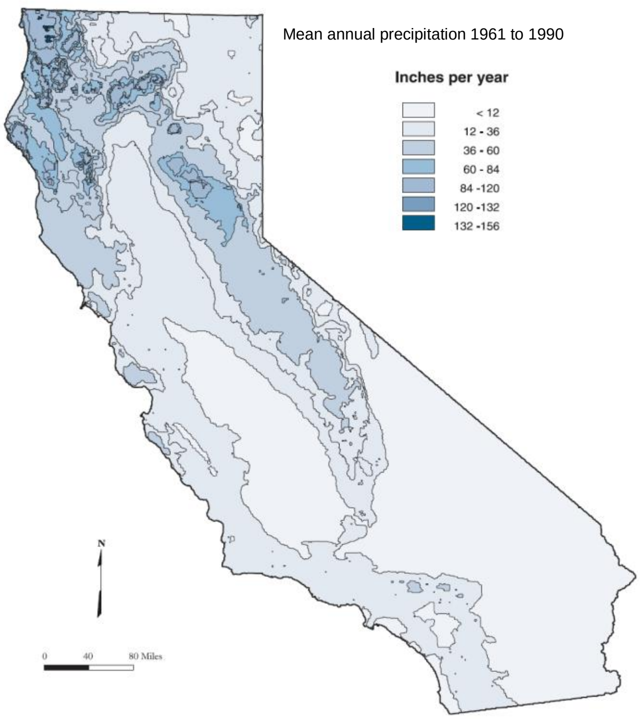


Figure 72: Rainfall intensity in California[55]

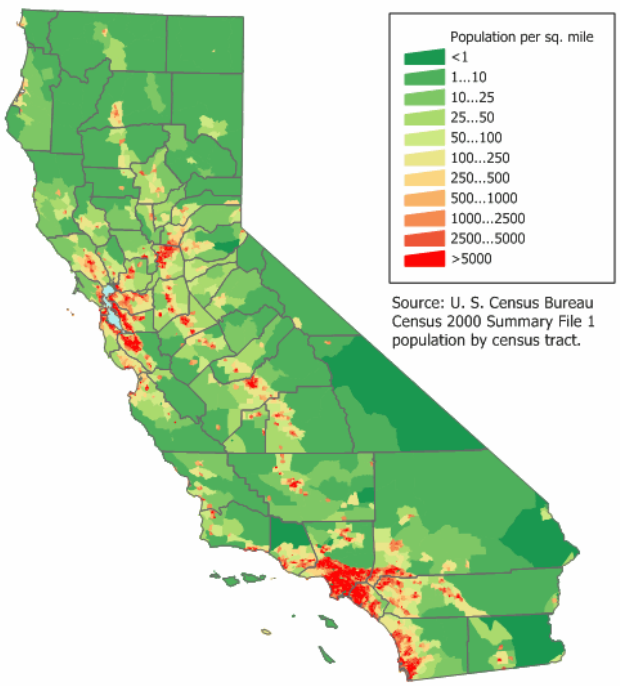


Figure 73: Population intensities[56]

[55] DWR 2003 http://www.waterplan.water.ca.gov/docs/portfolio/faf_data/precip/precip_61-90.jpg
[56] Image courtesy of the Wikimedia Commons http://en.wikipedia.org/wiki/File:California_population_map.png

In the last century, Californians have embarked on a series of ambitious projects that have altered the landscape and waterscape of the state. These projects were built and are managed by a variety of private businesses, local water providers, regional agencies, and the state and federal government.

The city of Los Angeles pioneered large water transfers by financing the Owens River aqueduct, built by LA's chief engineer William Mulholland from 1905 to 1913. By all accounts, this was a remarkable undertaking. Not only was the cost unprecedented, there were engineering and political challenges to be overcome; by expropriating water from the Owens Valley, the pipeline stirred a controversy that lives on in various forms to this day and has been chronicled in various popular books and films.

In 1923, San Francisco completed its own major water delivery system, the Hetch Hetchy project -, which dammed the Tuolumne River inside the borders of Yosemite National Park. This project continues to serve San Francisco and other Bay Area cities.

The major city of Oakland and other East Bay communities banded together to dam another Sierra Nevada River, the Mokolumne, and build an aqueduct to the East Bay in 1929. In the dry Colorado Desert, renamed the Imperial Valley in a fit of local boosterism, a handful of farmers began to tap water from the Colorado River around 1922, and greatly expanded irrigation with the construction of the Hoover Dam, completed in 1936, and related transfer facilities in the region.

California voters narrowly approved bond financing for the State Water Project in a 1960 referendum, creating what was at the time the world's largest inter-basin water transfer for both urban and agricultural use. This included a wide range of physical infrastructure and management systems, including the Oroville Dam, San Luis Reservoir, and the California Aqueduct, which provide water to Central Valley farms and communities, managed by the California Department of Water Resources and local agencies.

A project of even greater scope, the Central Valley Project, was also constructed beginning in the 1960s by the federal government through the United States Bureau of Reclamation. Like the State Water Project, this project also supplies both irrigation and municipal water, produces hydropower, and provides flood control and recreation on its many large reservoirs. In total, it consists of 20 dams and reservoirs, 11 hydroelectric power plants, and around 500 miles of canals.

All told, around 1,200 reservoirs have been built in the state with a total storage capacity of over 14.4 million acre-feet. For the most part, California relies on water resources from within its borders, with the important exception of the Colorado River.

Figure 74: California's major water facilities[57]

[57] From the 2005 Water Plan, figure 302 on page 3-3

Future Concerns

As the state's population and economy continue to grow, California is increasingly running up against peak water constraints in both renewable and non-renewable water systems.[58] While most of the state's population is clustered around the coastal cities of San Francisco, Los Angeles, and San Diego, much of the future growth is expected to occur in hotter, dryer inland areas. This raises concerns about future water use. Consider the Los Angeles basin averages 15 inches of rain per year. According to one estimate, local water resources could support a population of about 150,000, leading to the construction of the complex water-delivery systems and infrastructure described above.[59] Today, the basin is home to some 25 million residents, and demographers predict that it may grow by several million more by mid-century. A report by the Public Policy Institute of California points out that the trend is for larger homes on larger lots in the Central Valley and Inland Empire.[60] A corresponding increase in landscaped area could result in increased outdoor water use, which this study reveals comprises more than half of the water used by most households. Some studies, such as traditional assessments prepared by the California Department of Water Resources, project that significant increases in demand are likely in the future.

A major part of the debate about water in California is how to meet this projected increase in demand. It has become increasingly unlikely that there are any major new sources of supply. It is getting more difficult to build new dams for a wide range of economic, ecological, physical, political, and social reasons. California has made only modest additions to reservoir capacity in the past few decades because of these constraints. Further, the majority of California's dams were built during a different era, before the passage of the 1960s and 1970s landmark environmental laws such as the Environmental Protection Act, the Clean Water Act, and the Endangered Species Act. It is often said that existing projects would be much more difficult to build today because of the environmental protections in place. In addition, in much of the state, groundwater withdrawals already exceed renewable supplies, putting constraints on finding new sources of groundwater to meet projected increases in demand.

Given these constraints on new supplies, considerable attention is now focusing on alternative sources for urban use such as desalination, recycled treated wastewater, conjunctive use, and especially, improvements in water use efficiency.[61]

[58] Gleick, Peter and Meena Palanipappan, "Peak Water Limits to Freshwater Management and Use." In press, Proceedings of the National Academy of Sciences (PNAS).

[59] Carle, David. "Introduction to Water in California", University of California Press (2004)

[60] Hanak, Ellen and Matthew Davis (2008), Lawns and Water Use in California. Public Policy Institute of California. 24 pages. http://www.ppic.org/main/publication.asp?i=691

[61] Gleick, P.G. et al. (2003) Waste Not, Want Not: The Potential for Urban Water Conservation in California. Pacific Institute, Oakland, California.

Water Use in California

Single family water use makes up the subject of this research effort. Generally, single-family water use makes up the largest proportion of treated water deliveries. Also, being relatively homogenous it is easier to model and make predictions concerning conservation potential.

Total Water Use (urban, agricultural, power plants, other)

Human use of water varies from year to year, largely dependent on weather and the amount of water that state and federal agencies are able to deliver to irrigators. In a year of average rainfall, water use in California averages 43 million acre-feet (MAF) per year. That is equivalent to about 1,000 gallons per person per day (gpd), which implies a statewide population of 38.4 million persons. (Note that in this estimate of water use we do not include “environmental water” that is included in tallies of water use by the state’s Department of Water Resources. Environmental water includes instream flows, flow in designated “wild and scenic” rivers, outflow from the Delta to San Francisco Bay required by law, and managed wetlands water use.)

DWR reports that during 1998, a wet year with 171% of the average rainfall, water use was around 35 MAF, 20% less than during a normal year. During 2001, a dry year with 72% of the average rainfall, total water use was about 43 MAF, similar to an average year. During dry years, irrigators can often make up for lower water deliveries through the use of groundwater; significant water use reductions are often not observed until a few years into a prolonged drought.

Water use in California’s suburbs and cities, referred to as “urban water use,” averages 8.7 million acre-feet, according to the 2009 California Water Plan, published by the Department of Water Resources. That is equivalent to about 200 gallons per day for every California resident. (This is a reasonable first estimate as 98% of California’s 38 million people live in urban areas.)

Trends in urban water use and population are shown in Figure 75. The data for this graph comes from a table compiled by DWR staff and supplemented by the authors using information from data obtained from DWR staff. In their words:

The data in the following table has been accumulated from older versions of Bulletin 160 (1972-1985), Annual Reports prepared by District Staff (1989-1995) and the Water Portfolio from California Water Plan Update 2004 (1998-2001). There is no single database location that accumulates water use and supply information for the entire State.

Figure 75 shows California’s population and urban water use from 1972 to the present (solid lines) along with projections to the year 2050 (dashed lines). Note that the final year in which reliable water use data were available was 2005. Population projections are estimates from California’s Department of Finance. Water use projections are based on successfully reaching a 20% per-capita reduction in water use (through efficiency improvements) by the year 2020. Under this scenario, urban water use declines over the next 10 years. After 2020, per-capita water use is held steady, and population growth causes an increase in urban water use over the next three decades.

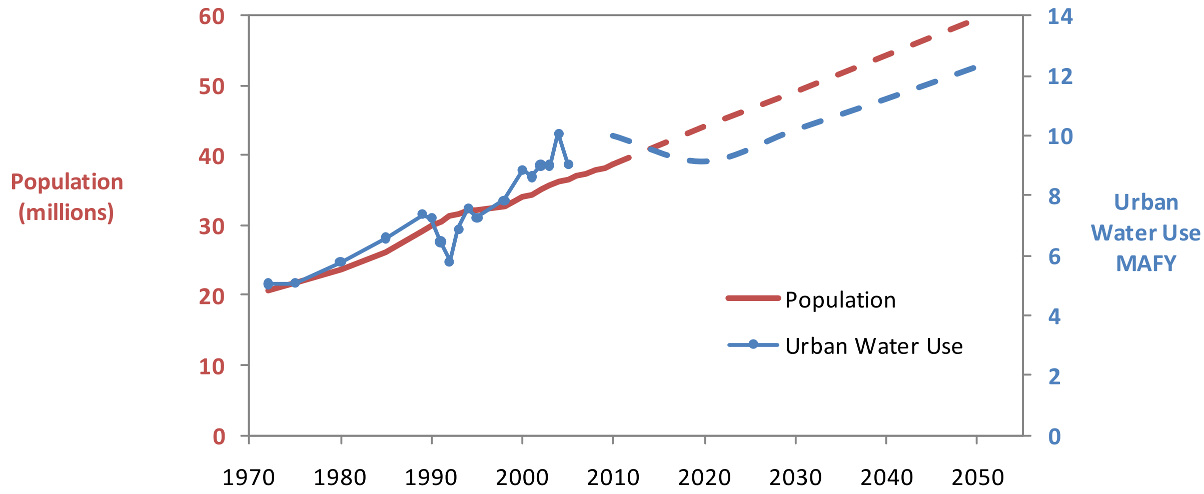


Figure 75: Population and urban water use versus time

Urban water use has increased roughly in proportion to population over the last four decades, with some fluctuation. A marked decrease is seen in the early 1990s, as water use was curtailed due to drought restrictions. Urban water use reaches a peak in 2004 of 10.1 MAF, before declining somewhat to 9 MAF in 2005, the last year for which DWR has published data. Droughts can have two opposing effects on urban water use. Dry conditions lead to increased demand for landscape irrigation. The state Legislative Analyst's Office notes that during dry years, urban use can actually increase by up to 10%, due to increased water use for landscaping.[62] Prolonged drought, however, can lead state and local authorities to call for voluntary cutbacks and other conservation measures, decreasing consumption.

The state appears to now be emerging from the drought of 2006-2009. During this time, water suppliers launched a number of efforts to reduce demand, from mandatory prohibitions on certain outdoor uses of water, increased rates, appliance rebates, and giveaways of efficient fixtures. Although DWR has not yet published data for water use after 2005, there is evidence from several areas that per-capita consumption did indeed decrease in response to efforts by water suppliers. In Long Beach, for example, per-capita consumption was the lowest since the city began keeping records.[63] A number of water suppliers have been forced to raise rates after their customers' cutbacks led to less revenue. For example, the Metropolitan Water District, Southern California's biggest water wholesaler has seen sales drop off 20 percent over the last

[62] California Legislative Analyst's Office (2008). California's Water: An LAO Primer. Sacramento, 77 pages. http://www.lao.ca.gov/laoapp/PubDetails.aspx?id=1889

[63] Veeh, M. (2010). "Long Beach Sets Another Water Conservation Record". Press release from the Long Beach City News Department, May 4, 2010 http://www.longbeach.gov/news/displaynews.asp?NewsID=4561&TargetID=55

three years, causing them to raise rates by 12.4 percent. Similar situations have been reported throughout the state.[64]

The US Geological Survey also estimates water use for the United States. The following figures are estimates of water use by type in 2005, as reported in Kenny et al.[65] Note that this table only includes freshwater use. Large quantities of saltwater are used to cool thermoelectric power plants, and smaller quantities are use in industry and mining.

Table 88: Freshwater use in California in 2005 (USGS)

Category	Million Gallons Per Day (MGD)	Million Acre-feet Per Year (MAFY)	Gallons Per Capita Per Day (gpcd)	Percent of Total
Irrigation	24,400	27.3	765	74%
Public Supply	6,990	7.8	219	21%
Domestic	486	0.54	15.2	1.5%
Aquaculture	646	0.72	20.2	2.0%
Livestock	197	0.22	6.17	0.6%
Industrial	72.2	0.081	2.26	0.22%
Mining	53.1	0.060	1.66	0.16%
Thermoelectric power	49.6	0.056	1.55	0.15%
Total	32,900	36.9	1,030	100%

According to the USGS figures, water supply and domestic water use accounted for 8.3 million acre-feet per year in 2005. This is the same as 234 gallons per capita per day. These figures are roughly equal to DWR's estimate for 2005 (9.3 MAF). Figure 76 shows the breakdown of water use by category in 2005. Agriculture and public supply (urban use) make up 96% of all use in the state.

[64] Fikes, B.F. (2010), "Water: Conservation, recession cause wave of rate hikes" North Country Times, April 10, 2010. http://www.nctimes.com/business/article_7e6c6830-61e5-5d0b-8bf0-27212cdafdc7.html

[65] Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p. http://pubs.usgs.gov/circ/1344/

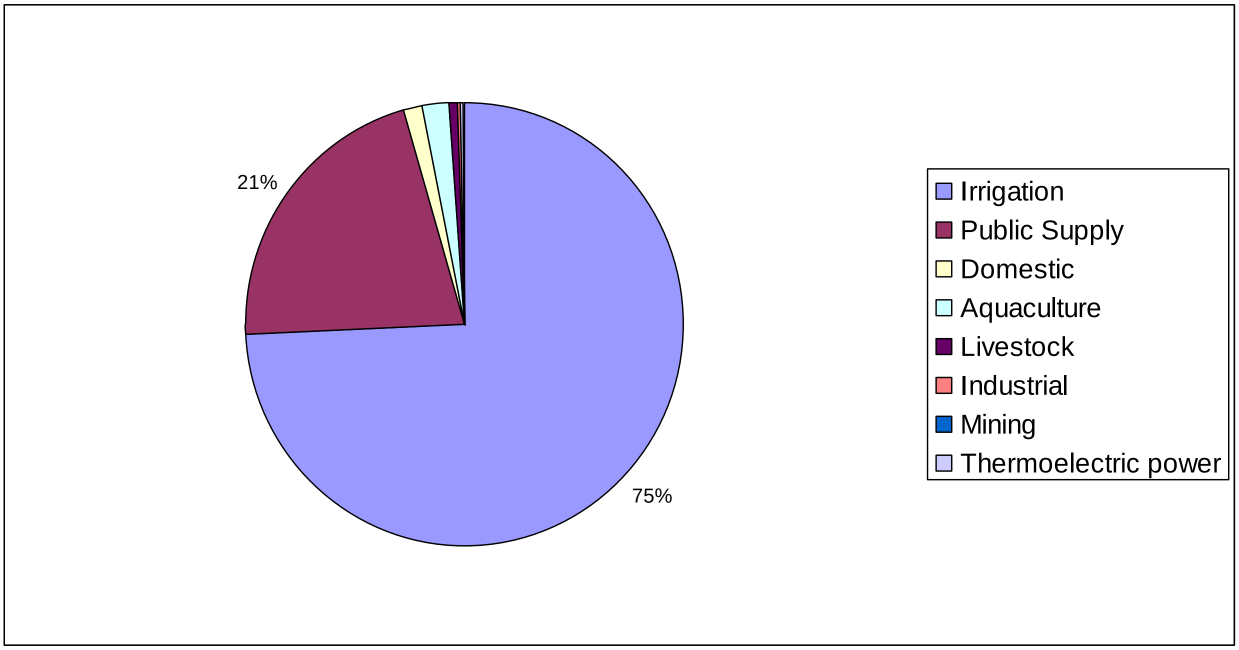


Figure 76: California water use by category in 2005

Urban Water Use

Across California, about 57% of single-family residential household use, or 2.5 million acre-feet (MAF) is indoors (Table 10-2). The remaining 43%, or 1.9 MAF, is applied to lawns, gardens, pools, and other outdoor uses. The statewide estimate, however, obscures significant regional variability.

Table 89 gives a breakdown of uses of water in California's urban sector. The information in the table was assembled by the authors from DWR's 2005 Water Plan supplemented by data provided by DWR staff. Based on this information, for single-family residences, outdoor water use exceeds that used indoors (3.3 versus 2.3 MAF). This is consistent with previous studies, including the 1999 national Residential End Uses of Water Study (REUWS), which reported outdoor water use was 58% of the total (averaging 232 outdoors gpd vs. 168 gpd indoors). The study went on to note that outdoor use was much greater in hot climates (59 – 67 percent in Phoenix, Tempe, and Scottsdale) and lower in cooler climates (22 – 38 percent in Seattle, Tampa, and Waterloo.) A similar pattern is seen in California's inland (and southern) regions compared with the cooler coastal (and northern) regions.

Table 89: Estimated urban water use (2000)

	Outdoor (MAF)	Indoor (MAF)	Total (MAF)	% of Total
Single-Family Residences	1.90	2.50	4.4	52%
Multi-Family Residences	0.36	0.8	1.2	14%
Commercial, Industrial, Institutional	0.63	1.6	2.2	26%
Large Landscapes	0.68	-	0.68	8%
Total Urban Use	3.60	4.9	8.5	100%

Based on data in DWR's Water Plan Update 2005 and personal communication with DWR staff.

Figure 77 shows the breakdown of urban water use graphically. These data show that two thirds of urban water use was for residential customers, and single-family customers accounted for over half of urban demands. Single family demands represented approximately 80% of all residential demands.

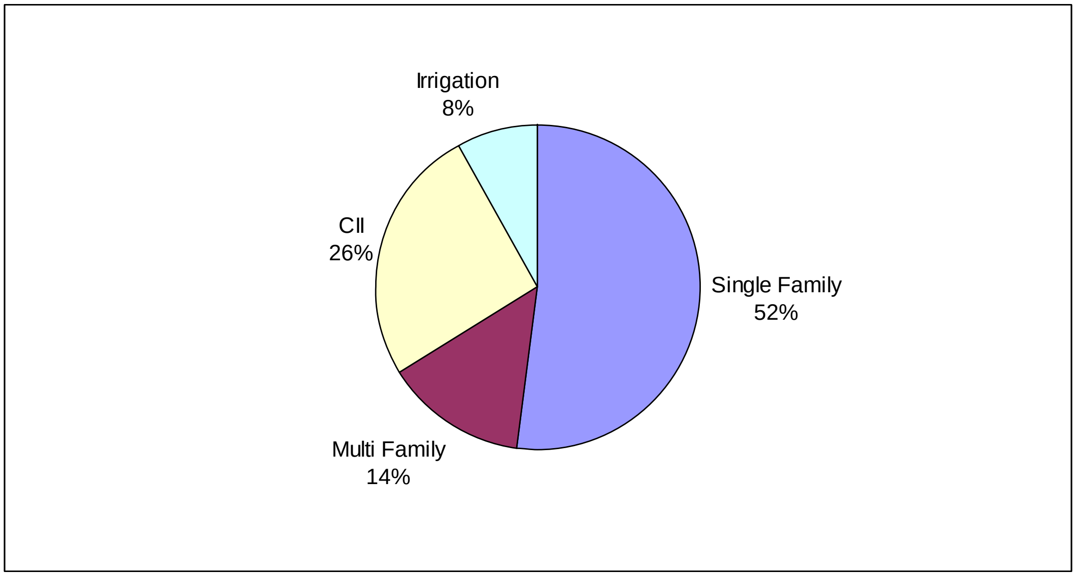


Figure 77: California urban water use by customer category

The state's 20x20 planning document presents per-capita urban water use by hydrologic region. The state's 10 hydrologic regions are planning boundaries developed to manage watersheds and water supply. In the map in
Figure 78, county boundaries are shown by light gray lines. Note that hydrologic region boundaries do not overlap with political divisions; some counties lie in two or three different hydrologic regions.

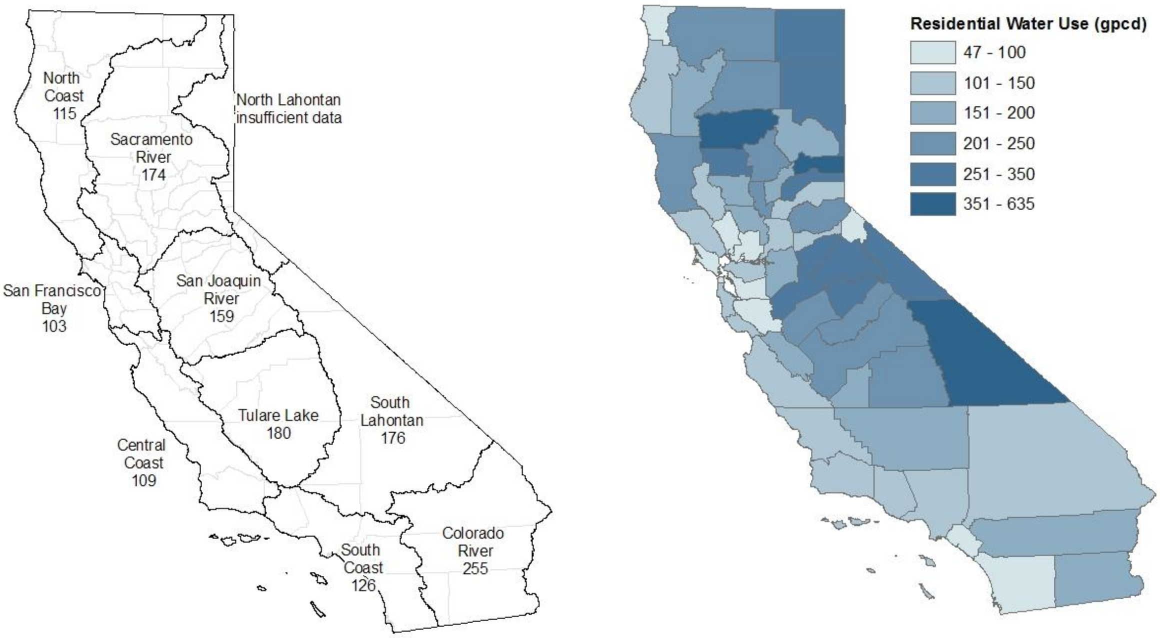


Figure 78: Per capita urban water use from DWR by hydrologic region (left) and the USGS by county (right) (gpd)

Table 90: Per capita urban water use by county from the USGS (gallons per day)

County	GPCD		County	GPCD
Alameda	53		Orange	72
Alpine	78		Placer	138
Amador	128		Plumas	181
Butte	211		Riverside	192
Calaveras	278		Sacramento	101
Colusa	187		San Benito	160
Contra Costa	139		San Bernardino	141
Del Norte	100		San Diego	87
El Dorado	216		San Francisco	47
Fresno	228		San Joaquin	175
Glenn	299		San Luis Obispo	147
Humboldt	114		San Mateo	102
Imperial	156		Santa Barbara	112
Inyo	474		Santa Clara	80
Kern	173		Santa Cruz	126
Kings	168		Shasta	240
Lake	120		Sierra	635

Lassen	310		Siskiyou	216
Los Angeles	113		Solano	95
Madera	205		Sonoma	135
Marin	82		Stanislaus	251
Mariposa	350		Sutter	224
Mendocino	214		Tehama	431
Merced	221		Trinity	192
Modoc	295		Tulare	221
Mono	268		Tuolumne	321
Monterey	103		Ventura	113
Napa	92		Yolo	193
Nevada	306		Yuba	191

The USGS also provides estimates of water use by county for the United States (Figure 78) .[66] Per-capita urban water use was obtained by dividing the quantity Domestic, total use (withdrawals + deliveries) by the total population of the county. Domestic use is the sum of self-supplied withdrawals (for example, from a well, spring, or river) and deliveries from public supply.

The values from DWR and USGS are not directly comparable, as they are compiled for different geographic boundaries, but the general patterns appear the same, and values are similar. The USGS's per-capita water use for the state as a whole is 124 gpcd, which fits comfortably within the ranges reported by DWR.

The most reliable estimates of water use come from individual water utilities, as these are based on actual billing data. The following table reports per-capita total water use for selected water agencies in 2006. This information was developed by DWR staff using data from the Public Water Supply System database (From the California Water Plan Update 2009, page 4-46). These figures again demonstrate the variability of urban water use in the state. Low consumption in San Francisco is usually attributed to the city's density, minimal landscape irrigation, and cool coastal climate. Fresno, by contrast, averages only 11 inches of rain per year and has hot, dry summers. Furthermore, 55 percent of residents are not metered, and pay a flat rate regardless of how much water they use.[67]

Table 91 Water use by selected agency service area for 2006 (gallons per capita per day)

City	GPCD
San Francisco	95
Santa Barbara	127
Marin County (MMWD)	136

[66] U.S. Geological Survey. 2005. Circular 1344, Estimated use of water in the United States in 2005. Reston, Virginia.
[67] Khoka, S. (2009). "Without Meters, Fresno Water Beyond Measure" May 26, 2009. National Public Radio. http://www.npr.org/templates/story/story.php?storyId=104466681

Los Angeles (LADWP)	142
Contra Costa (CCWD)	157
San Diego	157
East Bay (EBMUD)	166
Victorville (VVCWD)	246
Bakersfield	279
Sacramento	279
San Bernardino	296
Fresno	354

Single-Family Residential

There are a number of methods that can be used to estimate and evaluate single-family home water use. The most direct way to estimate single-family water use in the state is by using data from the 2009 updated State Water Plan. Table 92 shows per capita demands and population data for each of the hydrological regions of the state (minus the North Lahontan, for which there are no data). The population and per capita residential use data were used to calculate the total residential water demand for each region. The total residential demand came to 5.45 MAF, and based on 80% of this demand coming from single-family accounts, the single-family residential demand came to 4.4 MAF.

It is interesting to note that the estimate of single-family use made from treatment plant production records is approximately 12% higher than the estimate derived from the study group, which was based on billing data. Using billing data, which averaged 134 kgal per account per year equates to a projection of 3.9 MAF for the single-family customers' use as measured at their water meters. Use of water treatment production records and population data result in an estimate of 4.4 MAF.

Table 92: Estimated single-family residential demand

Hydrological Region	Population	Per capita Residentia l Demand	Total Residential Demand	
	(million)	(gpcd)	MG/YR	MAF
North Coast	0.7	115	29,383	0.090
Sacramento River	2.9	174	184,179	0.565
San Francisco	6.3	103	236,849	0.727
San Joaquin River	2.0	159	116,070	0.356
Central Coast	1.5	109	59,678	0.183
Tulare	2.0	180	131,400	0.403
South Lahontan	0.8	176	51,392	0.158
South Coast	19.6	126	901,404	2.767
Colorado River	0.7	255	65,153	0.200
Total	36.5			5.451
Est. % SF				80%
SF Res. Demand				4.4

For this assessment, we applied the regression equation developed in this study to predict indoor water use as a function of the number of household residents, as described in Chapter 9. We estimated the number of households in each of California's hydrologic regions, using Census Bureau's American Community Survey data on housing characteristics aggregated by county subdivision.

Because the census groups all households with five or more residents into a single category, we used a power-law distribution to estimate the number of households with five or more residents. The shape of the tail distribution was estimated using this study's survey results as shown in Figure 79(a). Out of 499 completed surveys, 26 homes had six or more residents, with a maximum size of 17 residents.

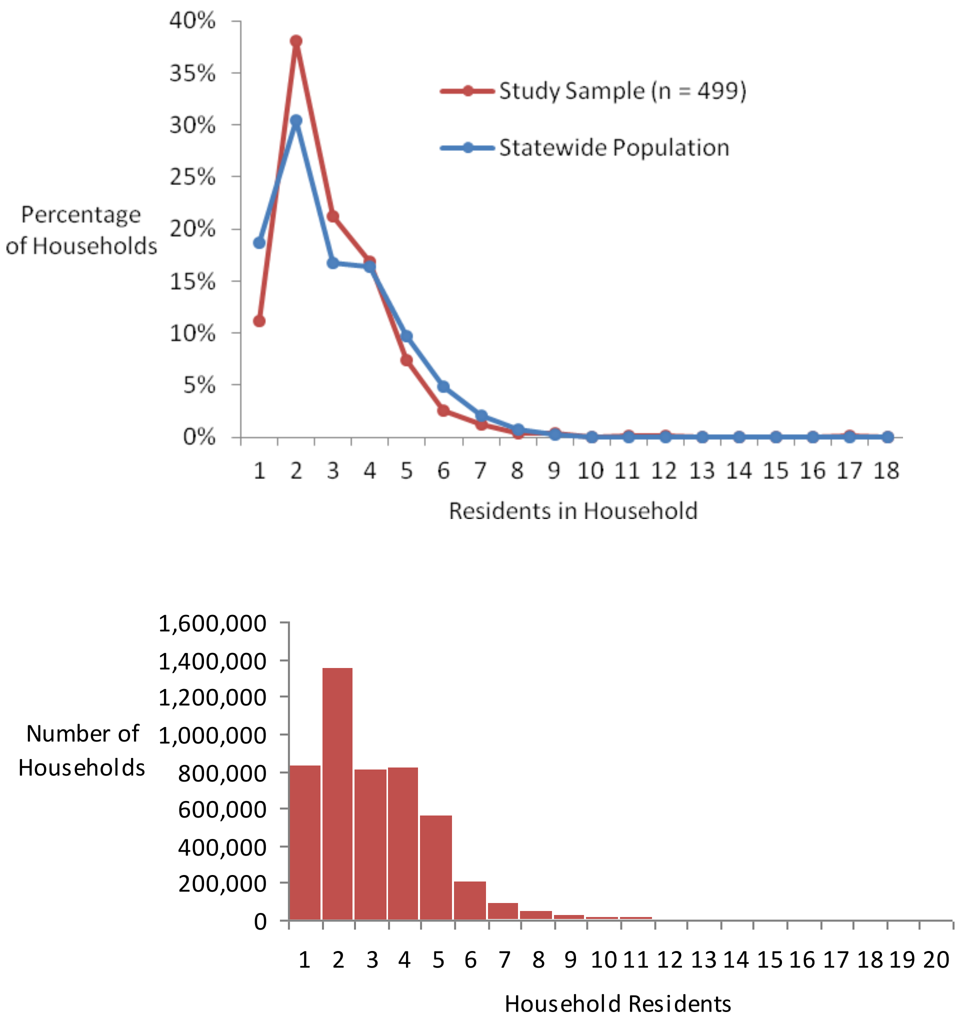


Figure 79 (a) Comparison of household size in state with the study sample and (b) the estimated household size distribution in Hydrologic Region 4 (South Coast).

The Department of Water Resources Statewide Water Planning Branch estimates water use by end use type, and reports this information in the Water Plan Update every five years. Estimates of per-capita urban water use circa 2000 are reported in Table 93 below.

It is notoriously difficult to estimate urban outdoor water use because of the lack of measured data. Water agencies sometimes use dual meters to measure indoor and outdoor consumption for large commercial accounts, but these are rarely used for residential customers. Most estimates are determined analytically, through the use of simple models. The first class of model is based on theoretical irrigation requirement and assumptions about typical landscapes. The second starts with measurements of total water use, and subtracts assumed indoor water use. This approach is based on the assumption that indoor water use is better understood, and more reliably predicted, than outdoor water use.

DWR's analysis conducted for the 2005 California Water Plan reports outdoor water use as 3.6 MAFY for all urban uses for the year 2000 (Table 89). Water use is not reported for different housing types. The Pacific Institute has previously estimated year-2000 residential outdoor water use at 1.45 ± 0.45 MAFY. This is equivalent to between 70 and 150 gallons per household per day.[68] DWR estimates that the water used in large landscapes in the year 2000 was 0.68 MAF. This represents about 19% of urban outdoor water use, or about 8% of urban water use. As noted in the California 20x2020 assessment, "retail water suppliers in California have reported per capita water use remaining steady or dropping since the early 1990s in many parts of California".[69]

Table 93 Per-capita water use for California's 10 hydrologic regions

Region		Residential (Single- and Multi-Family)	Per House-hold	Commercial and Institutional	Industrial	Un-Reported Water	Total Baseline
1	North Coast	115	(290)	18	8	24	165
2	San Francisco Bay	103	(278)	19	17	18	157
3	Central Coast	109	(311)	17	8	20	154
4	South Coast	126	(378)	23	9	22	180
5	Sacramento River	174	(456)	25	21	33	253
6	San Joaquin River	159	(474)	27	32	30	248
7	Tulare Lake	180	(565)	23	43	39	285
8*	North Lahontan	155	(394)				243
9	South Lahontan	176	(509)	19	11	31	237
10	Colorado River	255	(711)	38	3	50	346

* Region 8 (North Lahontan) does not have enough usable data in the Public Water Systems Survey (PWSS) database to compute for baseline values by sector. We use an average of the water use in other regions as a surrogate.

[68] Gleick, P.G. et al. (2003) Waste Not, Want Not: The Potential for Urban Water Conservation in California. Pacific Institute, Oakland, California.

[69] State Water Resources Control Board (2010), Final 20x2020 Water Conservation Plan, February 2010. Sacramento, CA, 60 pages. http://www.swrcb.ca.gov/water_issues/hot_topics/20x2020/index.shtml

Regulatory Issues Facing California

The state's 2009 Water Plan Update lists a number of challenges to water managers in the state. Environmental factors, population growth, and challenges such as climate change are among the most likely to affect the quantity of water that will be available in the future. Protecting and restoring the environment has become an important societal value in the last few decades, and the authors conclude that changes to water management will be necessary: "California has lost more than 90 percent of the wetlands and riparian forests that existed before the gold rush. Successful restoration of aquatic, riparian, and floodplain species and communities ordinarily depends upon at least partial restoration of physical processes that are driven by water."[70]

There is also extensive and growing evidence that climate change will have a significant impact on hydrology and water management. There are likely to be impacts on the supply of, and demand for water. On the supply side, climatologists expect changes to the timing and frequency of streamflow, less snowfall, and more rain. Higher temperatures may increase demand for irrigation water, as evaporation increases, depleting soil moisture.[71]

In the following sections, we describe some recent regulatory actions that affect water management and urban water supply in California.

Bay-Delta Agreement and MOU

Much of California's water supply passes through the Sacramento-San Joaquin River Delta, known by many simply as the Delta. Fishermen and environmentalists have been concerned over declines in fish populations in the Delta, and pointed to freshwater diversions and exports from the Delta as a cause of their decline. There are a number of species of concern (considered threatened or endangered), but the most publicity has revolved around a small, once-abundant forage fish called the Delta Smelt, which is listed as endangered by the State of California and considered an important indicator of the health of the system. Similarly, water agencies and irrigation districts are concerned about the reliability of water deliveries through the Delta and about declining water quality. Among the unresolved issues around the Delta is the effect of the California Department of Water Resources (DWR) and the United States Bureau of Reclamation's (Reclamation) joint operations of the State Water Project and Central Valley Project on the delta fisheries.

A seminal document in California water resources is the Bay-Delta Agreement. The original Bay Delta proceedings were held in the late 1980s -and required that exports from the Bay/Delta system be managed and reduced by water conservation in order to avoid damaging the Bay-Delta ecosystem. In order accomplish a reduction in demands from urban water systems a document known as the Memorandum of Understanding (MOU) was signed. The signatories included

[70] California Department of Water Resources. 2009. The California Water Plan – Bulletin 160-09. Sacramento California.
http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2c22_ecorestoration_cwp2009.pdf

[71] Kiparsky, M. and P. H. Gleick. 2003. Climate Change and California Water Resources: A Survey and Summary of the Literature. California Energy Commission Report 500-04-073. Sacramento, California.

urban water providers, public advocacy organizations, and other interested groups. A dedicated group, the California Urban Water Conservation Council (CUWCC), was formed from the signatories to the MOU and charged with monitoring its implementation. Together, the Bay-Delta agreement and the Memorandum of Understanding form the prime driving force for urban water conservation in California.

The original MOU was adopted in December1991. It has been revised several times since then; most recently in June 2010.[72] The MOU is an agreement between the State and the major urban water providers that the latter will make good faith efforts to implement water conservation measures in order to conserve water and reduce urban demands on the Bay-Delta. The MOU requires regular reporting by the signatories of their progress in implementation of the BMPs. Reporting and tracking of the implementation of the MOU is managed by the California Urban Water Conservation Council.

The general goal of the MOU was "to reduce long term urban (water) demands." The initial method used to accomplish this purpose was the implementation of Best Management Practices (BMPs) The MOU had two specific objectives:

- "to expedite implementation of reasonable water conservation measures in urban areas."
- "to establish assumptions for use in calculating estimates of reliable future water conservation savings resulting from proven and reasonable conservation measures."

At the maximum there were a total of 14 BMPs, four of which were directed at residential customers (1, 2, 6 and 14 using the original numbering system). Each of these had a built in set of assumptions about how much water would be saved through implementation. For example, each toilet replacement was deemed to create a certain and reliable amount of water savings, as was each showerhead, faucet aerator, landscape audit, clothes washer replacement etc. The reliable water savings could then be calculated by simply multiplying the number of BMPs implemented by the water savings assumption. The assumptions of water savings were to be revised every three years, and BMPs that fail to demonstrate water savings are to be removed, while other promising measures might be added.

The BMPs also have coverage requirements. Some of these are based on achieving a certain level of "market saturation" or "market penetration." The MOU does not define precisely what is meant by these terms, though generally they are considered to refer to the percentage of individual fixtures and appliances meeting the relevant efficiency criteria. As discussed above, in cases where multiple devices are found in households, primarily with respect to toilets, it is possible to have a difference between the percentage of devices that meet the efficiency criteria and the percentage of houses based on how the devices are mixed among the houses.

As of this writing, 190 of California's water agencies have signed the MOU, serving two-thirds of the state's customers. Still, there remains considerable uncertainty on the effectiveness of the BMP approach. According to an evaluation conducted by the state, "the impact of the MOU has varied considerably by region and rates of compliance for most BMPs remain low. BMP data strongly suggest the MOU process is not working as intended and its impact on urban water use remains well below its full potential." The report suggests that over 13 years the MOU process

[72] http://www.cuwcc.org/WorkArea/showcontent.aspx?id=15180 (to download the latest version of the MOU).

may have reduced per-capita urban water use by about 2%. As the state's population grew over this period, urban water use increased overall.

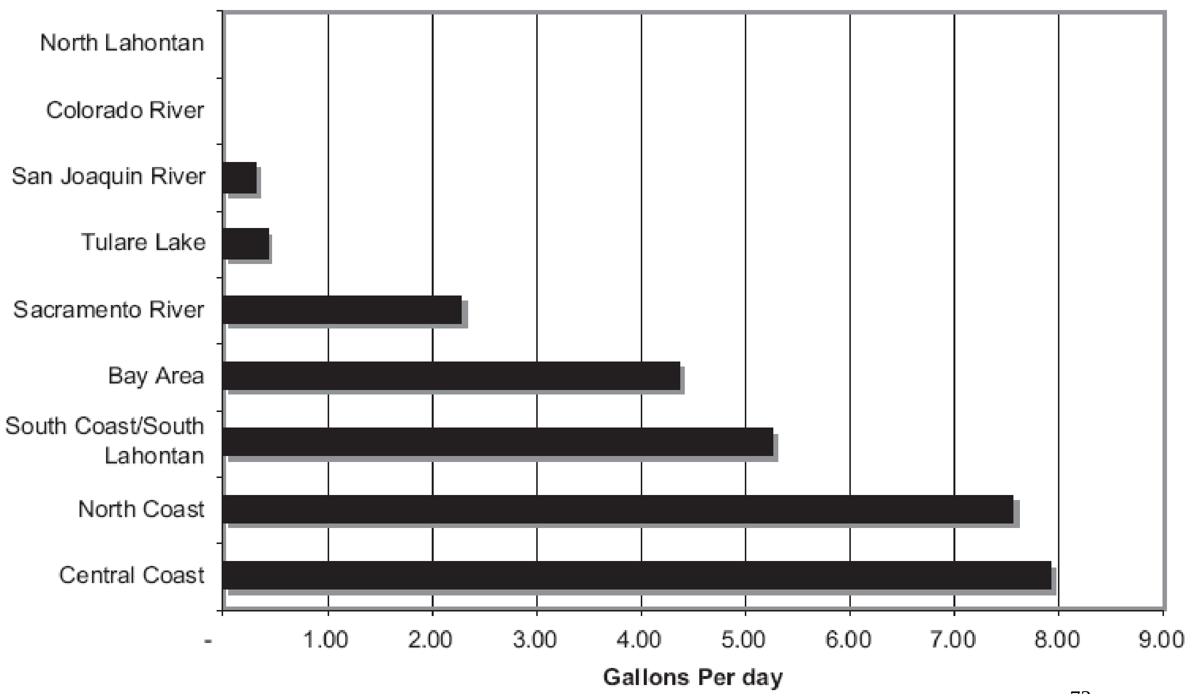


Figure 80: Water savings in 2004 achieved by water conservation BMPs, by region.[73]

According to the voluntary agreement, signatories agree to implement all measures that are "cost-effective and appropriate at the local level." The state's audit of the BMP program found that most water agencies, including most of the largest water suppliers, have not implemented all of the conservation practices, nor have they offered the requisite documentation explaining why they need not.[74]

A more recent law, AB 1420, signed in 2007, ties receipt of water-related state grant funding to BMP implementation. In effect, participation in the program will remain voluntary, but this may provide a stronger incentive for agencies to be fully compliant.

[73] California Bay-Delta Authority (2006), Water Use Efficiency Comprehensive Evaluation. Sacramento. http://calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf

[74] Ibid.

Table 94: List of Best Management Practices

BMP	Description	New BMP Category
BMP 1	Water survey programs (Survey 15% of residential customers within 10 years)	Programmatic: Residential
BMP 2	Residential plumbing retrofit (Achieve 75% market saturation prior to 1992 with low-flow showerheads, toilet displacement devices, toilet flappers and aerators)	Programmatic: Residential
BMP 3	System water audits, "leak" detection and repair (Audit the water distribution system regularly and repair any identified leaks)	Foundations: Utility operations, loss control
BMP 4	Metering with commodity rates for all new connections and retrofit of existing unmetered connections	Foundational: Utility operations, metering
BMP 5	Large landscape conservation programs and incentives (Install meters in 100% of existing unmetered accounts within 10 years; bill by volume of water use; assess feasibility of installing dedicated landscape meters)	Programmatic: Landscape
BMP 6	High-efficiency clothes washing machine financial incentive program (Achieve 1.4% per year penetration during first 10 years)	Programmatic: Residential
BMP 7	Public information programs (Provide active public information programs in water agencies to promote and educate customers about water conservation)	Foundational: Education, Public Information Programs
BMP 8	School education programs (Provide active school education programs to educate students about water conservation and efficient water uses)	Foundational: Education, School Programs
BMP 9	Conservation programs for commercial, industrial, and institutional (CII) accounts (Provide a water survey of 10% of these customers within 10 years and identify retrofitting options; reduce water use by an amount equal to 10% of the baseline use within 10 years)	Programmatic: Commercial, Industrial, Institutional

BMP	Description	New BMP Category
BMP 10	Wholesale agency assistance programs (Provide financial incentives to water agencies and cities to encourage implementation of water conservation programs)	Foundational: Utility Operations, Operations
BMP 11	Retail conservation pricing (Eliminate non-conserving pricing policies and adopt pricing structure such as uniform rates or inclining block rates, incentives to customers to reduce average or peak use, and surcharges to encourage conservation)	Foundational: Utility Operations, Pricing
BMP 12	Conservation Coordinator (Designate a water agency staff member to have the responsibility to manage the water conservation programs)	Foundational: Utility Operations, Operations
BMP 13	Water waste prevention (Adopt water waste ordinances to prohibit gutter flooding, single-pass cooling systems in new connections, non-recirculating systems in all new car wash and commercial laundry systems, and non-recycling decorative water fountains)	Foundational: Utility Operations, Operations
BMP 14	Residential ultra-low-flush toilet (ULFT) replacement programs (Replace older toilets for residential customers at a rate equal to that of an ordinance requiring retrofit upon resale)	Programmatic: Residential

In its original form, the MOU relied strictly on demonstration of accomplishment of specific BMPs as sufficient to demonstrate the required water conservation. The latest revision of the Memorandum of Understanding, dated September 2009, discusses three ways in which signatories may demonstrate compliance with BMP water savings from the BMP list.

- The first of these is to demonstrate accomplishment of the specific measurers listed in the description of each BMP|. (The assumption being if the measures are installed, the water savings will follow based on the estimates of reliable savings.)
- The second is to use the Flex Track option to generate water savings that are equal to those anticipated from the BMP compliance, but which are derived from other measures not already identified as specific BMPs.
- The third is to demonstrate reductions in per-capita water demand in the signatory's water system without specifically crediting a particular BMP or group of BMPs with causing the savings.

20x2020 Mandate and SBX 7-7

In February 2008, then-Governor Arnold Schwarzenegger issued an emergency directive to protect the ecosystem of the Sacramento-San Joaquin river delta. The plan had seven parts, the first of which is water conservation. The governor said that the state must have:

"A plan to achieve a 20 percent reduction in per capita water use statewide by 2020. Conservation is one of the key ways to provide water for Californians and protect and improve the Delta ecosystem. A number of efforts are already underway to expand conservation programs, but I plan to direct state agencies to develop this more aggressive plan and implement it to the extent permitted by current law. I would welcome legislation to incorporate this goal into statute."

The legislature followed up in November 2009 with a bill (SBX 7-7) promoting statewide water conservation for all sectors of use, including a mandate for a 20% reduction in urban per capita use by 2020. In February 2010, the 20x2020 Water Conservation Plan was published, with input by a number of state agencies. The plan recommends a number of policies and actions to reduce urban water consumption, including:

Reduce landscape irrigation demand
Reduce water waste
Reinforce efficiency codes and related BMPs
Provide financial incentives
Implement a statewide public information and outreach campaign
Increase enforcement against water waste
Increase use of recycled water and non-traditional sources of water

Most commentators have noted two serious shortcomings in the law: First, the 20x2020 plan addresses only urban water use, and ignores agriculture, which accounts for about 80% of the state's water consumption in most years. A related bill addressing agricultural water use, but without specific quantitative targets, was passed with the water reform package in 2009. While this does not go as far as some would like, it is in the words of a DWR employee, "a huge change in the way things are done in the state." The intent behind the 20x2020 program is to prompt suppliers to expand conservation programs. Currently, eligibility for grants from the state will be tied to whether an agency has fully implemented all of the required BMPs, but in 2015 eligibility will be tied to demonstration of actual reductions in per capita demands.

From the perspective of single-family water use, a reduction in per capita use is equivalent to a reduction in household use, barring a massive change in the number of persons per dwelling unit. We know from the data presented in Table 73 and Figure 71 that as the number of persons per household increases the per capita use decreases. However, the average number of persons per household is a fairly stable number in single-family residences, varying around 2.7 to 2.8 persons per household. Consequently, any increase in water use efficiency in single-family customers will show up as a decrease in household water use. As shown in Table 73 these estimates can be refined by normalizing them to a standard household size for comparison if data are collected, which allow a mathematical relationship to be generated between indoor use and number of residents.

Colorado River Administration

The authors of the landmark 1975 California Water Atlas call the Colorado River "one of the most litigated, regulated, and argued about rivers in the world." The river's flow is shared by seven states and Mexico. Historically, California has used more than its legal allocation of Colorado River water, as laid out in the Colorado River Compact of 1922. As the upstream states have expanded irrigated area (through such projects as the Central Arizona Project), and as cities such as Denver, Salt Lake City, Phoenix, and Las Vegas, have grown, it has forced California to scale back its use of Colorado River water to its legal allotment. The Compact agreements grant California the use of 4.4 million acre-feet per year. The main beneficiaries of imported Colorado River water are cities in Southern California and farms in the Imperial Valley.

In addition to the current challenges associated with over-allocation of the Colorado River and disputes among the different users, long-term changes in climate now seem likely to reduce overall flows. In 2008, scientists at the Scripps Institute at UC San Diego published a study that gave a 50 percent chance that Lake Mead could be dry (or reach "dead pool" levels) regularly by 2021, based on climate change and current levels of consumption.[75]

Other regulatory drivers

Urban Water Management Planning Act

The state legislature passed the urban water management planning act in 1983. The Act required every water agency that serves over 3,000 customers to prepare an Urban Water Management Plan every five years and submit it to the Department of Water Resources. The plans are required to include a description of the supplier's demand management measures, defined as "water conservation measures, programs, and incentives that prevent the waste of water and promote the reasonable and efficient use and reuse of available supplies." Thus, all California water suppliers are required by law to at least consider the role that demand management should play in providing sustainable water service. The 2010 plans must also provide baseline information on gpcd use, and then report on compliance with the 20 x 2020 legislation in 2015 and 2020.

1992 National Energy Policy Act

The National Energy Policy Act, or NEPA, passed by Congress in 1992, mandated water efficiency standards for plumbing fixtures, as shown in the table below.

Fixture	Standard
Water Closets (Toilets)	1.6 gallons per flush
Showerheads	2.5 gallons per minute
Faucets	2.2 gallons per minute
Urinals	1 gallon per flush

[75] Barnett, T. P., and D. W. Pierce (2008), When will Lake Mead go dry?, Water Resour. Res., doi:10.1029/2007WR006704

It is widely believed that these standards have led, nationwide and in California, to reductions in per-capita domestic water use, as old fixtures have been swapped out through natural replacement and as new construction has become a larger and larger fraction of total housing stock. A number of policy and regulatory discussions are underway to identify how to expand the savings from these kinds of standards and how to accelerate uptake and hence market saturation of efficient appliances and fixtures. We hope that the current study will contribute to this discussion.

State Efficiency Standards

The legislated efficiency standards for single family homes in the State of California have been continuously evolving since the 1992 passage of the National Energy Policy Act. In 2007 the state adopted law AB 715 that requires that only High-Efficiency toilets and urinals be sold or installed after January 1, 2014. This law amended the 2007 California Plumbing Code and is stricter than the US Energy Policy Act requirements described above.

In 2009 the legislature passed SB 407 that deals with plumbing fixture upgrades as part of property transfers. The bill requires all single family homes that were built prior to Jan 1, 1994 to have all toilets that do not comply with the currently defined water conserving standard to be replaced. Presumably, that would require upgrading to HET toilets after January 1. 2014, since these will be the model designated as water conserving as of that date. This act also requires sellers of property to disclose the presence of any non-compliant toilets to prospective buyers.

The California Green Building Standards, adopted in 2010 require the use of HET toilets if the builder choses to rely on the prescribed set of fixtures and appliance (rather than measured water use) in order to qualify as a “green” building. The net effect of all of these measures is that over time the State will see an increasing number of HET toilets installed in its single family homes.

Table 95: Legislative requirements for toilet replacements for single family homes

Category of SF Homes	AB 715 (2007)	SB 407 (2009)	California Green Building Standards
Resale homes	Not Addressed	As of January 1, 2017 requires written disclosure by Seller to Buyer of non-compliant fixtures on property	Not addressed
Renovated SF Homes	All toilets sold or installed after January 1, 2014 must meet HET standards	All renovated SFR must have non-compliant toilets replace after Jan 1, 2014	1.28 gpf max if prescriptive path is chosen for green building qualification.
All Other SF Homes	Not addressed	All SFR must	Not Addressed

Model Water Efficient Landscape Ordinance

Water managers in the state have recognized the importance of addressing outdoor water use: in most of the state, more than half of a household's water is used outdoors, mostly to water lawns and gardens, but also in pools and spas, and for car washing and other purposes. In our study sample 53% of total water use was for outdoor purposes. In 1990, the state legislature passed AB 325, which limited the landscape ratio (the ratio of the Theoretical Irrigation Requirement to the Reference Requirement) to 80% of the reference crop evapotranspiration for the site. The model ordinance applied to large commercial and public properties and to residences with professionally-installed landscapes. Even though this ordinance does not apply to most of the homes in our study group it is interesting to note that their landscape ratio was very close to 1.0.

In 2000, an independent review of the model landscape program found several shortcomings in its implementation: "the legislation neither prescribed clear conservation goals, nor did it require meaningful levels of compliance. It also did not deal with pricing and enforcement issues. The most serious problem was the lack of actual irrigation monitoring: "enforcement of the maximum water allowance virtually nonexistent" and "few developers and contractors were even aware of the Model Ordinance. This lack of awareness, in a setting where water for the most part is still very cheap and agency monitoring nonexistent, makes wasteful irrigation virtually inevitable."

The landscape ordinance, which goes by the balky acronym MWELO, was developed by the Department of Water Resources at the direction of the legislature. AB 1881, signed into law in 2006, was designed to hold local agencies to tighter standards for outdoor water use. The law also required the California Energy Commission to adopt performance standards for irrigation equipment. It also contained a provision designed to prevent "common interest developments" (such as condominiums) from restricting the use of low water-using plants. (This was designed to counter the problem of homeowner associations that require lawns, in conflict with the state's water-saving goals.)

Cities and counties can use the state ordinance as a model, and must have adopted a local ordinance at least as effective by January 2010 (although delays in the program have slowed its full implementation). The most important effect is on new landscapes and major renovations, and mostly covers large landscapes: 2,500 square feet (0.06 acres), or for homeowners 5,000 square feet. According to our calculations, this law will cover approximately 30% of California single-family homes (see the section on Outdoor Water Use for details). Critics of the law contend that it is overly complicated for most laymen to understand and that it can unfairly burden homeowners: in some instances, re-landscaping will be required if a homeowner applies for a permit for an unrelated project such as renovating a bathroom. Supporters note that outdoor use comprises more than half of household water use, and a landscape ordinance is a fair approach that reduces waste while permitting green and attractive landscapes.

Residential Water Metering

Research by the Sacramento-based nonprofit Public Policy Institute of California has found that, in cities with meters, water use is about 15% less than in unmetered cities. Among cities where users pay volumetric rates, those with a tiered structure have water use that is 10% lower. A 2004 study by Aquacraft demonstrated water savings of 15.3 percent when comparing submetered to non-submetered properties. An earlier study by Industrial Economics in 1999 estimated savings of 18 to 39 percent. There are no reliable estimates for how many of California's homes are unmetered, but our interpretation of the 2006 California Water Rate Survey suggests that up to 6% of the state's water providers charge a bulk rate, which would imply an absence of meters.

The state has recently passed three different laws that will eventually result in universal metering, where every household has a water meter. Since 1992, state law has required the installation of water meters on all new construction. For meter-less cities like Sacramento, this meant that new homes had meters but customers still paid a flat rate. The law required utilities to begin charging volumetric "commodity" rates to all customers with meters beginning on January 1, 2010. (Before this, Sacramento customers with a meter had an option of paying an average flat rate or being billed according to their meter.) AB 975, signed into law in 2009, re-affirmed the state's intention to move to universal metering. Before this, existing law said that private utilities regulated by the Public Utilities Commission should not install meters unless they showed that metering would be cost effective, reduce water consumption, and not impose an unreasonable financial burden on customers. The new law removed this hurdle to metering by requiring meters for all connections, even if it resulted in increased costs to customers.

The state has also mandated that all California cities must be metered by 2025 (AB 2572 passed in 2004). The 20x2020 taskforce has recommended that this target be accelerated to occur by 2020. Another law states that cities that get federal water via the Central Valley Project must have meters installed by 2013.

The Graywater Law

Reuse of graywater water is a very powerful way to reduce demands because the act of reusing the water essentially eliminates the demand for fresh water equal to the amount of reuse. There are a number of obstacles, however, to fully implementing these systems. In the summer of 2008, the California Senate passed SB 1258 requiring the state to revise building codes "to conserve water by facilitating greater reuse of gray water in California." Prior to August 2009, when drought prompted emergency adoption of the new codes, re-use of residential graywater from sinks, showers, and washing machines for irrigation, was limited. Although the systems were legal, they required a detailed design and permit. In fact, it is estimated that in 2009 there were fewer than a dozen fully-permitted systems in the state, while some residents opted to install unpermitted graywater systems.

The revised rules have made it a great deal easier for residents to install a simple low-tech way to reuse water for landscape irrigation. While widespread public acceptance of graywater reuse appears to be low, there is a great deal of interest and enthusiasm from some quarters. The ability to re-use water could have a significant impact on household water use.

Clothes washer standards

Statistics from CHAPTER 7 showed that the second biggest use of water in most homes, after toilets, came from washing machines. It was also noted that the water-efficient models, while they cost somewhat more, used around 20 gallons per wash, compared to typical models that averaged closer to 40 gallons per wash. For a typical household, the indoor use model shows that the presence of a high-efficiency clothes washer translates to savings of 6,200 gallons per year.

In 2002, the state legislature passed a law requiring the California Energy Commission to create washing machine efficiency standards. In 2006, the Department of Energy denied the state's request to institute standards more stringent than the federal government. The state filed suit in 2007, and in October of 2009, the Ninth Circuit Court of Appeals overturned DOE's ruling, and ordered DOE to re-consider its ruling.

As of this writing, it remains to be seen whether the federal government will allow California to put in place stricter clothes washer standards, or will create national standards similar to those proposed in the state. If such standards are allowed, they will go a long way to saving water in residences throughout the state.

Show-Me-the Water Laws and the Vineyard Decision

Historically there has been somewhat of a lack of coordination between land use planning and water availability in that developments could be approved without demonstrating a firm supply of water. This issue was addressed by the California legislature in 2001, when it passed SB 610 in 2001 and SB 221, the so-called "Show Me the Water" laws. Under these laws, developers of large projects (usually more than 500 housing units) must demonstrate that a 20-year water supply is available.

In 2007, the Supreme Court issued a ruling that will likely affect water planning for some time. In the Vineyard Area Citizens for Responsible Growth vs. City of Rancho Cordova (or the so-called Vineyard Case) the court laid out general principles for dealing with water supply under the California Environmental Quality Act. The court stated that an applicant for a large project must do a thorough analysis of long-term water supply for the project. They went on to write that "speculative sources and unrealistic allocations (e.g. "paper water") are insufficient bases for decision making."

Water-Use of Single-Family Sector

In most cases residential water use predominates in urban systems, and single-family residences make up the bulk of residential use. Consequently, savings in single-family water use, while small on a per unit basis are of great importance to the state as a whole due to the large numbers involved. This section discusses how the results from this research project can be extrapolated to the state as a whole.

Number of Single-Family Residences

Single-family homes comprise 70-75% of the housing stock in California. In this study, no differentiation was made between detached houses and attached units with up to four units (i.e., duplex, triplex, and quadruplex) provided each unit was individually metered. Further, no differentiation was made on housing tenure, i.e., whether the residents rent or own the home. Based on this definition of a single-family home, according to the US Census Bureau's American Community Survey, in 2008 there were 9,474,895 occupied single-family residences in California. The stated margin of error for this estimate is ±0.1%.

The number of households counted by the Census in 2000 was updated to account for population growth and the construction of new homes over the last 10 years. We applied a percent increase in the number of housing units for each county based on information from the California Department of Finance spreadsheet titled "Population and Housing Estimates for Cities, Counties and the State, 2001-2010, with 2000 Benchmark."[76] The state's estimates of housing growth do not differentiate between single-family, multi-family or other types of residences; we assumed that each stock of housing increased at the same overall rate.

Research by the Public Policy Institute of California reveals trends in the types of housing being built in California. They found that the share of multi-family homes reached a peak of 58% from 1950 to 1960, and the share has steadily declined each decade until 2000. After 2000, the trend began to reverse. While the construction of single-family homes still dominates with 72%, the share of multi-family homes began to rise after three decades of decline. In the long run, the trend in housing type has important implications for urban water use, as multifamily homes consume less water due to lower outdoor water use per household.

[76] State of California, Department of Finance, E-5 Population and Housing Estimates for Cities, Counties and the State, 2001-2010, with 2000 Benchmark. Sacramento, California, May 2010. http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2001-10/

Table 96: Occupied housing units in California in 2008

Units	Percent	Units
1, detached	58.8%	7,160,577
1, attached	7.0%	852,450
2 apts	2.5%	304,446
3-4 apts	5.6%	681,960
5-9 apts	6.2%	755,027
10+ apts	16.0%	1,948,456
Mobile home or other	3.9%	474,936
Total	100.0%	12,177,852
Total SF		9,474,369

Source : U.S. Census Bureau, 2008 American Community Survey. Note shaded cells denote single-family.

We then estimated the number of single-family residences in each of the state's 10 hydrologic regions. This was done using geographic information system (GIS) software to overlay hydrologic region boundaries with the 387 census-defined county subdivisions.

Because the homes metered in the current study are only a subset of all the homes in the state, we evaluate evidence that the 733 homes in the study group are representative of single-family homes throughout the state. Below, we examine how the sampled households where flow traces and surveys were collected compare to the state as a whole. Based on their similarity, we discuss extrapolating the results of the survey to understand potential conservation in the state as a whole.

Characteristics of Single-Family Residential Population

Average age

The median age in California is 33.3, according to the 2000 Census. The median age for females (34.4) is slightly higher than that of males (32.2). The census does not tabulate the average age within households of different types. They do however, report the age of the self-reported head of the household by household tenure (rent vs. own). Of the state's 11.5 million occupied households in 2000, 57% were owned-occupied vs. 43% occupied by renters. Householders in owner-occupied homes tend to be somewhat older, as shown by the distributions in Figure 81.

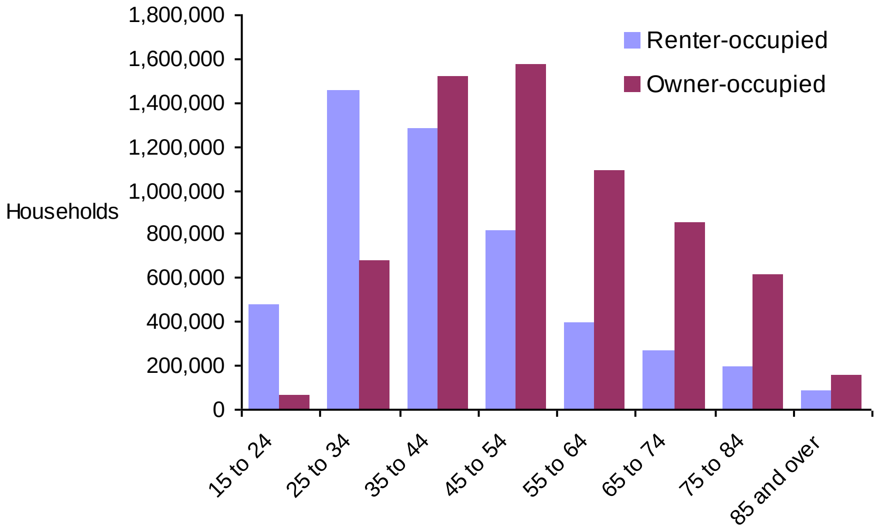


Figure 81: Number of households, by age of householder and housing tenure in California in 2000

Average number of residents

Overall, California households have an average of 2.87 residents (Table 8). There is some variance in number of residents by region, and by housing type. Owner-occupied homes are slightly larger on average than those occupied by renters (Table 97). Also, households appear to be larger in communities in the Central Valley and in Southern California (Figure 82).

Table 97: Average household size in California

Total	2.87
Owner occupied	2.93
Renter occupied	2.79

We conducted a more detailed analysis of household residents using data from the US Census Bureau. The Bureau's Summary File 4 data is comprised of information from a selective sampling of the entire census data. The table HCT19 reports household size by housing type in each of the state's 387 county subdivisions, as shown in Figure 82.

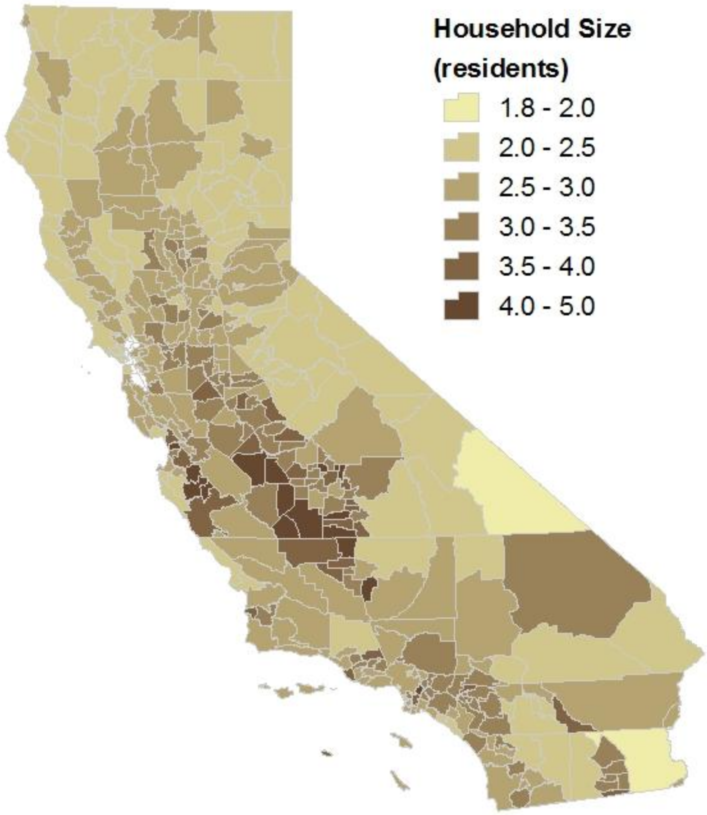


Figure 82 Average Household Size[77]

We compared the household size of single-family residents in the state with household sizes in the study, based on the 499 returned questionnaires. The overall average occupancy for the sample was 2.96, while for the state as a whole it was 2.87. This represents a variance of 3%. Given that the number of occupants was the only continuous variable found to be significant for indoor use, the close agreement between the sample and state as a whole is encouraging. Figure 83 shows that the sample household sizes reasonably approximate those in the state, though there are some differences. The sample appears to have fewer one-person households, and a greater preponderance of two-person households than the state population. It is conceivable that two-person households are more likely to return questionnaires than households with a single resident.

[77] U.S. Census Bureau, Detailed 2007 American Housing Survey Data Using Census 2000-based Weighting. http://www.census.gov/hhes/www/housing/ahs/ahs07/ahs07.html

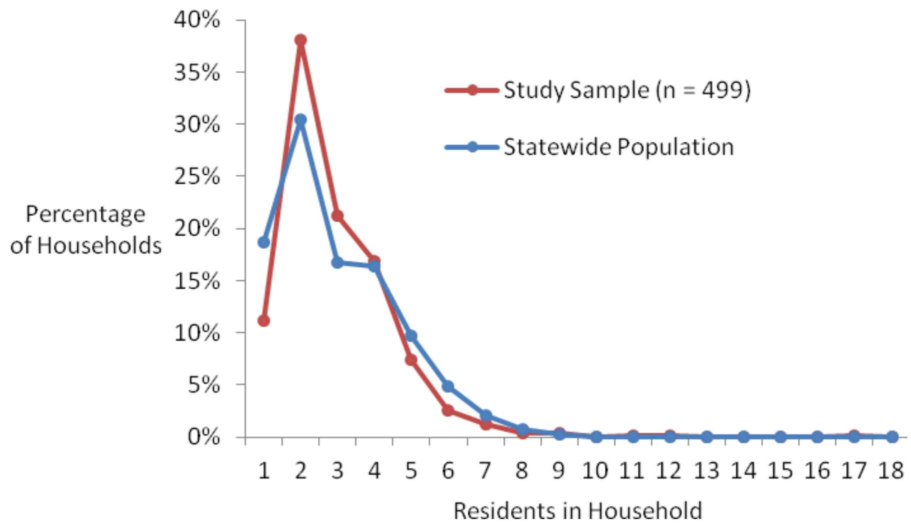


Figure 83: Distribution of household sizes in this study's sample and statewide

Table 98: Single-Family Households, household size, and population by hydrologic region, estimated for 2010.

Region	Number of SF Households	Household Size (residents/hh)	Population
North Coast	233,821	2.52	589,000
San Francisco Bay	1,733,198	2.70	4,680,000
Central Coast	491,323	2.85	1,400,000
South Coast	4,751,287	3.00	14,300,000
Sacramento River	949,212	2.62	2,490,000
San Joaquin River	653,547	2.98	1,950,000
Tulare Lake	582,509	3.14	1,830,000
North Lahontan	36,908	2.54	93,600
South Lahontan	209,449	2.89	605,000
Colorado River	244,399	2.79	682,000
CALIFORNIA	9,885,653	2.89	28,600,000

Average lot size

Nationally, the median lot size is 0.35 acres, or 15,000 square feet, according to data collected by the Census Bureau as part of the American Housing Survey in 2007.

Table 99: Lot size in the United States (data in thousands) for all housing units

	Units	Percent
Less than 1/8 acre	13,614	15%
1/8 to 1/4 acre	25,775	28%
1/4 to 1/2 acre	17,703	19%
1/2 to 1 acre	11,216	12%
1 to 5 acres	17,713	19%
5 to 10 acres	2,785	3%
10 + acres	4,402	5%
Total	93,208	100%

Reliable figures for lot sizes throughout the state are difficult to come by. Lot size is usually included with the property records maintained by county assessors' offices. While this information is officially part of the public record, there are difficulties in accessing it and using it for research. Many of California's 58 counties maintain paper records, and have not yet converted records to a digital format.

Researchers from the Public Policy Institute of California used county assessor data to measure trends in single-family lot sizes.[78] They obtained data for 22 counties via the housing research firm DataQuick, which compiles parcel records from the counties. The authors of this study broke all single-family residences into two categories: one with small lots under 0.25 acre, and those over a quarter acre, which they refer to as "ranchettes." For smaller lots, the authors estimate the size of the yard by subtracting the building footprint area from the lot, and estimate irrigated area as 35% of the yard, citing a 1995 study by the East Bay Municipal Utility District. The average irrigated area was from 2,000-3,600 square feet. For the larger "ranchette" properties, the irrigated area is estimated as 10% of the irrigated area, averaging about a quarter acre, or about 11,000 square feet.

The American Housing Survey

The American Housing Survey (AHS) collects data on the Nation's housing, including apartments, single-family homes, mobile homes, vacant housing units, household characteristics, income, housing and neighborhood quality, housing costs, equipment and fuels, size of housing unit, and recent movers. National data are collected in odd numbered years, and data for each of 47 selected Metropolitan Areas are collected currently about every six years. The national sample covers an average 55,000 housing units. Each metropolitan area sample covers 4,100 or more housing units. The information below is collected from census-designated Primary Metropolitan Statistical Areas (PMSAs).

[78] Hanak, Ellen and Matthew Davis (2008), Lawns and Water Use in California. Public Policy Institute of California. 24 pages. http://www.ppic.org/main/publication.asp?i=691

Metropolitan Area	Survey Year	Median Lot Size (acres)	(sq. ft.)
Anaheim-Santa Ana PMSA	2002	0.18	7,800
Oakland PMSA	1998	0.20	8,700
Riverside-San Bernardino-Ontario PMSA	2002	0.23	10,000
Sacramento PMSA	2004	0.23	10,000
San Diego MSA	2002	0.21	9,100
San Francisco-Oakland PMSA	1998	0.16	7,000
San Jose PMSA	1998	0.19	8,300
Los Angeles-Long Beach PMSA	2003	0.19	8,300

The Department of Water Resources estimates land and water use for the California Water Plan, which is updated every five years. Because the distribution of lot sizes is positively skewed, with a minority of households on larger lots, the median is lower than the mean, or average, lot size.

Here, we use a sample of single-family homes in California to determine the average irrigation requirement. A geographic dataset was previously developed (Gleick and other 2009) to represent reference crop irrigation requirements in an average year, where rainfall and evapotranspiration do not stray from the normal, long-term average. Irrigation requirements may be lower during cool or rainy years, and will be significantly higher during hot and dry years.

It was found that, on average, 51% of the lot is irrigated area, according to a simple linear curve fit based on 604 homes. Note that only eight of the homes are on lots greater than one acre (43,560 sq. ft.), and so we follow PPIC's assumption that the irrigated area will increase by another 10% for each acre after the first acre.

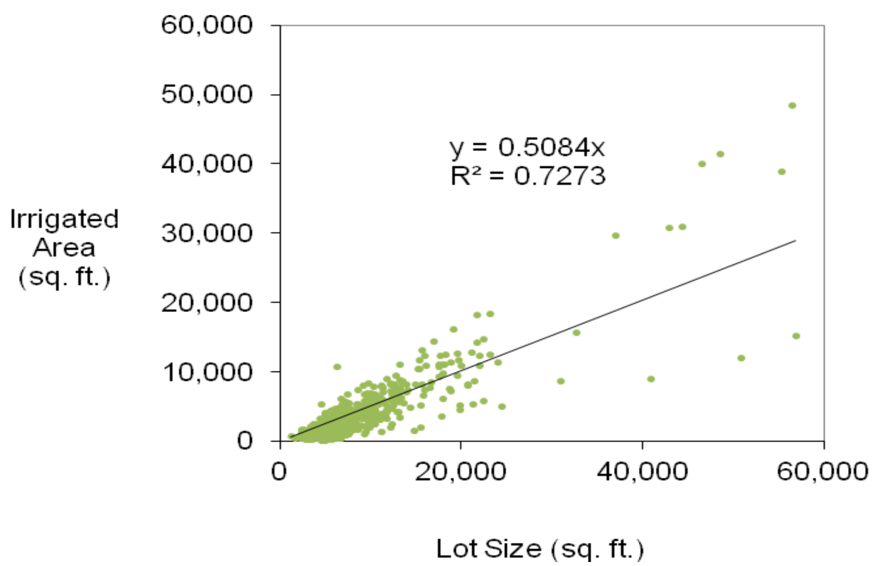


Figure 84: Irrigated Area vs Lot Size from 604 California Homes (Pacific Institute, 2009)

Household Income

The median household income for Californians in 2008 was $61,154 with a mean of $83,970. The stated incomes of the 417 survey respondents were higher. For example, 29% of California households earn less than $35,000 per year, compared to 10% of households in the study. It was not possible to determine the incomes of single-family households directly. However, the census bureau does provide tabulations of income by housing tenure (rent vs. own). This is an imperfect surrogate; however it may provide a better idea of single-family residents, as it excludes apartment renters.

In general, we can conclude that the study households included a lower percentage of low-income households, and more high-income earners than the state population as a whole. Figure 85 shows that households earning over $150,000 were more common in our study than in the state as a whole.

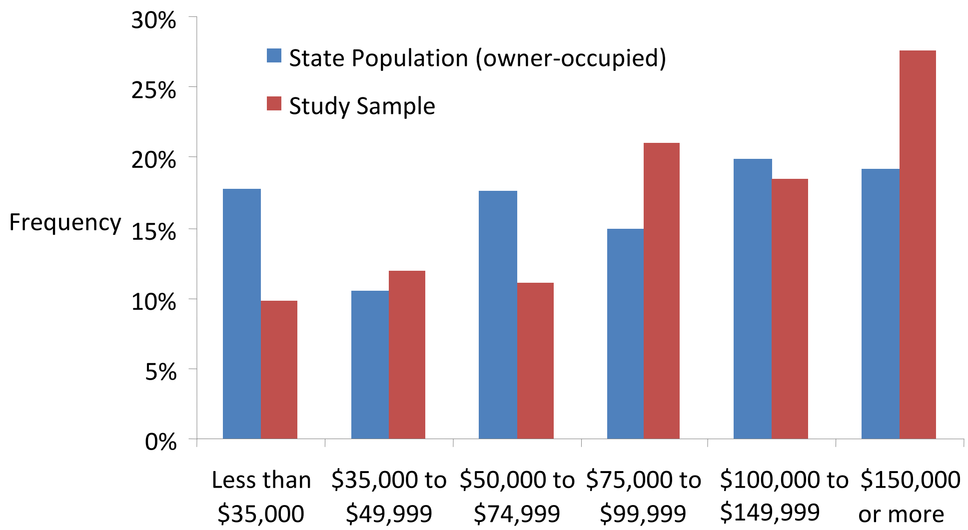


Figure 85: Household incomes for the state population and surveyed households

Projections of Potential Statewide Water Savings

Based on the data presented in previous chapters on the water use within the study group, and data collected for the statewide population of single-family homes, it is possible to make reasonable projections of potential water savings for single-family customers in the state as a whole.

Indoor Savings

The performance-based analysis from Table 84 showed that it would be possible to reduce indoor water use to 120 gphd by achieving four major water conservation goals:

- Reducing the average gallons per load of clothes washers to 20 gpl would reduce the average household use by 13.6 gphd.
- Reducing faucet use by 10% would reduce the average by 3.3 gphd
- Limiting household leakage and continuous uses to 25 gpd would reduce the average by 17.5 gphd
- Reducing toilet flushes to a maximum of 1.28 gpf would reduce the average use by 20.3 gphd

Clothes washers

Modern horizontal-axis, front-loading clothes washers use significantly less water than top loading clothes washers, which are the most prevalent in the United States. The Pacific Institute has previously noted that "horizontal-axis washing machines, long popular in Europe where they have captured over 90 percent of the market, have only recently been introduced to the United States."[79]

Among the 735 homes sampled in this study over 97% reported having a clothes washer in the home. Of these 76% were top loading and 24% were front loading. The average load of wash measured by the flow traces was 36 gallons. The U.S. Department of Energy's EnergyStar program, in a 2009 analysis, found an average of water use of 14.9 gpl for efficient, EnergyStar-rated clothes washers. Our indoor savings analysis assumes that clothes washers using 20 gpl as a maximum become the norm over time. It is not necessary that this transformation occur immediately, but could easily occur over the next 20 to 30 years.

Faucets

This study found that faucets accounted for 19% of all indoor water use. It has been noted that this category is somewhat of a catch-all: the specific water use is diverse and difficult to determine without intrusive investigations into the home. As the average home used the faucet 58 times per day, for a total of 33 gallons, conservation efforts here may be fruitful. Faucet use can be affected both by reducing the flow rates of the fixtures and by reducing the run times.

Before 1992, faucets' rated flow rates ranged from 2.5 to 7 gpm. In 1992, California updated its plumbing code to set a maximum flow rate of 2.2 gpm, but this was replaced by the new federal

[79] Gleick, P.G. et al. (2003) Waste Not, Want Not: The Potential for Urban Water Conservation in California. Pacific Institute, Oakland, California.

standard of 2.2 gpm in 1994, which is still in place. Previous analysis by the Pacific Institute pointed out that a low-flow faucet will not always reduce water use: "filling a pot will require the same volume of water regardless of flow rate. The amount of water used for brushing teeth while leaving the faucet running, however, will be larger with a faucet that flows at a higher rate. Thus, a low-flow faucet may or may not reduce water needs, depending on the use and individual behavior."

Field studies have observed significant water savings from reduced faucet flow rates. Seattle's Home Water Saver Apartment/Condominium program installed faucet aerators in 65,702 multi-family units and found that faucet flow rates were reduced by 0.7 gpm, resulting in an 18 percent reduction in faucet water use.[80] In 2003, a study conducted in Tampa tested bathroom and kitchen faucet aerators and hands-free electronic faucets of the type ordinarily found in commercial settings.[81] This study found savings of 3.2 gallons per day.

The latest faucet aerators on the market are available in a variety of flow rates, ranging from 0.5 gpm (for bathroom faucets) to 2.5 gpm. Newer kitchen faucet aerators are designed with a range of features, such as swivel action to reach every corner of the sink, fingertip controls to temporarily halt water flow, and dual flow mode: a higher flow for filling pots and low flow for washing up. It seems more attention is being paid to providing the right amount of flow and pressure when and where it is needed. Aerators are also inexpensive: The retail price for aerators ranged from $0.99 to around $4, based on a survey of online retailers.

In addition to their flow rates, the other aspect of faucets that can be addressed is their duration of use. In Table 43 we see that the average duration of the faucet events in the database was 37 seconds. Presumably, much of this was wasted time in which the faucet was running but the water was simply going down the drain. Devices which allow better control of faucet through sensors, foot pedals, level or other hands free devices may be worth investigating as to their savings potential. In addition to device operation, there is a significant behavioral component in the way existing faucets are used. This behavioral element may best be addressed by education and informational campaigns.

There is strong evidence that there is untapped conservation potential to be gained from contemporary low-flow faucets and aerators. Because of the low cost of aerators, these savings could be cost-effective. Also, because faucets often use warm or hot water, residents will save money on their energy bills, making these more attractive. The indoor model in this study assumed only a reduction of 10% in faucet use. Given the wealth of devices available to limit both the flow rates and durations of faucets this seems like a modest goal.

[80] Skeel T. and S. Hill. 1998. Evaluation of Savings from Seattle's "Home Water Saver" Apartment/Condominium Program. Seattle Public Utilities. Seattle, Washington. http://www.ci.seattle.wa.us/util/rescons/papers/p_tssh1.HTM

[81] Mayer, P.W., Deoreo., W.B., Towler, E., Martin, L., Lewis, D.M., Tampa Water Department residential water conservation study: The impacts of high-efficiency plumbing fixture retrofits in single-family homes. Submitted to: Seattle Public Utilities and the USEPA, 2004., by Aquacraft, Inc. Boulder, Colorado. www.aquacraft.com

Leaks and continuous uses

This study has shown that homes with large volumes of leakage and continuous uses raise the average indoor water use for the entire group. In order to reduce the short term leaks the best strategy is to improve the performance of the fixtures and appliances, e.g. reduce the frequency of leaky toilets. In order to eliminate the large volume leaks from continuous events a system that recognizes these flows and turns the water off would be needed. These devices would act the way that a circuit breaker does on an electric system, and would prevent both water waste and damage to homes due to burst pipes and broken valves.

Strategies for finding customers with leaks include:

- Audits – expensive, voluntary, limited reach
- Data mining of billing records (look for sudden jumps, households with much higher non-seasonal water use than similar properties, or that would be expected from the size of the property.
- Smart meters – real-time feedback to users, alert them of a sudden jump in water use that may signify a leak.
- "Leak" detection devices – flow sensors installed in the service line that detect leaks, alert owners, and turn off the water.
- Water budgets – homes with leaks will exceed budgets and pay excess use rates, thus encouraging repair.

Toilets

Toilets are major indoor water users and there are significant differences in water use per toilet among models, especially models installed before new federal and state standards came into force. Data collected in this study revealed that there remains a great deal of savings potential for toilets. In flow trace data collected in 1996-1997, the Residential End Uses of Water Study revealed that toilets were the biggest component of indoor water use. Ten years later, it appears this is still the case, accounting for 20% of indoor water use. The indoor modeling showed that if the average flush volume were brought down to HET specifications (1.28 gpf) this would reduce average indoor use by 20.3 gphd, the largest projected savings of the group.

Other Actions

Conservation efforts do not need to be limited to the four categories identified from the performance based analysis. Savings are possible from other indoor uses, which would provide additional savings, and thereby increase the potential of meeting or surpassing the conservation target of 120 gphd as the average for the group.

Dishwashers

The indoor modeling results for faucets, shown in Table 77, suggest that the presence of a dishwasher reduces daily faucet use by 14 gpd, or 500 gallons per year. This matches the Energy Star website, which advises (without citing a source) that: "washing dishes by hand uses much more water than using a dishwasher. Using an ENERGY STAR qualified dishwashers instead of hand washing will save you annually 5,000 gallons of water, $40 in utility costs, and 230 hours of your time."

According to Table 67, the survey results from this study, 82% of the homes have dishwashers. This suggests that if dishwashers were installed in the 18% of homes that do not have them, the average household water use would be reduced by approximately 1,000 gallons per year.

Garbage Disposals

Table 77 also suggests that the presence of a garbage disposal also saves water in the home, approximately 13 gphd. This is counter intuitive since one would expect that the use of a garbage disposal would lead to more use of the faucet. It is possible, however, that homes without garbage disposals actually use more water to clear the drains than do homes with them. It is also possible that since the homes with garbage disposals were also more likely to have an automatic dishwasher present, and as discussed above, dishwashers correlate to a decrease in faucet use, it is therefore possible that the decrease in faucet use is due to the combination of the garbage disposal and dishwasher. Virtually all new homes are equipped with both dishwashers and disposals, so this is not an issue for new home standards. It does suggest, however, that water agencies should not consider disposals as water wasting appliances.

Showers

In this study it was not possible to detect a change in household water use based on the average flow rates of the showers in the homes. The reason for this, as explained in CHAPTER 9, was due to the fact that there was so little variability among the average flow rates among the houses. We do know that the majority of showers flow at or below the 2.5 gpm standard for the 1992 EPAct. This is due to a combination of plumbing restrictions and throttling by the users. In the EPA Retrofit study replacement of existing showerheads with 2.5 gpm devices led to no significant reductions in daily shower use. In one of the sites, however, where the old showerheads were replaced with devices flowing at 1.7 gpm, which match existing WaterSense specifications, a reduction of 9.7 gpd was measured. This is equivalent to approximately 3,500 gallons per year of potential savings.

Water Monitors

The faucet model results shown in Table 77 showed that three factors associated with peoples' knowledge of how much water they were using were linked to reduced faucet uses. These questions were whether people knew how much water they used in a year, whether they knew the cost of wastewater charges, and whether they felt that the cost of water was an important factor in their decisions about how much water to use. All of these factors suggest that having more knowledge about the actual use of water and its costs tends to decrease discretionary uses such a faucet use. This suggests that measures such as real time water monitors may play a role in reducing discretionary uses by informing people of their actual usage.

Other Uses

The other domestic use category includes items such as water treatment systems, humidifiers, swamp coolers and other uses that did not fall into any of the other categories. There is no single measure for dealing with all of the miscellaneous uses, but the category does show that they account for nearly 4% of average indoor uses. Knowing that these uses exist and insuring that they are properly operated and maintained by the users is an important step in managing them.

Outdoor Savings

In order to extrapolate the outdoor results from this study to the state as a whole, the regression models developed in CHAPTER 9 were used. The variables were adjusted based on the best available information for the population of single-family homes across the state in order to derive adjusted estimates of outdoor household water use for the general single-family population. In areas where specific data were not available for adjustments we assume that patterns of outdoor water use from the study group are similar to those throughout the state, for example we assumed that the percentage of homes that practice irrigation (87%) found in this study can be applied across the state. On the other hand, census data showed that the statewide household income was lower than the study group, so the outdoor use model was used to correct for this.

Table 100 shows the baseline estimate for outdoor water use in the state after correcting for household income and the percent of homes that are irrigating. In this and the following tables the outdoor use model from Chapter 9 was used to estimate the predicted outdoor household use. This value equals the product of the factors in rows one through eight of the table, plus the correction factor in row nine. The baseline use is shown in row 10, which in this case is 87.103 kgal per household. This value stays constant in the following case studies, and savings are taken as the difference between the baseline use and the use predicted by varying the values for the test cases. The savings per household are then multiplied by the estimated number of single-family households that are irrigating to arrive at estimates of statewide savings projections from conservation in outdoor use.

Table 100: Baseline outdoor water use corrected for percent irrigators and income

Parameter	Coefficient	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3802.615	275.348
Net Eto (in)	1.659	42.193	42.193	496.060
Landscape Ratio	0.506	0.960	0.960	0.979
Excess Irrigators (%)	3.130	0.505	0.505	2.076
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061
Log_household_income ($1000)	0.125	83.97	83.970	1.74
Correction	-9.200			-9.200
Observed Mean Use (kgal)				87.103
Predicted Value (kgal)				87.103
Savings (kgal)				0.000
Irrigating SF Homes (87% of total)				8,242,701
Total savings (kgal)*				0
Total savings (MAF)*				0

*Baseline data, therefore no savings values

Using the outdoor regression model we can make projections of the likely impact on household water use among the 8.24 million irrigating single-family residences if various modifications are made to their outdoor water patterns. In the first case we assume that the rate of over-irrigation can be cut in half from the current 50.5% to 25.25% of irrigating households that are over irrigating.

Table 101 shows that this simple expedient would reduce average outdoor use from 87.103 kgal per year to 62.152 kgal, and results in statewide savings of 0.631 million acre feet of water. Based on our best estimate of 4.4 MAF of single-family water use from Table 89 this means that a savings of nearly 15% of total single-family use could be achieved simply by cutting the number of over-irrigators in half--not eliminating over irrigation, but just halving it.

Table 101: Outdoor case 1: reduction in rate of excess irrigators by 50%

Parameter	Coefficient	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3802.615	275.348
Net Eto (in)	1.659	42.193	42.193	496.060
Landscape Ratio	0.506	0.960	0.960	0.979
Excess Irrigators (%)	3.130	0.505	0.253	1.538
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061
Log_household_income ($1000)	0.125	83.97	83.970	1.74
Correction	-9.200			-9.200
Observed Mean Use (kgal)				87.103
Predicted Value (kgal)				62.152
Savings (kgal)				24.951
Irrigating SF Homes (87% of total)				8,242,701
Total savings (kgal)				205,660,996
Total savings (MAF)				0.631

A second scenario supposes that a fraction of households' high-water use plants such as grass are replaced with climate-adapted, low-water use plants, in effect reducing their landscape ratios. This type of landscaping is often referred to as "drought-tolerant" or "low-water using" plantings. Southern Californians sometimes promote drought-tolerant and native plants as "California Friendly Landscaping," it is referred to as "Bay-Friendly" in the San Francisco Bay Area, and in Santa Rosa and in Sacramento the term is "River Friendly." Replacing grass with native plants, in particular, reduces water use and has other benefits including flowers that attract pollinators, more diverse habitat, lower fertilizer and pesticide use, less polluted runoff, and healthier lakes, streams, and coasts. The California model landscape ordinance suggests a maximum landscape ratio of 0.8.

This study found an average "landscape ratio" of 0.96. The landscape ratio captures the impacts of different plant materials since it is the ratio of the theoretical irrigation requirement to the reference irrigation requirement. Landscape professionals and agronomists use the concept of a crop coefficient or a plant factor to describe the water demands of different types of plants. A plant factor, when multiplied by reference crop evapotranspiration, determines the amount of water needed by a plant. California's Water Efficient Landscape Ordinance, AB 1881, reports plant factors for different types of landscapes. The factor for low-water-use plants is 0 to 0.3, for moderate water use plants 0.4 to 0.6, and for high water use plants 0.7 to 1.0. Plant factors cited in the ordinance are derived from the Department of Water Resources 2000 publication "Water Use Classification of Landscape Species."

For this scenario, we estimated the water savings that would result from reducing the average landscape ratio from its current average of 0.96 to 0.80, which is the suggested ratio in the model landscape ordinance. This would be done by replacing turf and high water-using trees and shrubs with plants having a lower water requirement. Note that this scenario does not involve reducing landscaped area, since creating additional hardscape could increase impervious cover and runoff, and may not be a recommended practice. Making this modification to the outdoor water use model achieves an additional 0.16 MAF, bringing total outdoor savings potential to 0.790 MAF, which is an equivalent savings to 18% of the total single-family demands.

Table 102: Outdoor case 2: reduction in landscape ratio to 0.80

Parameter	Coefficient	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3802.615	275.348
Net Eto (in)	1.659	42.193	42.193	496.060
Landscape Ratio	0.506	0.960	0.800	0.893
Excess Irrigators (%)	3.130	0.505	0.253	1.538
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061
Log_household_income ($1000)	0.125	83.97	83.970	1.74
Correction	-9.200			-9.200
Observed Mean Use (kgal)				87.103
Predicted Value (kgal)				55.872
savings (kgal)				31.231
Irrigating SF Homes (87% of total)				8,242,701
total savings (kgal)				257,424,478
Total savings (MAF)				0.790

The final outdoor scenario assumes that the average irrigated area is reduced by 20% through the use of hardscapes, mulches, and non-irrigated areas. This would lower the average landscape area to 3042 sf, and would generate another 0.232 MAF of outdoor water savings. In this case the total outdoor savings would amount to 1.022 MAF of water per year, as shown in Table 103.

Table 103: Outdoor case 3: reduction in landscape area by 20%

Parameter	Coefficient	Study Mean	Assumed Value	Predicted Outdoor Use
Factor	1.6207E-04	--		1.6207E-04
Irrigated Area (sf)	0.682	3802.615	3042	236.503
Net Eto (in)	1.659	42.193	42.193	496.060
Landscape Ratio	0.506	0.960	0.800	0.893
Excess Irrigators (%)	3.130	0.505	0.253	1.538
In ground sprinklers (%)	1.212	0.739	0.739	1.157
Swimming pool (%)	1.385	0.158	0.158	1.061
Log_household_income ($1000)	0.125	83.97	83.970	1.74
Correction	-9.200			-9.200
Observed Mean Use (kgal)				87.103
Predicted Value (kgal)				46.692
savings (kgal)				40.411
Irrigating SF Homes (87% of total)				8,242,701
total savings (kgal)				333,093,996
Total savings (MAF)				1.022

The results of the three scenarios of outdoor water use are shown in Table 104. The total savings estimated from the three outdoor conservation efforts described above range from 15% to 23% of the total single-family baseline water use.

Table 104: Estimated outdoor water savings for single-family residences in California

	Baseline Current Estimate of SF Outdoor Water Use	Scenario 1 Reduce Rate of Over-irrigation by 50%	Scenario 2 Reduce Average Landscape Ratio to 0.8	Scenario 3 Reduce Average Irrigated Area by 20%
Income corrected Water Use (kgal/yr/)	87.103	62.152	55.872	46.692
(MAF)	2.27	1.62	1.48	
Savings (kgal/yr)		24.95	31.23	40.41
Savings (MAF)		0.631	0.790	1.022
% reduction for SF Outdoor use		28%	35%	45%
% Reduction of total SF use		14%	18%	23%

Finally, a note about "cash for grass" programs: these have become increasingly popular as tools for water savings, most notably in Las Vegas, which recently increased the incentive from $1.00 to $1.50 per square-foot (Southern Nevada Water Authority 2010). We estimate that, in Los Angeles, each square-foot of grass replaced with "California-friendly" landscaping saves 12 gallons of water in a normal year, and up to 18 gallons in a drought year. Beyond financial incentives, agencies are employing other strategies to give up water-thirsty lawns for more appropriate land cover. These include enforcement of local landscape ordinances as described in the above section on new regulations.

Another approach seeks to use the techniques of social marketing to convince residents of the many benefits of dry gardens, both environmental and aesthetic. While it is more difficult to measure the impact of these "soft" approaches, they are important to bringing about a culture shift that will contribute to more sustainable use of California's water resources.

Total Savings Potential from Single-Family Homes

This study showed that a range of water savings is available from single-family homes in California. Most of these savings come from the elimination of waste and use of best available water technologies. Additional savings are available from changes in lifestyle such as landscape redesign or reduction of landscape areas.

The indoor savings potential are limited by the end-point chosen for indoor household use. In CHAPTER 9 we estimated a potential average savings of 20 kgal per home assuming that the indoor use benchmark would be 120 gphd. In this chapter the estimate was 30 to 40 kgal per household assuming that benchmarks of 105 gphd could be achieved and more aggressive indoor technologies used. Consequently, we can conceive of three levels of indoor water conservation benchmarks: a low, medium and high level at 20, 30 and 40 kgal per year per home. Total indoor estimates are based on the estimate of 9.5 million single-family households in the state.

Outdoor potential conservation savings have been estimated at a low of 0.631, medium of 0.790 and high of 1.022 MAF per year. The savings in the low and medium ranges are deemed technically achievable, and do not require draconian demand restriction efforts. Furthermore, the low-end savings would more than achieve the desired 20% reduction in use. The practicality of achieving savings in the high range is less clear, and closely related to the value placed on the saved water. Achieving the high range outdoor savings may be achievable if residents are willing to scale back on the size and water requirements of their landscapes. Table 105 shows the summary of the estimated potential conservation savings derived from this study. It is worth repeating that what is achievable is a function of the value being placed on the saved water. As water becomes scarcer its value will rise, which will make things that may not have appeared economically practical become so.

Table 105: Summary of projected statewide savings (MAFY)

	Baseline Use	Low Savings	Medium Savings	High Savings
Indoor	2.13	.58	.87	1.16
Outdoor	2.27	.63	.79	1.02
Total	4.4	1.21	1.66	2.18
% of Total		27%	37%	50%

Issues Concerning Potential Water Conservation in California

There are a number of issues that need to be kept in mind when considering how water conservation might impact future water demands in California.

The Post-Drought Rebound Effect

The sampling for this study took place in the middle of a three-year drought that struck California from 2006- 2009. This is reflected in the governor's declaration of a drought in June 2008, followed by a more serious declaration of a state emergency in February 2009. During this time, a statewide public education plan was conducted encouraging people to conserve water. At the same time, newspapers, radio, and television carried stories on the drought, usually accompanied by an exhortation to conserve water. During a drought, water savings come from a combination of changes to behavior and technology. As an example of behavioral change, customers may take shorter showers, or scale back on lawn watering or car washing. Some customers install water-saving fixtures that they purchase or receive via a giveaway or rebate from the utility. A "rebound effect" is often observed following a drought when customers return to their former patterns of water use. However, a certain amount of savings are more lasting, partly due to the spread of water-efficient technologies, but perhaps also due to lasting behavioral changes. It is reasonable to assume that some households in the sample modified their water use based on these messages, suggesting that the sample may underestimate water use in a normal, non-drought year.

Skewed nature of use and savings potential

The distribution of water use among single-family residents is heavily skewed. It seems that household water use like many other quantities in social science, obeys the law of the long tail: a small number of households use large amounts of water. This has important implications for the design of conservation programs, since a small number of customers hold the biggest conservation potential; targeting these customers may lead to the most savings at the lowest cost. Yet, there are some difficulties in identifying these customers and running targeted conservation programs.

One strategy is to use the techniques of data mining of billing data to determine households where water use is unexpectedly high. It may be useful to look for sudden unexplained jumps in water use by a customer. This may help to identify leaks in the customer's home which they may not be aware of.

Billing data becomes even more useful when it is linked to other kinds of information. High water use may be explained by a large family or a house that is on a large lot. Comparing billing data to property information from assessors' offices (often called cadastral data) may make these queries more informative.

Agencies that use an allocation-based billing structure, based on the number of residents or size of the lot, already have this type of information about their customers. Irvine Ranch Water District in California is an example of an agency that has successfully used a "water budget" approach for over a decade.

Need for price signals

Many analysts have noted that California's water customers do not all receive adequate price signals to indicate that water resources are scarce. In general, there are four kinds of rate structures at use in the state: flat, declining block, uniform, and increasing block rate.

The California Urban Water Conservation Council has encouraged the use of "conservation pricing" since 1991. By their definition, conservation pricing means that customers should pay for each additional unit of consumption. These so-called volumetric rates can include either uniform or increasing block rates.

Economists had formerly assumed that demand for water was relatively inelastic. In other words, a household's need for demand for water is relatively fixed, and does not respond to changes in price. Two decades worth of research stands this notion on its head. According to Tsai et al. (2009), "Literature on the price elasticity of water use – impact of water price on water demand – is so well-developed that meta-analysis is now possible (for example, see the meta-analysis of 64 previous studies by Dalhuisen et al. 2003)." [82] Arbués and others surveyed the literature on residential water demand and conclude that while conservation pricing remains an important tool for water managers, it will be most effective when "complemented by other instruments."

The fact remains, however, that water is fairly inexpensive, and comprises a small portion of a typical household's budget. A spate of recent newspaper articles publicized the profligacy of the biggest water users. Relying solely on rate increases to bring about savings will be difficult. Most agencies face some opposition from the public for any rate increase, no matter how modest. Raising rates can also create an unfair burden on poor families. Some have proposed allocation-based rate systems to alleviate these concerns, where a base allocation for a household is based on the number of residents.

As of 2006, 93% of California water agencies charged volumetric rates to residential customers, according to a study of water rates by the engineering firm Black & Veatch.[83]Inclining tiered rates are becoming more widespread. Before 1991, tiered rates were used by only 20% of suppliers. Their use spread from 38% of suppliers in 2001 to 43% in 2006,
Figure 86.

[82] Tsai, Y., Cohen, S., and R.M. Vogel, The impacts of water conservation strategies on water use, Journal of American Water Resources Association, submitted, November 2009. http://engineering.tufts.edu/cee/people/vogel/publications/impacts-water-conservation.pdf

[83] Black & Veatch. (2006) California Water Charge Survey.

The study also found that water rates across the state had increased by an average of 17% over the three-year period from 2003 to 2006. The study's authors did not attribute the rate increase to conservation efforts but rather to "increasing cost in construction materials, stringent water quality regulations and an aging infrastructure."

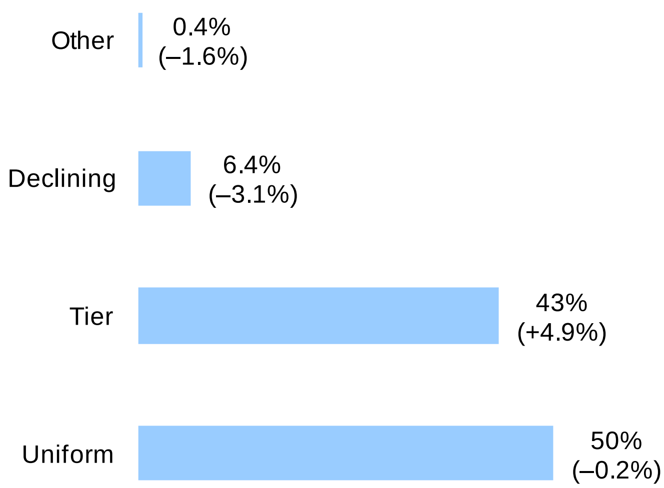


Figure 86: Water rate comparison for California water agencies in 2006 (percent change from 2001 shown in parentheses) based on 289 water suppliers surveyed by Black & Veatch, 2006

Research by the Public Policy Institute of California reveals that water consumption by households subject to a uniform volumetric rate is 13% lower than by those paying a flat rate. Switching to a tiered rate reduces consumption by another 10%.

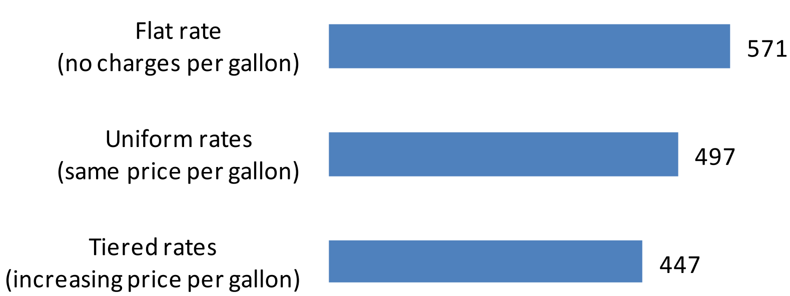


Figure 87: Household water consumption (gallons per day) under different rate structures in 2003 (adapted from Hanak, 2008)

An increasing body of evidence shows that some customers will respond to "community norms" more readily than price signals. These efforts may fall under the heading of "social marketing," the use of marketing techniques to achieve specific behavioral goals for a social good. Social marketing has been traditionally employed to promote health and safety, with notable campaigns against smoking, skin cancer, and drunk driving. Campaigns such as California's "Save Our Water" can be considered a form of social marketing. Overall, social marketing may use other forms of persuasion.

An article in On Tap magazine describes how the ubiquitous water conservation cards in hotel rooms were modified to test their effectiveness:

There was about a 37 percent compliance rate when the card carried a standard "help save the environment" message. Altering the card's message to say that 75 percent of the guests in the hotel reused their towels, compliance climbed to 44 percent. When upping the ante by indicating that 75 percent of the people who stay in this room re-used their towels, compliance again rose, to 49 percent.

A limited body of social science research supports the idea that if you tell people, "You are consuming more than is normal in our community," that they will respond by lowering their consumption. The idea goes thus: even residents for whom the price of water is inconsequential will react strongly to being considered in violation of normal behavior in their community. A study by the National Bureau of Economic Research in April 2010 indicates that these messages may backfire among certain segments of the population. In an electricity conservation program where customers were given feedback on their own and peers' electricity usage, they found that "a Democratic household that pays for electricity from renewable sources, that donates to environmental groups, and that lives in a liberal neighborhood reduces its consumption by three percent in response to this nudge. A Republican household that does not pay for electricity from renewable sources and that does not donate to environmental groups increases its consumption by one percent."

Frequency of Billing

Some have hypothesized that infrequent billing is an obstacle to conservation efforts. Customers who receive a water bill every three months or six months will be less likely to respond to price signals, or so the thinking goes. While we believe this reasoning to be sound, there has not been a great deal of study to back it up. In 2008, a group of researchers in Massachusetts studying conservation efforts in the water-stressed Ipswich River basin hypothesized that "more frequent water bills would enable customers to recognized sharp increases in water use at the beginning of the irrigation season and respond by voluntarily reducing outdoor uses".[84] They separately tracked a group of 500 customers who began receiving monthly bills, where others in the area received only two bills per year. The study failed to show that more frequent billing resulted in lower water use, perhaps because a drought resulted in regulatory water-use restrictions during

[84] Tsai, Y., Cohen, S., and R.M. Vogel, The impacts of water conservation strategies on water use, Journal of American Water Resources Association, submitted, November 2009. http://engineering.tufts.edu/cee/people/vogel/publications/impacts-water-conservation.pdf

the same summer. It is possible that other educational outreach efforts may be required in tandem with more frequent billing to trigger voluntary conservation.

Real-time feedback

Some utilities are beginning to upgrade water meters to so-called "smart meters," which are a part of what goes by the terms AMR for "automated meter reading" and AMI for "advanced metering infrastructure." These types of metering systems can automatically transmit usage data to the utility, saving the time and expense of deploying meter readers. Another advantage is providing customers greater knowledge and control of their water use.

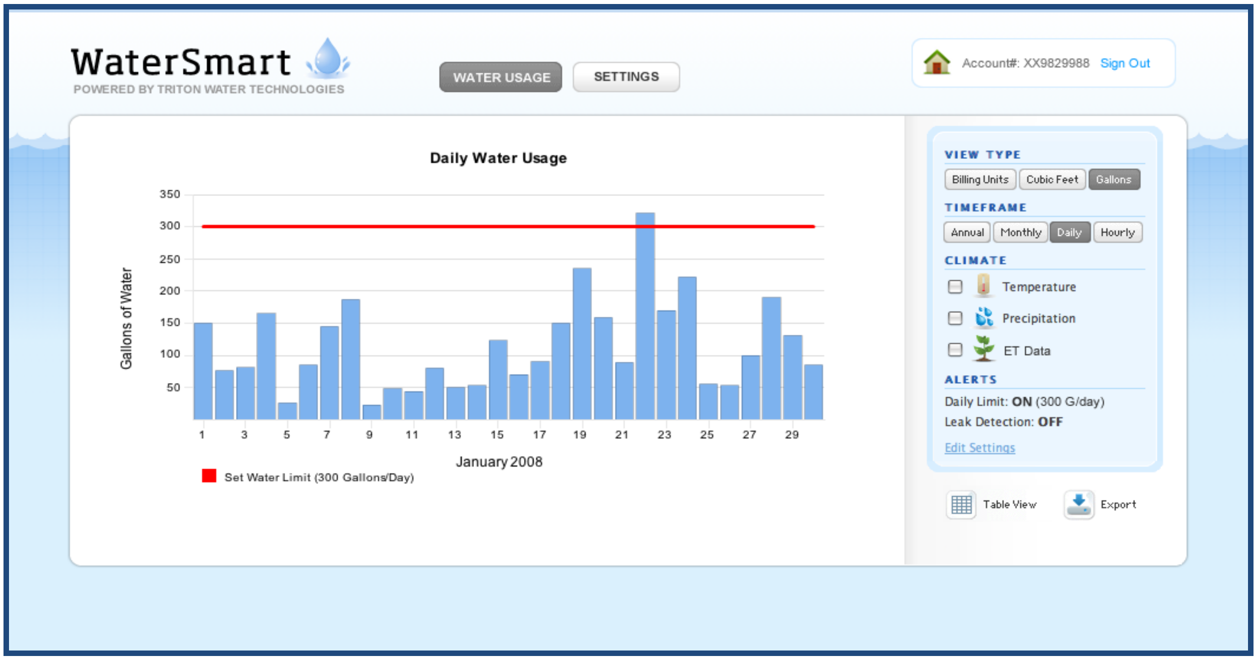


Figure 88: Prototype online user interface for a smart water meter. (Courtesy of the East Bay Municipal Utility District.)

California's experience with electric "smart meters" will be a useful guide as we move forward with smart water meters. A key element of at least one brand of AMI meters is their ability to provide real-time data on water use through a monitor installed in the home, normally on the refrigerator with a magnet. This system also has a "leak" detection alert.

A Silicon Valley entrepreneur has launched a company called Aguacue to promote a real-time flow measurement technology similar to the one used in this study. The company's product consists of a measurement device they call a "barnacle" that attaches to a water meter and online software that helps customers to monitor and better understand their water use patterns. Since there are no products available to measure end uses of water at home, this may help people to get a better idea of how much water they are using for different purposes.

A study conducted by California State University, San Marcos, of households in Carlsbad near San Diego, revealed that customers who received real-time feedback and information about how much water their neighbors were using cut their water use significantly:

"...those who got the feedback used 20 percent less water compared with the same period the year before. The control group reduced its water use by only 11 percent compared with the previous year. The results also suggest that people who were already interested in reducing their water use before the study began, conserved the most once they got the devices and software."[85]

[85] Moss, Andrea, "Study's results show feedback helps water customers conserve." North County Times, October 4, 2009.

CHAPTER 11 – CONCLUSIONS AND RECOMMENDATIONS

The research team offers the following conclusions and recommendations.

Conclusions

Since the signing of the original Memorandum of Understanding, the water agencies in the State of California have made a concerted effort to implement water conservation programs. These efforts have clearly paid off in the form of reduced water use. The data collected for this study has shown that indoor water uses have been reduced by 13% compared to the 1997 demand patterns. The penetration rates of toilets has increased to the point that 60% or more individual units are ULF or better models, and 30% of all homes appear to be fully equipped with toilets that are flushing at two gallons per flush or less. Similarly, 30% of homes now have clothes washers that use 30 gallons per load or less, and these volumes are falling continuously as newer, more efficient models come on the market. Showers appear to be fully saturated with 2.5 gpm devices. The areas where the most interesting challenges persist are in managing leaks (and continuous uses that appear to be leaks) and eliminating excess irrigation applications.

The fundamental conclusion of this report is that there has been significant progress made in single-family water conservation. Indoor use, normalized for a family of three has declined by 13% since the REUWS study was completed. The data show, however, that there is still a significant amount of remaining potential available. This is true for both indoor and outdoor uses. Tapping these potential savings could represent a major portion of the conservation savings goals for the state.

In the most conservative case, indoor savings are estimated at approximately 20 kgal per year per household and outdoor savings at 25 kgal per household per year. This equates to 45 kgal per household per year, or 1.2 MAF for the households in the state. These savings represent 27% of the baseline single-family demand. In the most aggressive conservation program investigated, the total household savings are 40 kgal per household indoors and 40 kgal per household outdoor. In this case the total savings from the single-family category would amount to 2.18 MAF per year, which equates to 50% of the baseline demand.

Savings associated with the conservative estimates could probably be achieved without making any major adjustments to lifestyles, but they would require some technological and programmatic advances. The primary indoor challenge is to develop ways to eliminate the long term “leakage” patterns seen in some homes. Our assumption is that most of these are true leaks or malfunctions of some sort. Some additional work needs to be done to determine if there are legitimate uses (such as water treatment, medical or other uses) that require a constant flow of water. If these uses are avoidable they would reduce overall indoor water use significantly. There are devices on the market for detecting and interrupting these types of flows that should be investigated. For outdoor uses the challenge is to find ways of eliminating over-irrigation for customers where it is occurring, without simultaneously causing irrigation use to rise for customers who are under-irrigating.

The more aggressive conservation scenarios would require increasingly lifestyle changes. Additional work needs to be done to determine how these scenarios might be accomplished technically, economically and from the perspective of customer acceptance. This report did not deal with cost-effectiveness analyses.

The savings projections made in this study are based on clearly defined assumptions and parameters. They are theoretically possible to achieve, and have been demonstrated to be achievable in pilot studies. Only future studies and efforts by agencies working with their customers in practical situations will demonstrate how achievable they may be and what techniques are most promising. It is clear, however, that the more valuable water becomes the more cost-effective the conservation efforts will prove.

These average savings estimates are not evenly distributed over the population. In most homes the savings potential is smaller than the average, but in a few homes it is far larger than the average. The skewed nature of both water use and potential savings is another key finding of this report, and has important implications on how to best achieve water savings in the most practical manner and in program design.

The water use in the study homes matched the water use of the populations from which they were drawn in both average and median annual water use. While geography was not one of the selection criteria, in cases where it was checked, as, for example in San Francisco and Los Angeles, the proportion of study homes in zip codes was found to match the percentage of single-family customers therein.

The research team believes that in general the study homes in this sample were fairly typical of single-family homes in the state. Exceptions to this were found in that the average occupancy of the study homes was slightly larger than the statewide population and the income of the study homes was higher than for the state as a whole. The savings estimates in the study have been corrected to account for these differences.

The basic sample of 60 homes per study site uniformly provided sufficient accuracy in results such that the 95% confidence intervals around the mean values of end uses was less than 10% of the mean, and provided sufficient accuracy to detect whether changes in the mean use were statistically significant and whether the percentage of homes complying with efficiency criteria were significant. The pooled sample group provided a more than adequate data set for performing the indoor and outdoor modeling on a range of explanatory variables.

The errors and inaccuracies in the data and analysis were unavoidable given the available data and the fact that water use was being disaggregated by examination of a flow trace from a single water meter. The errors in the data, however, were mainly random in nature, creating plusses and minuses in the results, and we do not believe significant systematic errors occurred.

The data collected for this study reveal a wide array of details about single-family household use in the study homes and by extension for California, and how these uses have changed over time. Some of the key findings are:

- The annual water use in the 1.3 million single-family customers from which the study sample was selected was 132 kgal (176 CCF) per year. This is equivalent to 361 gphd. Based on the average occupancy of 2.94 persons per home, this equates to an average per capita use of 123 gpcd for annual single-family use.
- Analysis of the data on an annual and seasonal basis indicates that that 47% of the single-family household use was for indoor uses and 53% was for outdoor uses. This equates to 62 kgal per year for indoor uses and 70 kgal per year for outdoor uses, averaged over all single-family households in the study.
- Based on data logged consumption, the total indoor water use for the study homes was 175 gphd, which was statistically similar to both the indoor use for the entire REUWS group, which was 177 gphd, and just the California homes from the REUWS, which was 186 gphd.
- The only continuous variable found to be significant with respect to predicting indoor water use was the number of residents living in the home. The age of the home, household income, number of bedrooms or bathrooms, and the size of the home were not significant predictors.
- Indoor water use is not linear with respect to the number of residents, but follows a power curve relationship, with the exponent of the equation less than 1.0.
- When corrected for the number of occupants by normalizing household demands for a family of three, the indoor water use from the current study group was 13% lower than for the REUWS group.
- As an efficiency benchmark, this study used the data from the EPA Retrofit Study, which showed the water use in homes that had been retrofit with high-efficiency fixtures and appliances. The average indoor use for the Retrofit group was 107 gphd, although for projections of savings, we only sought to obtain savings down to the level of 120 gphd in order to be conservative.
- There were eight indoor end uses identified, five of which are major end uses:
    - toilets (20%)
    - clothes washers (18%)
    - showers (19%)
    - faucets (18%)
    - leakage (16%)

  These account for 91% of indoor uses by volume. Baths, dishwashers and other uses make up the remaining 9%.
- Of the eight indoor end uses analyzed in this study:
    - Two categories, toilets and clothes washers, showed unambiguous reductions in use compared to the REUWS sample.
    - Four categories, showers, faucets, leaks and baths showed increased usage.
    - Two categories: other (miscellaneous) uses and dishwasher uses remained unchanged.

There were 122,869 toilet flushes recorded in the flow trace database.

- According the survey data 67% of all of the toilets in the study group are ULF or better devices. The data show that this rate of penetration still leaves the majority of homes flushing above the 2.0 gpf threshold, which is due to a combination of the mixtures of high volume and ULF toilets in the homes, and the fact that many ULF design toilets clearly flush at more than 1.6 gpf.
- In 1999, when the REUWS was published, only 22% of all toilet flushes were at 2.5 gpf or less. In this study 59% of all flushes are at 2.5 or less. That represents a major improvement and demonstrates the benefits of the conservation efforts that have been made.
- The household use for toilet flushing decreased from 45.2 gphd in the REUWS to 37.7 gphd in this study.
- The average toilet flush was 2.76 gallons per flush, which compares to an average flush volume of 3.48 gpf in the REUWS data. The median flush volume was 2.45 gal.
- It appears that 75% of all homes have at least one ULF or better toilet and 25% do not.
- Overall, 30% of the houses had average toilet flush volumes at 2.0 gpf or less. The remaining 70% of homes have a mixture of toilets and would benefit from additional toilets upgrades or repairs.
- The data show a clear improvement in the water use efficiency for toilet flushing, but they also show that there is still a considerable amount of remaining potential available.
- The toilet flush data in this study suggest that around 30% of the homes use ULF or better toilets exclusively, 25% of the houses do not use ULF or better toilets to a significant extent, and 60% of the toilets in the population are ULF or better devices.

There were 7,935 loads of clothes identified from the flow trace data during the logging study.

- The data show clear improvements in clothes washer efficiencies.
- In the REUWS group only 1% of the loads were washed at 30 gallons or less. The current data show that 29% of all homes use 30 gpl or less.
- The household water use for clothes washing dropped from 39.3 gphd in the REUWS to 33.2 gphd in this study.
- The average gallons per load was 36 gpl, which compared to 40.9 gpl in the REUWS study.
- If all clothes washers were high-efficiency devices, which in this study was set at only 30 gpl, the household use could be reduced to less than 20 gpd for clothes washing. Obviously, if lower wash volumes provided by the more recently produced machines with lower water factors this would drop further.

There were 17,334 showers recorded during the logging study

- The household use for showering increased from 31.9 to 35.3 gphd from the REUWS group to this.
- The average flow rate for the showers was 2.14 gpm, which is less than the 2.5 gpm standard.

- The average minutes per day for showers in the homes was 17.1 minutes. At 1.7 gpm this would require 29 gphd for showering, which gives an indication of the potential for conservation from shower heads when compared to the 35 gphd recorded use.
- The average volume of water used for showers in the homes was 18 gallons per shower. This is approximately the volume required to fill up a standard bath tub with someone sitting in the tub.

During the 9,021 days logged in the study period the average volume of events classified as leaks or leak-like events was 30.8 gphd.

- Only 7% of the homes showed volumes for leaks and leak-like events at 100 gpd or more, but these homes were responsible for 44% of the total volume assigned to leakage. A few of these homes may have devices such as reverse osmosis systems that are being run continuously, and this needs further study.
- The leaks in homes with 100 gpd or more of leakage tend to be of long duration, which would lend themselves to interruption by various devices currently on the market.
- The regression model of leakage showed a 12.8 gphd difference in leakage between manual and sprinkler irrigators. This implies that a significant percentage of the observed leakage was due to leaky irrigation systems.
- Elimination of these long and large volume “leak” events should be a high priority for making residential water use more efficient.
- If there are devices, such as whole house reverse osmosis systems, that create a continuous demand these should be documented, and criteria established for categorizing their use.

In terms of the number of events per day, faucets rank number one.

- There was an average of 57 faucet events per day in the homes, which lasted an average of 37 seconds at a flow rate of 1.1 gpm.
- Faucet use appears to be reduced by having a dishwasher.
- The presence of a disposal also was associated with *decreased* faucet use, which was not anticipated.
- Faucet use accounts for 33 gphd, up slightly from the REUWS sample of 26.8 gphd.
- A combination of reduced flow rates and devices to reduce flow durations are probably the best approach to reducing faucet use.

The data show an increase in the penetration rates of water efficient devices in the homes.

- In the REUWS group, only 1% of homes met high-efficiency clothes washer criteria and 10% met efficient toilet criteria.
- The current data show that 29% of the California homes meet clothes washer criteria and 30% meet toilet criteria. Nearly 80% of all homes meet shower criteria.
- It is safe to conclude that approximately 30% of all clothes washers in the single-family group are high-efficiency, since there is normally only one washer per home.
- Since there are multiple toilets per home the percentage of these devices that are efficient would be substantially greater than the 30% percent of homes meeting the efficiency criteria. The data suggest that a 30% household efficiency rate is equivalent to at least a 60% toilet fixture rate.

- The quantification of the precise percentage of ULF or better toilets in the study group is complicated by the fact that ULF toilets often flush at more than 1.6 gpf.

The average outdoor use for the group as a whole was 80.6 kgal (108 CCF) per year.

- Approximately 87% of the homes in the sample appeared to be irrigating, or using significant amounts of water for outdoor purposes.
- The split between indoor and outdoor use, while variable from site to site averaged approximately 40% indoor to 60% outdoor for the houses that were irrigating.
- Irrigation use is more heavily skewed by large users than is indoor use. The top half of the irrigators (those using more than the median use of 67 kgal per year) account for approximately 75% of the total outdoor use.
- The average irrigated area on these lots was 3,631 sf while the median area was 2,634 sf.
- There was a fairly good relationship between lot size and irrigated area for these homes which were included in the outdoor analysis.
- The actual application rate for the sites equaled 58.3 inches, compared to the average ET requirement of 42.1 inches, implying that the overall application ratio was 138% of the required irrigation amount, but this was not evenly distributed. Most homes are not over-irrigating.
- Roughly 50% of the irrigators, 42% of all homes are over-irrigating.
- The average volume of over-irrigation was 27.9 kgal per year for all irrigators.
- The average excess irrigation on just the lots that were over irrigating was 60 kgal.

Since most of the water agencies were following similar practices in their water conservation programs it was difficult to identify differences in water use patterns that could be attributed to individual conservation programs.

Most of the survey respondents had little knowledge about how much water they use or how much money they spend on water. Most respondents also did not consider price when deciding how much water to use either indoors or outdoors. Only 16% of respondents agreed with the statement “I conserve water mainly for environmental reasons,” while 80% of respondents disagreed with this statement. This may simply point out that there are more reasons for conserving water than just the environmental benefits.

The factors that were found to be significant in modeling indoor water use were:

- the number of residents in the home,
- whether there was a significant leak,
- whether youth were present, and
- the presence of high-efficiency fixtures and appliances.

The factors that affected outdoor use included:

- ET,
- irrigated area,
- household income,
- landscape coefficient,
- pool,

- sprinkler system,
- Whether the home is over-irrigating.

The water use models derived from the study data were used to project water use and water savings for the general population of single-family homes across the state. As shown in Table 105, these resulted in projected water savings ranging from a low of 1.21 MAF per year to a high of 2.18 MAF per year of water from the single-family customers. This equates to 27% to 50% of the baseline single-family demands.

The data lead to the conclusion that in order to achieve maximum savings the following things would need to be done:

- Reduce average indoor water use from 175 gphd to somewhere between 105 and 120 gphd.
    - Reduce average leakage to less than 10 gphd.
    - Install HET toilets over time.
    - Use high-efficiency clothes washers in all homes.
    - Use water smart shower-heads at 1.7 gpm, where compatible with existing plumbing so as to avoid scalding hazards due to incompatible flow rates.
    - Reduce faucet run times by >10%.
- Reduce outdoor use to an average of 46.7 kgal per year from current average of 86.1.
    - Reduce rate of over-irrigation from 50% to 25% of irrigators.
    - Reduce landscape ratio from 0.96 to 0.80.
    - Reduce average irrigated area by 20%, from 3802 sf to 3042 sf.

This study did not deal with the costs to achieve each of these savings or other issues surrounding economics or customer acceptance. The main goal of this study was to quantify the potential savings based on an analysis of the water use patterns circa 2007.

The conclusions on water savings included in this study are based on what has been shown to be technically feasible with respect to reducing both indoor and outdoor single-family residential water use. The study, however, did not deal with the cost-effectiveness of any individual conservation program aimed at making these reductions. The entire issue of cost-effectiveness and the economics of water conservation are topics for future studies.

Recommendations

One of the key recommendations from this study is that more attention needs to be given to the performance of customers measured by their water use, rather than the counting of activities such as rebates, audits and other conservation practices. Accounting for activities is a necessary part of evaluating a conservation program, but it is not sufficient technique on its own. The approach of tracking changes in measured water use is also reflected in the recent revisions to the BMP programs, which focus on reductions of water use by the customers. Such performance-tracking could be accomplished by the creation of annual reports that are based on normalized parameters (e.g. gphd annual and winter use, gallons per sf of irrigated area) which can be compared and tracked over time. The use of total gallons of water deliveries divided by estimated population is too imprecise a measure for good analysis.

The State of California has specified that per capita water use is to be used as the primary measure of water use efficiency. The 20% reduction in water use called for by the legislature means that the per capita water use is to decline by 20%. Barring a massive increase in the number of residents per household, a 20% reduction in single-family per capita water use is equivalent to a 20% reduction in household water use.

Since it is difficult to accurately determine the population served, and small errors in these estimates can change per capita use estimates significantly we recommend that the procedure used in this study be followed, where household use is first analyzed for scientifically selected samples of customers, and then normalized on the basis of population. This technique made it possible to identify a 13% reduction in indoor water use shown in Table 73, which was not evident in just the raw household use data.

The number or residents per household is a highly significant factor in predicting indoor water use. The fact that this relationship is non-linear has implications for the establishment of water budgets. Since the water use does not rise proportionally with the number of persons in the home then establishing water budgets in a linear manner will results in artificially large budgets for larger households and inadequate budgets for small households. Some agencies, such as IRWD, deal with this by providing a minimum budget based on a default value for their residences.

Use of household consumption as a primary performance indicator implies that when evaluating the effectiveness of a water conservation program, actual levels of household use by residential customers must be determined, and that a *reduction* of these numbers should be demonstrated based on a standard number of residents. This reduction in household (and per capita) use should be given more weight than the numerical BMP implementation numbers as is required by the revised MOU.

The notion that water savings due to specific BMPs such as toilet and clothes washer retrofits will automatically carry through as household water use savings is supported by this study. The study showed that there was a total reduction in toilet and clothes washer use of nearly 17 gphd, but that indoor water use did not decline by this amount. These data show that water savings from installation of higher efficiency devices tended to get obscured by increased water use elsewhere. This may be an example of the rebound effect (also known as the Jeavons paradox). This is an area that needs additional work, and should be pursued.

Water agencies should keep track of and report the number of single-family accounts, their average and median annual use, seasonal use and non-seasonal use. This will allow household water use to be continuously compared against known efficiency benchmarks to see how well the conservation targets are being met.

It would also be very useful if water agencies could expand their customer information systems to include the number of residents per home, irrigated areas, and other key parameters shown to be important for predicting water use in CHAPTER 9. This would make it possible to make adjustments to billing data information as needed to account for changes in these key parameters so that changes, say in the number of persons per house, do not mask or masquerade as changes in efficiency.

The data in this study indicate that logical goals for indoor water conservation should be to achieve consumption levels of 120 gallons or less per household per day for an average home. Outdoor goals should be based on halving the occurrence of excess irrigation, design of landscapes that have landscape factors no greater than 0.8, and where more aggressive measures are needed, a reduction in irrigated area. Each community will need to decide which of these it wishes to emphasize based on local policies.

This study did not deal with the costs of achieving specific efficiency levels, only the technical feasibility of doing so. Additional studies need to be done to quantify the types of measures that could lead to the target efficiency levels and the costs of their implementation. It is possible that many of these can be developed that involve little or no cost to the customer or agency. As the marginal cost of water increases, so will the value of conserved water and the cost-effectiveness of water conservation efforts.

The fact that, according to the survey, few customers are even aware of the cost of water or how much water they are using suggests that there may be benefits from using rate structures that send strong price signals for customers that fall into the excess use category. Communication of this over-use (and hopefully avoiding it) could be improved by implementing improved methods of providing real-time information to the customers on their water use.

Even though there are problems in doing so, it would make sense to express water bills in terms of gallons instead of billing units (hundreds of cubic feet). Customers find billing units or CCF to be highly confusing and do not know how to interpret the information. Given that water-using devices in the home are measured in gallons, the basic unit of measurement in the United States, is seems reasonable to bill in units of gallons where practical to do so.

We know of no better way of sending price signals than by developing water budgets linked to indoor and outdoor use. The results of this study show clearly that the water savings available in the population derives from a relatively small number of users. This is especially true for highly skewed categories such as leakage and excess irrigation use. It is very inefficient and difficult to devise programs to be applied to the general population in order to reach a small number of customers. Water budgets automatically identify the customers in need of attention, and provide incentives to the customers to address their water use problems in the form of price signals.

To the extent that water budgets or highly tiered water rates are used, it becomes more important to provide the customers with real-time information on their water use. Fortunately, there are an increasing number of ways to do this as more systems install AMR/AMI metering systems. Providing customers with targets from their water budget and feedback on their real-time consumption should be considered as two sides of the same coin.

Even though significant progress has been made in the areas of clothes washers and toilets, just less than one third of the potential has been achieved for these devices. So, continued efforts need to be made in upgrades to HET devices and repairs of malfunctioning units. That does not mean, however, that this necessarily involves rebates. Building codes, water budgets, retrofit on sale ordinances and other incentives may be a more cost-effective method of accomplishing upgrades and replacements of obsolete devices.

Additional research should be done on the degree to which toilets that are rated as ULF models are actually flushing at their design levels, and on ways to correct the problem of over-flushing through repairs and design changes. A significant number of toilets in this study that were flushing between 1.6 and 3.5 gpf may be malfunctioning ULF devices.

Leakage is a category that has increased as a dilemma. Leaking water does nothing useful, and should be eliminated to the degree practical. There are increasingly effective technical devices such as smart meters, and sensor linked valves that are capable of recognizing and interrupting leaks. The issue of what types of "uses" of water may be creating continuous demands that mimic leaks also needs further investigation. A water budget rate structure is effective at leak reduction by making the customer aware of their excess consumption through their bills.

Faucet use has also been shown to decrease with the presence of dishwashers and disposals, and with increased knowledge about water use and costs. One-touch faucets and hands-free faucet controllers could help shorten the duration of faucet events. Clearly these are expensive devices which would have to be introduced on a voluntary basis, subject to customer acceptance and after additional investigation.

The data showed a strong correlation between automatic sprinkler systems and leakage. One excellent way to reduce leakage in sprinkler systems is to equip these systems with master valves which de-pressurize the system when active irrigation is not taking place. When a zone valve is open this acts to reduce pressure in the system so most of the water goes to the actively irrigating zone. When all zone valves are closed, the pressure in the system rises, and any leaks are exposed to the full static pressure of the system. These leaks will continue indefinitely. A master valve, however, shuts off the water at the top end of the system, and will eliminate leakage. Master valves should be required on all automatic sprinkler system to the extent it is practical to do so.

Adopting more aggressive building codes provides an opportunity to ensure that new homes constructed in the state use the best available technologies described above. The most practical time to install water conserving devices is when the home is built. The CalGreen building codes were adopted in California in 2010.

The results of this study suggest some items that should be considered for new homes and retrofits of existing homes:

- WaterSense fixtures and appliances.
- High-efficiency clothes washers meeting Tier 2 or 3 standards of the Consortium for energy efficiency. (i.e. using 4.5 gal/cf or less of water per load)
- Hands free faucet controllers, or other devices for limiting run times, for kitchen and bathrooms should be investigated to determine their effectiveness in reducing faucet use and the acceptability to customers.
- Real time feedback on water use for the customer.

- Devices that sense and interrupt continuous uses of water due to leakage.
- Master valves on irrigation systems.
- Landscapes that have landscape factors or 0.8 or less.
- Appropriate limits on irrigated areas.
- Systems that discourage over-irrigation while allowing deficit irrigation to continue.
- Water budgets for all single-family residential customers based on WaterSense criteria for indoor uses and locally appropriate water conserving landscapes outdoors.

The State of California has adopted a goal of reducing per capita water use by 20% by the year 2020. Single-family residential water use can meet or beat this goal by reducing waste and leakage, use of high-efficiency fixtures and appliances, reducing the number of customers who are over-irrigating and by making modest modifications to landscape plant material and irrigated area.

Efforts at improving single-family residential water use efficiency should not be discontinued, but should be refocused on achieving measurable reductions in household water use towards the efficiency benchmarks described in this report. By doing so in an aggressive manner, savings from 1.2 to 2.2 million acre feet per year are achievable from existing single-family households.

The approach of sampling scientifically selected groups of customer and collecting highly detailed information on their water use and other characteristics could provide a way of understanding baseline use and changes in water use patterns in the state's single-family customers on a much timelier basis than reliance on reports prepared from billing data. Small changes in water use can be identified using the data logging technique, which are not apparent from billing data analysis. Just as the comparison between this study and the 1997 REUWS results provided information on changes in residential water use, future studies using similar techniques can provide additional information on how water demands in the single-family sector are changing during coming years.

APPENDICES

APPENDIX A: Utility Water Conservation Program Questionnaire

Agency Information		
Agency		
Address		
City		
State		
Zip		
Coordinator name		
Coordinator phone		
Coordinator email		
General		
Population served		
Number of Employees in Program		
Annual Budget		
O&M		
Capital		

Conservation Measure	Code	Comment
Residential Indoor		
Toilet replacements		
Showerhead replacement		
Faucet aerators		
Dishwashers		
Clothes Washers		
Audits		
Hot Water Recirc		
Other Res. Indoor?		
Residential Outdoor		
Controller replacement		
Rotating water days		
Xeriscape		
Irrigation audits		
Other Residential?		
CII Indoor		
CII Audits		
HET toilet program		
Cooling tower inspections		
Pre rinse spray nozzles		
Waterless urinals		
Bleed controllers		

Commercial Washers		
Other CII?		

Conservation Measure	Code	Comment
Irrigation Accounts		
Irrigation audits		
Xeriscape		
Rotating water days		
Workshops		
Budget rates for Irrigation		
Controller replacement		
System Measures		
“leak” detection		
System Audits		
Tiered Billing Systems		
Water Budgets		
Revolving loans		
Water Recycling		
Public Education programs		
Other Water Cons. Measures?		
New homeowner outreach		
Advertising		
Provision of ET data		
Meter feedback devices		
Conservation Plan		
Date of last update		
Copies currently available		
How is it evaluated		
Part of an IRP?		
Drought Plan?		
Date of last update		
Drought Taskforce in place?		
Linkage with Water Cons. Plan?		

Codes for type of installation program
0=None
1= Direct (or Yes)
2= Distribution
3= rebate or owner install
4= upgrade on sale

Have any of the following ordinances been adopted by –your agency or others over last five years that affect your customers?		
Anti-Water Waste		
Toilet standards		
Clothes washer standards		
Water reuse ordinances		
Drought restriction enabling		
Other building codes		
Others		

Water and Sewer Rate Information		
Are your SF customers metered?		
Units of billing		
Billing period (months)		
Current SF Rate Structure type:		<---Fill in code in column B
Block	$/unit	Number of units included or percent of budget
Fixed charge		
Block 1		
Block 2		
Block 3		
Block 4		
Block 5		
Date Water Rates took effect		
Percent increase from old rates		
Are sewer charges included?		
If so, what rate structure?		<---Fill in code in column B
Fixed charge		
Block 1		
Block 2		
Block 3		
Block 4		
Block 5		

Codes to describe Water Rate Structure
0= Flat rate (charges are not based on amount used)
1= Uniform Rate (all water [purchased at same rate)
2= Increasing block rate (rates jump at breakpoints)
3= Water Budget Rates (jump points based on budget)
4= Decreasing block rate
5= Other (please provide description)

APPENDIX B – UTILITY SPECIFIC INFORMATION

Redwood City

Redwood City Utility serves the residents of Redwood City and parts of unincorporated San Mateo County including Emerald Lake Hills, and Cañada College.[86] Redwood City is a deep water port, located in the Bay Area 25 miles south of San Francisco, and about 27 miles north of San Jose. The 14 square mile service area[87] varies in elevation from sea level along the port to over 800 feet in the Emerald Lake Hills area.

Demographics and Census Information[88]

Redwood City is a center of high-tech industry.[89] Of the population over the age of 25, 82.9% have a high school diploma or higher and 35.7% have a college degree or higher. The median annual household income is $66,748; only 3.9% of families live below the poverty level. The median home price of $517,800 is the highest of the sites in the study; 53% of the homes are owner occupied with a median monthly mortgage of $2,351. Table 106 gives some additional information about the homes in Redwood City.

Table 106: Demographic and household statistics for Redwood City

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$2,351	53%	2.61	2.8	1959	9.4
Rental	$1,014	47%	2.63	1.5	1965	4.1

Climate

Redwood City's slogan is "Climate Best By Government Test" based on climate surveys and meteorological data gathered by the United States and German governments starting before World War I.[90] At present there is no CIMIS weather station located near Redwood City or in San Mateo County, although one was in the process of being installed at the time of this report.

[86] http://www.redwoodcity.org/publicworks/water/uwmp2005/Chapter2.pdf. City of Redwood. 2005 Urban Water Management Plan. Chapter 2 – Service Area Characteristics. *2.2 Description of Service Area.* Accessed June 28, 2006.

[87] Redwood City's 2005 Urban Water Management Plan does not include a map of its service area.

[88] http://factfinder.census.gov/home/saff/main.html?_lang=en. U.S. Census Bureau. 2000 Census Data. Redwood City, California. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed June 13, 2006

[89] http://www.redwoodcity.org/about/index.html. Redwood City, California. *About the City.* Accessed June 28, 2006.

[90] http://www.rcpl.info/services/climatebesthistory.html. Redwood City Public Library. Local History. *Climate Best.* Accessed June 28, 2006.

Table 107 contains weather data compiled for Redwood City's Urban Water Management Plan from NOAA weather station No. 047339 for the period from January 1, 1931 to July 1, 2005. Average annual rainfall is approximately 20 inches; most rainfall occurs from November through April with less than a half inch falling during the summer months. Redwood City is located in Zone 8 on the CIMIS Reference ET Zone map which is described as Inland San Francisco Bay Area with some marine influence.

Table 107: NOAA weather data from Redwood City station No. 047339 for the period of record from 1/1/1931 – 7/1/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	58.0	61.8	65.5	69.9	74.7	79.6	82.4	82.0	80.8	74.6	65.3	58.7	71.2
Avg. Min. Temp. (F)	39.2	41.9	43.6	45.2	48.6	52.1	54.5	54.3	52.9	48.9	43.5	40.0	47.1
Avg. Monthly Precip. (in)	4.3	3.6	2.8	1.2	0.4	0.1	0.0	0.1	0.2	0.9	2.3	3.8	19.7
Avg. Monthly ETo (in)	1.7	2.1	3.4	4.6	6.0	6.6	7.0	6.3	5.0	3.5	2.1	1.5	49.8

Customer Base

In 2005, Redwood City water utility had 22,980 accounts. There were 18,519 single-family residential accounts (80.5%), 1,680 multi-family accounts (7.3%), 1,570 commercial accounts (6.8%), 523 irrigation accounts (2.2%) and 688 institutional accounts (3.0%).[91] Figure B1 shows the percentages of 2005 metered accounts by sector in Redwood City.

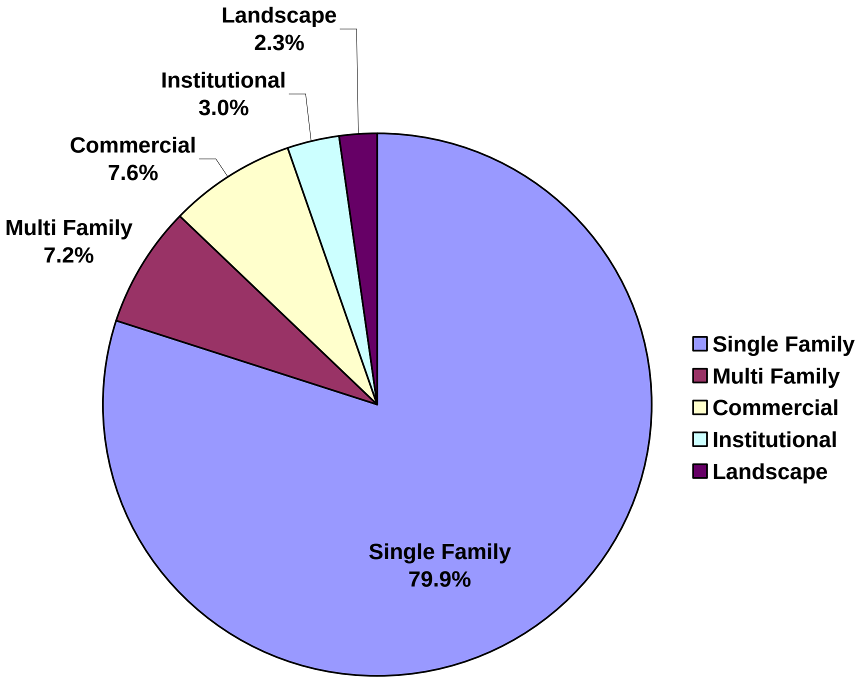


Figure 89: Percentage of 2005 metered accounts by sector in the Redwood City

Water Supply and Demand

One hundred percent of the potable water supply for Redwood City is currently derived from the Hetch Hetchy water system supplied by the Bay Area Water Supply and Conservation Agency. Redwood City's contracted supply is 12,243 AF/yr (3,988 MG/yr); however in recent years Redwood City has exceeded their contractual amount by 9%, or approximately 1,100 AF/yr.[92] Reducing the demands so that they fall within the city's allocation is one of the major goals of the water conservation program.

In 2004 the city began the design and construction of a recycled water project in an effort to reduce its dependence on Hetch Hetchy water. First Step is Redwood City's pilot project implemented to supply recycled water to 10 landscape irrigation customers resulting in a reduction of demand on the Hetch Hetchy water supply of 30 acre-feet annually. Redwood City

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[91] Customer account information provided by Manny Rosas, Water Resources Superintendent for Redwood City

[92] http://www.redwoodcity.org/publicworks/water/uwmp2005/Chapter3.pdf. City of Redwood. 2005 Urban Water Management Plan. Redwood City Water Supply Contract. Accessed June 29, 2006.

plans to expand its First Step customer base to include commercial and residential landscape irrigation, cooling, industrial uses, and new development.[93]

During 2005 the utility sold 5,186,660 CCF (3,880 MG) (11,911 AF) of water. Residential customers accounted for 69% of the total water demand (49% single-family and 19% multi-family), commercial customers used 18%, residential and commercial irrigation accounts used an additional 13%, and the remaining 1% was for other uses.[94] As much as 38% of the total annual billed consumption is related to outdoor use.[95]

Water Rates, Rate Structure, and Sewer Charges

Residential customers are billed bimonthly. In addition to the basic bi-monthly service charge of $24 there is a four-tiered inclining rate structure as shown in Table 108.Residential single-family customers pay $26.27 bimonthly for sewer.

Table 108: Redwood City 2006 water rate billing structure

Tier	CCF[96]	Kgal	Cost/unit
Tier 1 (lifeline rate)	Up to 10 units	0 – 7.48	$1.18
Tier 2	11 – 25 units	7.49 – 18.7	$2.16
Tier 3	26 – 50 units	18.8 – 37.4	$2.74
Tier 4	51 – 75 units	37.5 – 56.1	$3.53

The City is transitioning to a water budget rate structure as part of its water conservation and drought response programs. Water budgets are being developed that provide each customer with an adequate amount of water for reasonable use. Charges for water use within the budgets are strictly based on the cost of service, but use for water above the budgets is charged at much higher rates (both marginal costs for new firm supplies or penalty rates) with the intention of discouraging wasteful use. The water budgets are expected to provide the necessary incentives for customers to implement water conservation measures and to respond to droughts by reducing use relative to their budgets (not their previous year's water use).

Water Conservation Program

Redwood City has an active water conservation program that includes measures addressing all of the major water use categories. In 2006 the program had a staff of five, which included the program coordinator, a specialist, two technicians and a receptionist. The annual O&M budget was just under $1 million. Capital programs, mainly for the toilet replacement program, were initially funded with a $4.5 million fund, with an annual increment of $250,000 to fund ongoing capital expenses.

[93] http://www.redwoodcity.org/publicworks/water/uwmp2005/Chapter7.pdf. City of Redwood. 2005 Urban Water Management Plan. Water Recycling. Accessed June 29, 2006.

[94] Historical billing data provided by Manny Rosas, Water Resources Superintendent for Redwood City

[95] http://www.redwoodcity.org/publicworks/water/uwmp2005/Chapter5.pdf. City of Redwood. 2005 Urban Water Management Plan. Who Uses Redwood City's Water? Accessed June 29, 2006.

[96] One unit is 100 CCF or 748 gallons

The water conservation program is part of the larger urban water management plan submitted by Redwood City to the California Department of Water Resources. The goal of the plan is to reduce demand by 800 acre feet by the year 2009. This represents a 6.7% reduction, and will bring the City's use safely under its allocation of water from the regional raw water authority. Copies of the plan are available in print and online. The City evaluates its performance with respect to the plan by tracking monthly water use over time, and comparing actual use to the projections.

Residential Conservation Program

Redwood City is a signatory to the California Urban Water Conservation Council Memorandum of Understanding. Currently a major effort is underway to upgrade residential toilets in both single-family and multi-family accounts. Rather than relying on rebates or distribution, the City has adopted a direct install program where customers can select a toilet from several models, which is then installed by a licensed plumber at no cost to the customer. To be eligible, the replaced toilets must be 3.5 gpf or greater, and the replacement toilets must be on the list of qualifying high-efficiency toilets with a flush volume of 1.28 gallons or less. The City experimented with rebates and distribution programs, and installed 1,300 toilets through a distribution program in 2004-2005. They found that the rates at which customers were participating were too low to achieve the desired penetration rates, so, in order to accelerate the rate of toilet replacement the direct install approach was adopted in 2005. A total of 5,000 toilets were installed in 2005-2006. The goal is to have a total of 10,000 toilets replaced in the city, at which time they estimate that they should achieve their goal of 75% saturation.

The City provides residential audits and as part of the program all of the showerheads and aerators are upgraded free of charge. The audits also include "leak" detection analysis and a report for the customer. The City also has a program that distributes low-flow showerheads and efficient faucet door-to-door. The City offers irrigation audits for residential customers. These include an overall check of the irrigation system for leaks, poor coverage, damaged heads etc. While there is no zone-by-zone distribution uniformity analysis done, the customers are provided with a written schedule for their systems which tells them the appropriate durations for each zone of their systems on a monthly or seasonal basis.

Clothes washer replacements are encouraged through rebates. The size of the rebate increases with the efficiency of the machine being purchased. A rebate of $100 is provided for washers that meet Tier 3a specifications of the Council on Energy Efficiency. Rebates of $200 are offered for machines in the more efficient Tier 3b category. There are currently no rebates offered for dishwashers or hot water recirculation systems.

CII Conservation Programs

The program for commercial and industrial customers includes audits upon request of the customer. CII customers are eligible for the high-efficiency toilet replacement program. Laundries are offered a $450 rebate for installation of high-efficiency washing machines. In co-operation with the CUWCC a total of 237 pre-rinse spray nozzles have been installed in area restaurants and food preparation systems. The City will be starting a pilot program for inspection of cooling towers that will include the installation of conductivity controllers for managing blow-down more efficiently.

Large irrigation accounts are offered detailed irrigation audits. These include zone-by-zone determinations of application rates and distribution uniformities. Schedules are developed for the systems based on the data collected as part of the audits. Customers are provided with reports that include irrigation schedules and a water budget. Follow-up meetings are normally arranged in order to check on how well the report recommendations are being implemented and the water budgets are adhered to.

Education programs are offered by Redwood City for irrigation contactors. These programs are offered twice a year and are aimed at improving the knowledge of the contractors on how to manage irrigation systems in a way that minimizes water waste. An important topic that is covered in the education programs is how water budgets are developed, and the importance of staying within the budgets. The City is moving to a system where each customer will have a water budget, and the costs for water use over the budget limits will be much higher than costs for use within the budget. Water budgets, as described below, are planned to be a central element in the City's water demand management and drought response programs.

The City will begin a pilot program of replacing standard irrigation controllers with weather based controllers during 2007. So called "smart" controllers automatically adjust the irrigation in response to real time weather patterns. A properly installed and programmed smart controller is able to match actual irrigation applications to the theoretical requirement of the landscape. This offers good water conservation potential, especially in larger and commercial accounts where over-irrigation is more common.

System measures employed by the City for water management include annual calculation of percentage of unmetered water use, an increasing block rate billing system, and the gradual conversion to a full water budget rate structure for residential and irrigation accounts. Water budgets are calculated for indoor and outdoor uses. Indoor budgets are based on 70 gallons per person per day. Outdoor use is based on the irrigated areas of turf and non-turf plant types within the landscape and local ETo. Turf areas are allocated 100% of ETo and non-turf areas are allocated 80% of ETo. Surveys were sent out to all customers asking for information needed to develop the budgets. Customers have a strong incentive to return the surveys since the default budgets are intentionally set on the low end of the range.

Currently the water budgets are provided for educational purposes and are not linked to the billing system. It is the intention of the City, however, to link the rates to the budgets, starting with the irrigation accounts in 2008. Residential customers will have their budgets linked to their rates the next time drought conditions require use restrictions to be implemented. Water budgets are a key element of the City's drought plan. Having budgets for each customer based on their actual water requirement allows use restrictions to be set relative to the budget: a fair starting point for each customer. This is preferable to asking customers to reduce their use as a percentage of their previous year's water consumption since both conserving and wasteful customers would be expected to reduce their water use by the same percentage, and this may be much more difficult for a customer that is already using water sparingly than it is for a heavy user. In a water budget system customers who are using less than their budget will have this accounted for during droughts, and will have a smaller or perhaps no reduction in use required.

In summary, then, Redwood City has a fairly aggressive water conservation program in place. The most prominent feature of the plan at this time is the direct installation program for toilets. The City has been able to greatly increase the penetration rates of high-efficiency toilets using this approach. At the same time they have reported virtually no complaints or liability problems with the installations. Once the toilet replacements are completed they will be able to move on to other conservation opportunities. The other strong feature of the Redwood City water conservation program is their development of a water budget program that is closely linked to both long term conservation and drought response.

San Francisco Public Utilities Commission

The City of San Francisco is home to 776,773 people within a 49 square mile area[97]; New York City is the only U.S. city that is more densely populated. Fisherman's Wharf, the Golden Gate, Alcatraz Island, and Coit Tower are a just a few of many landmarks for which San Francisco is famous. Tourism is a leading industry in San Francisco with as many as 15 million tourists in 2004.[98] Water services are provided to the City by the San Francisco Public Utilities Commission.

Demographics and Census Information[99]

The residents of San Francisco have a high median age of 36.5 years, which is second only to Las Virgenes MWD in the study group. Of the population over the age of 25, 81.2% have a high school diploma or higher and 45.0% have a college degree or higher.

Although the median annual household income is $55,221, 11.3% of families live below the poverty level. The median home price is $396,400 and only 35% percent of the homes are owner occupied, with a median monthly mortgage of $1,886. The homes in San Francisco are the oldest of all the sites in the study; the median year the homes were built is 1940. Table 4 gives some additional information about the homes in San Francisco.

Table 109: Demographic and household statistics for the City of San Francisco[100]

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,886	35%	2.73	2.5	1940	2.5
Rental	$883	65%	2.06	1.3	1941	1.8

Climate[101]

Mark Twain is attributed with describing the weather in San Francisco with the famous quote "The coldest winter I ever saw was the summer I spent in San Francisco."[102] Whether or not Mark Twain actually said this, the quote aptly describes the weather in San Francisco. Located on the northern tip of a peninsula, San Francisco is cooled by the Pacific Ocean to the west and waters in the San Francisco Bay to the east. The moderating influence of the water means that there is very little variation between daytime and nighttime temperatures or between summertime

[97] San Francisco's 2005 Urban Water Management Plan does not contain a map of the service area.
[98] http://en.wikipedia.org/wiki/San_Francisco,_California. San Francisco, California. Accessed July 10, 2006.
[99] http://factfinder.census.gov/home/saff/main.html?_lang=en. U.S. Census Bureau. 2000 Census Data. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed July 11, 2006.
[100] Sites are being selected within the City of San Francisco therefore demographic information is given for San Francisco.
[101] http://www.wrh.noaa.gov/mtr/sfd_sjc_climate/sfd/SFD_CLIMATE3.php. NOAA Technical Memorandum NWR WS-126. Climate of San Francisco. Jan Null. January 1995. Accessed July 10, 2006.
[102] While this quote has often been attributed to Mark Twain, the attribution has not been verified.

and wintertime temperatures. Maximum daytime summer temperatures are between 60° and 70° F and nighttime summer minimums are between 50° and 55° F. Daytime winter temperatures are between 55° and 60° F and night time minimums average 45° to 50° F. San Francisco receives an average of 21.5 inches of rainfall annually, most of which falls from October through April. Fog is a common occurrence year round.

According to the CIMIS ETo Zone Map, San Francisco is located in Zones 1 and 2. Zone 1 is described as Coastal Plains Heavy Fog Belt and has the lowest ETo in all of California. Zone 2 is Coastal Mixed Fog Area with less fog and higher ETo than Zone 1. Currently there is no CIMIS station located on the San Francisco peninsula; weather data for San Francisco is from three WRCC sites: Richmond Station No. 047767, Mission Delores Station No. 047772, and WSO Airport Station No. 047769. The Richmond Station (Table 109) located on the northern end of the peninsula near the Pacific Coast, the Dolores Station is located on the bay side on the northern end of the peninsula and the WSO AP Station (Table 112) is centrally located on the peninsula at the airport.[103]

Table 110: NOAA weather data from San Francisco – Richmond Station No. 047767 for the period of record from 7/1/1948 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	57.4	59.5	60.0	60.7	61.0	62.4	63.1	64.2	66.0	65.8	62.2	57.7	61.7
Avg. Min. Temp. (F)	44.1	45.9	46.6	47.5	49.7	51.5	53.5	54.6	54.4	52.2	48.1	44.6	49.4
Avg. Monthly Precip. (in.)	4.2	3.5	2.8	1.2	0.5	0.2	0.0	0.1	0.2	1.0	2.7	3.7	20.0

[103] http://www.wrcc.dri.edu/summary/climsmsfo.html. Western Regional Climate Center. San Francisco Bay Area, California Climate Summaries. Accessed July 11, 2006.

Table 111: NOAA weather data from San Francisco – Dolores Station No. 047772 for the period of record from 1/1/1914 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	56.4	59.8	61.6	62.9	63.9	66.1	65.8	66.6	69.8	69.2	63.7	57.3	63.6
Avg. Min. Temp (F)	45.6	47.9	48.9	49.7	51.1	52.9	53.6	54.5	55.6	54.4	51.0	46.9	51.0
Avg Monthly Precip (in.)	4.4	3.8	2.8	1.4	0.6	0.2	0.0	0.1	0.2	1.0	2.6	4.1	21.1

Table 112: NOAA weather data from San Francisco – WSO AP No. 047769 for the period of record from 7/1/1948 to 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg.Max Temp(F)	55.7	59.1	61.3	63.9	66.8	70.0	71.4	72.1	73.4	70.2	62.9	56.4	65.3
Avg. Min.Temp. (F)	42.4	44.9	46.1	47.6	50.2	52.6	53.9	54.9	54.7	51.8	47.3	43.2	49.1
–Avg. Monthly Précis. (in.)	4.5	3.6	2.8	1.4	0.4	0.1	0.0	0.1	0.2	1.0	2.4	3.8	20.3

The data in the three tables demonstrate clearly that there is very little difference in the weather at the three sites. Average annual precipitation and average minimum temperatures are very nearly the same; however the coastal station of Richmond has lower average maximum temperatures than the other two stations due primarily to lower temperatures during the months from June through October.

Customer Base

During the study period there were a total of 171,366 customer accounts billed by the San Francisco Public Utilities Commission. Nearly 87% of the customer accounts were residential (64% single-family and 23% multi-family), 12% were commercial and the remaining 1% were irrigation, industrial, building and contractors, and municipal. Figure 90 is a graphical representation of the customer breakdown in the City of San Francisco by water use sector.

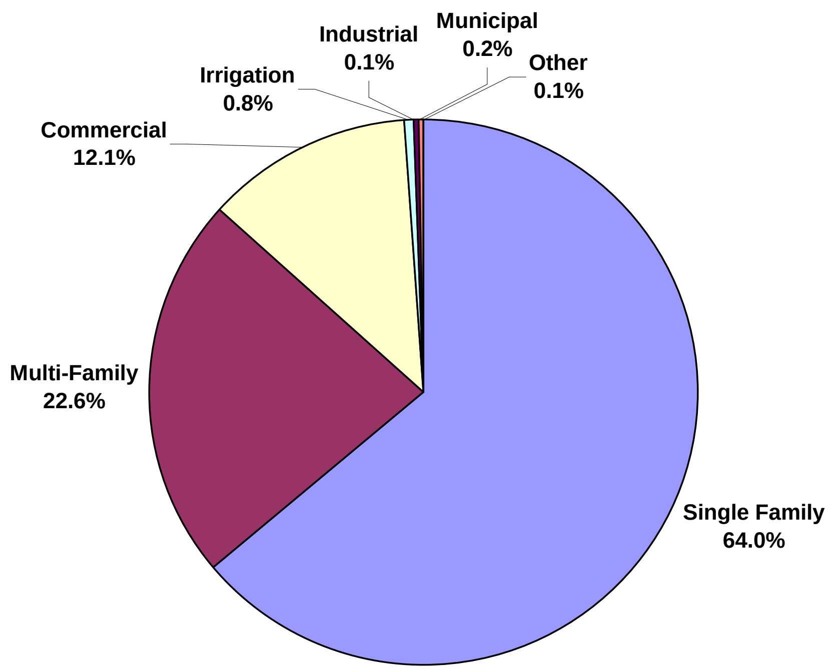

Figure 90: Percentage of 2005 metered accounts by sector in the City of San Francisco

Water Supply and Demand

Approximately 85% of San Francisco's water supply is from the Hetch Hetchy watershed located in Yosemite National Park. The Hetch Hetchy Reservoir, the largest reservoir in the SFPUC system, is filled as a result of spring runoff in the Tuolumne River. The remaining 15% is from the Alameda and Peninsula watersheds where surface water from rainfall and runoff, is captured and stored in six reservoirs mixed with groundwater from the Sunol Filter Galleries located near the Town of Sunol.[104]

[104] http://sfwater.org/msc_main.cfm/MC_ID/13/MSC_ID/165. San Francisco Public Utilities Commission. Water Sources & Water Supply Planning. *The Hetch Hetchy Source. The Alameda and Peninsula Sources.* Accessed July 13, 2006.

Table 113 is a breakdown of projected water deliveries supplied by San Francisco Public Utilities Commission (SPUC) to San Francisco customers for the years 2000 and 2005. Only 55% of the water is delivered to residential customers. "Due to the moderate climate and the high density housing in San Francisco, water use within the residential sector is used almost entirely indoors. For multi-family units, the average outdoor water use is considered negligible. For single-family residential units, the average outdoor water use is less than ten percent of their total use."[105] Unaccounted-for water losses, services, and retail trade make up an additional 36%.

Water deliveries are projected to decrease from 2000 to 2005 by 1.4%. Although the non-residential sector is predicted to increase slightly, the single-family and multi-family are predicted to decrease by 0.2% and 0.9% respectively, a decrease of 439 million gallons annually.

Table 113: Annual in-city deliveries by sector to SFPUC customers for 2000 and 2005[106]

Sector	Deliveries 2000 (MG)	% of Total Deliveries	Deliveries 2005 (MG)	% of Total Deliveries
Single Family1	6,8622	22.4	6,716	22.2
Multi-Family1	10,512	34.3	10,111	33.4
Non-Residential 1,5	10,184	33.2	10,658	35.2
Other (B&C and D&S) 4	883	0.3	88	0.3
Unaccounted for Water (losses)	3,030	9.9	2,665	8.8
Total	30,676	100	30,237	100

1 Includes the impact of water savings due to plumbing code changes
2 Current water use based on FY 1999-00 billing records
3 Current water use based on FY 1996-97 – FY 2000-01 billing records
4 Builders & Contractors and Docks and Shipping
5 Includes agriculture, mining, construction, manufacturing, transportation, wholesale trade, retail trade, F.I.R.E. (Finance, Insurance, and Real Estate), services, and government

[105] http://sfwater.org/mto_main.cfm/MC_ID/13/MSC_ID/165/MTO_ID/286. 2005 Urban Water Management Plan for the City and County of San Francisco. *Retail Residential Water Use.* Accessed July 13, 2006.
[106] http://sfwater.org/mto_main.cfm/MC_ID/13/MSC_ID/165/MTO_ID/286. 2005 Urban Water Management Plan for the City and County of San Francisco. *Projected Retail Demands*. Accessed July 13, 2006.

Water Rates, Rate Structure, and Sewer Charges[107]

Residential customers in San Francisco are billed on a bi-monthly basis. In 2005, the monthly base charge for water was $4.60 and then customers with a conservation affidavit were billed at a uniform rate of $1.71 per CCF ($2.29/kgal). Description of the affidavit is found in Chapter 12A of the San Francisco Housing Code - Residential Water Conservation. The uniform rate for customers without a conservation affidavit is $2.57 per ccf ($3.43/kgal).

Residential customers are charged for wastewater based on a tiered system. The first tier is $2.54 per Discharge Unit for the first three discharge units, $6.36/Discharge Unit for the next two discharge units, $7.27/Discharge Unit for each additional discharge unit. A discharge unit is based on the customer's metered water use multiplied by a flow factor which represents the quantity of water use that is returned to the system.

Water Conservation Programs[108]

SFPUC was the recipient of the "Best Conservation Program-Large Utility" awarded by the California Municipal Utilities Association in March 2000. As a result of several droughts and ongoing conservation programs, residential use is estimated to be 62 gpcd. The conservation program is run by five full-time employees who train and are assisted by as many as five high school interns throughout the year. As one of the original signatories of the 1991 Memorandum of Understanding Regarding Urban Water Conservation in California (MOU), SFPUC has incorporated the Best Management Practices (BMPs), outlined in the MOU, in their conservation program.

Residential Conservation Measures

The SFPUC conservation department provides its customers with a number of services aimed at reducing consumption. Free water audits, "leak" identification, rebates, and bill reduction are some of the tools utilized.

Since the 1990s, the SFPUC has provided programs to incentivize the replacement of older, high flush volume toilets with more efficient models – toilets with a flush volume of 1.6 gallons until 2008 and since then high-efficiency toilets (HETs) with a flush volume of 1.28 or lower. As of 2011, the SFPUC provides rebates of $125 for the replacement of tank style toilets that flush at 3.5 or higher with HETs. Other rebates amounts are provided for replacement of commercial toilets and urinals, and all rebate amounts are subject to yearly adjustment. In 2009, the SFPUC launched a HET direct install program for its low-income customers.

In 2009, San Francisco updated its indoor conservation ordinances to require all existing commercial properties to undergo leak detection and replace inefficient toilets, urinals, showerheads and faucets with efficient models by 2017, and that all residential properties meet

[107] http://sfwater.org/detail.cfm/MC_ID/14/MSC_ID/117/C_ID/2447/Keyword/water%20rates. SFPUC Proposed Rates Schedules for Water and Sewer Service. July 1, 2005. *Schedule W-21 and Schedule*. Accessed July 13, 2006.

[108] http://sfwater.org/detail.cfm/MC_ID/13/MSC_ID/165/MTO_ID/286/C_ID/2776. 2005 Urban Water Management Plan for the City and County of San Francisco. Water Resources Planning. Published: 12/23/2005. Updated: 04/27/2009. Accessed December 18, 2009.

the same requirements upon resale. In 2011 San Francisco updated its local building code to reflect state CalGreen requirements, among other things, and requires the installation of HETs and 0.5 gpf urinals.

The SFPUC began a clothes washer rebate program in 1999. It currently participates in a regional residential clothes washer rebate program, providing combined energy/water rebates of $125 and runs an in-house commercial washer rebate program, providing current rebates of up to $200.

To satisfy BMP 6, High Efficiency Washing Machine Rebate, San Francisco began a rebate program for high-efficiency clothes washers in 1999. Customers were provided rebates of $75; current rebates range from $100 to $200 per clothes washer and are based on the efficiency and size of the clothes washer. The utility has provided over 3,000 rebates for high-efficiency clothes washers.

Commercial, Industrial and Institutional Conservation Measures

As with its residential customers, SFPUC also provides auditing services for its CII customers. The goal of these audits it to reduce water wasted from cooling towers, large landscapes, and leakage while making customers aware of the potential savings available to them through rebates and lower water bills. The city has had a program of replacing inefficient showerheads and toilets in all of its municipal buildings and since 1999 has replaced 9,900 toilets and 1,000 showerheads. Before receiving a certificate of occupancy, all new commercial and industrial buildings must be inspected and the installation of water-efficient fixtures and other devices must be verified.

Additional Conservation Measures

Water pricing and the pricing structure were limited by Proposition H, which expired in 2006. As a way to encourage conservation, SFPUC implemented a three-tiered rate structure for wastewater and is in the process of developing a tiered rate structure for water.

Although only three percent of the city's water is used for irrigation SFPUC's landscape conservation program targets customers with landscaped areas of 1,000 sf or more. Water intensive landscape (such as turf) is restricted to 25% of the total landscaped area on all new landscapes and renovated landscapes involving between 1,000 and 2,500 sf of area. All large, irrigated areas must be separately metered and irrigation is limited to times between 5 p.m. and 10 a.m. Landscaping of slopes and narrow strips is limited; soil analysis is required and deficiencies must be rectified.

The city has an extensive public education program that includes many "how-to" brochures, some of which are printed in multiple languages. School presentations and calendar contests help teachers, children, and their families learn about conservation, the water supply, and even possible careers in the Water Department.

In addition to toilet rebates the SFPUC provides rebates for both commercial and residential horizontal axis clothes washers. Four hundred rebates were provided for clothes washers in 1999 alone. Over 2,000 pre-rinse spray valves have been distributed through a free replacement program.

SFPUC continues to seek opportunities to reduce water consumption and evaluate the effectiveness as well as the cost of implementing new programs. Although demand in the residential sector is expected to remain stable in the future, projected growth in the non-residential sector requires continued attention to reducing demand and providing adequate supply for its customers.

City of San Diego[109]

San Diego is California's second largest city and home to 1,305,736 people. The City's 330 square mile service area is located in the south central portion of San Diego County.[110]

San Diego is known for its good weather year round, miles of beaches and tourist attractions such as Sea World, Legoland, and San Diego Wild Animal Park.[111] In 2005, there were 10,000,000 visitors from June through August, alone.[112] In addition, it is home to the University of California, San Diego, as well as numerous high-tech and biotech companies.[113]

Demographics and Census Information

2000 U.S. Census data reveals that the median age of the residents of San Diego is 32.5 years. Eighty-three percent of those over the age of 25 have a high school diploma or higher and 35% have a college degree or higher. The median home price is $233,100 and the median household income is $45,733. Nine percent of families live below poverty level. The median monthly mortgage is $1,543 and 51.3% of the homes are owner occupied. Table 114 gives some additional information about the homes in San Diego.

Table 114: Demographic and household statistics for San Diego

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,546	51.3%	2.71	2.9	1975	6.7
Rental	$714	48.7%	2.52	1.6	1975	4.5

Climate

San Diego has mild weather year-round with cool summers and warm winters due to the modifying influence of the Pacific Ocean. The hottest temperatures are most likely to occur in September and October when hot dry winds, known as the Santa Ana winds, blow in off the desert from the east. Typically, San Diego receives only 10 inches of precipitation annually, most of which occurs between November and April.[114] However, it is clear from, Figure 91, a 35-year rainfall graph, located at Lindbergh Field in San Diego, that there can be tremendous variation in annual precipitation ranging from a low of three inches to a high of 22 inches.

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[109] http://www.sdcwa.org/manage/pdf/2005UWMP/Sections_1-9.pdf

[110] The 2005 Urban Water Management Plan for the City of San Diego does not have a map of its service area.

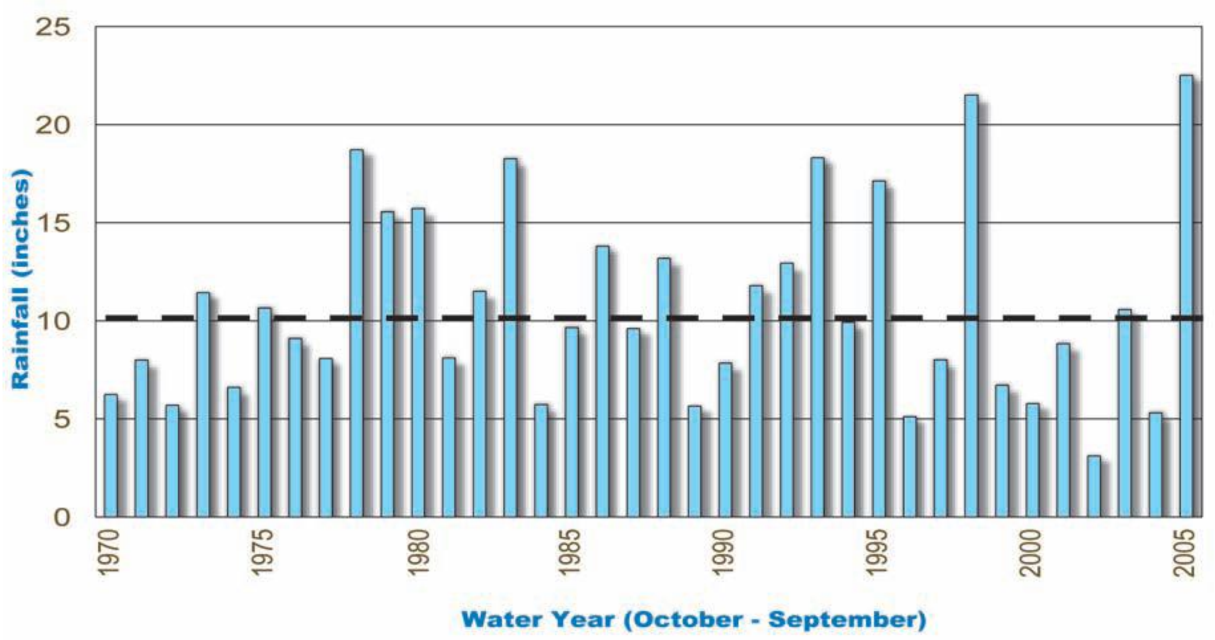
[111] http://www.sandiego.org/nav/Visitors/VisitorInformation/AboutSanDiego. Convention and Visitor's Bureau. Visitor Information. *About San Diego, Weather.* Accessed June 29, 2006.

[112] http://www.sandiegomag.com/issues/july06/business0706.asp. San Diego Magazine. Business. *Keep 'Em Coming Back.* Accessed July 6, 2006.

[113] http://en.wikipedia.org/wiki/San_Diego,_California. San Diego, California. Accessed June 29, 2006.

[114] http://www.sandiego.gov/water/pdf/uwmpfinal.pdf. City of San Diego. 2005 Urban Water Management Plan. City of San Diego Water Department. *Climate Data.* Accessed July 6, 2006

Figure 91: City of San Diego Annual Rainfall measured at Lindbergh Field Station[115]



There is also considerable variability in the climate from the coastal regions to the inland regions of the city. The areas located along the coast are subject to fog in the morning and daily temperatures rarely fluctuate more than 15 degrees; inland neighborhoods have more sunshine, warmer temperatures and can experience daily temperatures fluctuations of 30 degrees.[116] According to the CIMIS Reference Evapotranspiration Zones map there are three ETo zones in San Diego; Zone 1 is described as Coastal Plains Heavy Fog Belt, Zone 4 is South Coast Inland Plains, and Zone 6 along the eastern edge of San Diego is Upland Central Coast and Los Angeles Basin.

Table 115 shows some of the variation in the weather as a result of the location of the weather station. Table 115 contains CIMIS data for South Coast Valleys Station #150, located in Miramar, which is in northern San Diego and inland approximately six miles. Although average annual rainfall is nearly identical to that of South Coast Valley, San Diego II, Station #184, shown in

Table 117, the average annual ETo at the Miramar Station is nearly two inches higher. The Miramar and San Diego II stations are located at nearly the same longitude; however the Miramar Station is located approximately 11 miles north of the San Diego station (based on latitude and longitude measurements of the station locations from CIMIS). South Coast Valley

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115 http://www.sandiego.gov/water/pdf/uwmpfinal.pdf. City of San Diego. 2005 Urban Water Management Plan. City of San Diego Water Department. *Figure 1-1 (Lindbergh Field Station).* Accessed July 3, 2006.

116 http://www.wrh.noaa.gov/sgx/climate/san-san.htm . National Weather Service Forecast Office. Unique Local Climate Data. San Diego (Lingbergh Field). Climate Summaries for Area Cities. *ISMCS Station Climatic Narrative for San Diego.* Accessed June 30, 2006.

Station #173 is a coastal station located approximately six miles east of Stations #150 and #184, just north of Miramar Station #150, in Torrey Pines, near the Pacific Ocean. The ocean influence at the Torrey Pines station (located in ETo Zone 1) is apparent with an eight-inch annual decrease in ETo compared to inland stations Miramar and San Diego, which is most dramatic July through September. It is important to note that there has not been long-term monitoring at many of the CIMIS stations; the period of record for these three stations is less than six years and in fact Station #184 has only been active since April 2002.

Table 115: South Coast Valleys – Miramar #150 Lat 32°53’09” Long 117°08’31” – period of record April 1999 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	66.3	64.8	65.9	66.3	70.7	72.2	77.2	78.4	77.5	73.8	69.3	66.6	70.7
Avg. Max. Temp. 2005 (F)	65.9	63.7	65.2	67.9	71.5	70.7	78.0	78.3	76.6	72.9	72.8	66.7	70.9
Avg. Min. Temp. (F)	43.9	44.8	48.1	47.7	53.2	58.1	61.6	62.7	60.4	55.5	47.7	42.7	52.2
Avg. Min. Temp. 2005 (F)	47.4	49.2	51.2	47.6	54.7	58.5	63.1	63.5	58.5	54.8	48.5	45.1	53.5
Avg. Monthly Precip. (in)	1.9	3.4	1.2	0.7	0.2	0.0	0.2	0.0	0.1	1.0	0.6	1.1	10.4
Monthly Precip. 2005 (in)	6.4	5.9	2.0	-----	0.2	0.0	0.3	0.0	0.2	0.0	0.2	0.4	15.6
Avg. Monthly ETo (in)	2.2	2.4	3.7	4.0	5.2	5.2	6.1	5.8	4.5	3.3	2.4	2.1	46.9
Monthly ETo 2005 (in)	1.9	1.9	3.6	4.7	5.6	5.0	6.3	5.7	4.6	3.3	2.6	1.9	47.0

Table 116: South Coast Valleys – Torrey Pines #173 Lat 32°54'04" Long 117°15'00" – period of record November 2000 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	61.8	60.9	60.0	58.7	60.6	64.9	68.1	69.7	70.1	66.1	63.9	61.7	63.9
Avg. Max. Temp. 2005 (F)	61.8	61.6	61.7	62.2	65.2	65.6	68.0	70.1	69.9	66.9	66.4	61.6	65.1
Avg. Min. Temp. (F)	48.3	48.0	48.1	47.9	51.1	58.0	61.0	62.0	60.8	56.5	51.8	48.2	53.5
Avg. Min. Temp. 2005 (F)	50.6	51.1	52.4	50.4	56.9	58.4	61.7	62.8	59.6	56.8	54.6	49.5	55.4
Ave. Monthly Precip. (in)	1.3	2.7	1.2	0.9	0.4	0.3	0.2	0.2	0.1	1.2	0.5	1.0	10.1
Monthly Precip. 2005 (in)	4.5	6.1	2.1	0.9	0.4	0.4	0.4	0.3	0.3	0.9	0.3	0.5	17.1
Avg. Monthly ETo (in)	2.1	2.3	3.2	4.0	3.9	4.0	4.5	4.5	3.6	2.5	1.9	1.9	38.3
Monthly ETo 2005 (in)	1.8	2.0	3.2	4.3	4.8	4.2	4.5	4.2	4.0	2.9	2.4	1.8	39.9

Table 117: South Coast Valleys – San Diego II #184 Lat 32°43'47" Long 117°08'22" – period of record March 2002 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	67.5	65.0	65.5	66.3	68.2	68.7	75.0	76.2	76.9	71.7	69.9	65.7	69.7
Avg. Max. Temp. 2005 (F)	65.9	64.5	65.3	67.2	69.6	69.6	75.0	77.2	76.2	72.2	71.9	67.1	70.1
Avg. Min. Temp. (F)	47.5	47.6	50.5	51.8	56.0	58.7	62.6	63.4	62.1	57.9	50.8	47.4	54.7
Avg. Min. Temp. 2005 (F)	49.1	49.6	52.2	51.4	56.8	59.1	62.7	63.4	59.4	56.6	52.0	49.2	55.1
Avg. Monthly Precip. (in)	0.9	3.5	1.5	2.3	0.3	0.1	0.1	0.1	0.1	1.4	1.0	1.4	12.6
Monthly Precip. 2005 (in)	2.6	3.3	2.9	0.7	0.1	0.1	0.1	0.0	0.1	0.4	0.2	0.3	10.7
Avg. Monthly ETo (in)	2.4	2.5	3.7	4.0	5.0	4.6	5.6	5.5	4.5	2.9	2.5	2.0	44.9
Monthly ETo 2005 (in)	2.0	2.1	3.6	4.8	5.4	4.8	5.9	5.5	4.6	3.1	2.7	2.1	46.6

Customer Base

Table 118 shows that as of 2005, there were a total of 270,526 customer accounts served by San Diego Water Department. These consisted of 245,995 residential connections (217,893 single-family and 28,102 multi-family), 15,300 commercial, 247 industrial, 1,845 Institutional 1 (military, university, and school), 1,822 Institutional 2 (city, public, and government), 5,524 landscape, and 1,383 other (outside city). Figure 92 shows the percentage of 2005 metered accounts by sector in the City of San Diego.

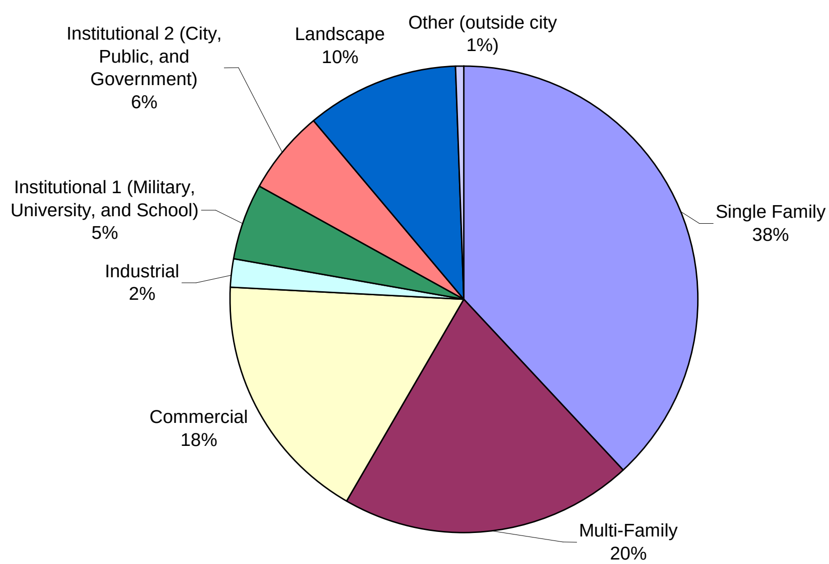

Figure 92: Percentage of 2005 metered accounts by sector in the City of San Diego

Water Supply and Demand

The City of San Diego purchases between 75 and 90 percent of its water from the San Diego County Water Authority (SDCWA). The remaining 10 to 25 percent is collected as runoff in various city reservoirs. SDCWA purchases Colorado River water from Lake Havasu from Metropolitan Water District of Southern California. This water is transferred via aqueduct to a facility in Riverside County where it is blended with water from the State Water Project and then transferred, stored, and treated at various facilities throughout the city. During the last 20 years the amount of water the City of San Diego has purchased annually has ranged from 100,000 AF to 228,000 AF.[117]

Table 118 shows the number of 2000 and 2005 metered water accounts and the amount of water delivered in each sector annually in both acre-feet and gallons. In 2005, the City of San Diego supplied 200,460 acre-feet (65,320 MG) of water to 270,526 accounts. Residential customers accounted for 58% of the water deliveries (38% single-family and 20% multi-family),

[117] http://www.sandiego.gov/water/pdf/uwmpfinal.pdf. City of San Diego. 2005 Urban Water Management Plan. City of San Diego Water Department. Water Sources. *Imported Supplies.* Accessed July 7, 2006.

commercial customers received 18%, landscape customers used 10% and industrial, institutional and other accounted for the remaining 14%.

It is interesting to note that while the number of accounts increased in five of the sectors from 2000 to 2005 by 10,860 (4.2%), water deliveries decreased by 4,101 MG (5.9%) in those same sectors during that same time period. The most significant change was in the Institutional 1 sector where the number of accounts increased 33% while water use decreased by 25%. The number of landscape accounts increased by 15% during this time period and yet water use supplied for landscape accounts decreased by 2%.

Table 118: Annual water delivery to accounts by sector for 2000 and 2005 in the City of San Diego[118]

Sector	Number of Connections 2000	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries	Number of Connections 2005	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single Family	208,377	77,801	25,351	36.5	217,893	76,529	24,937	38.2
Multi Family	27,832	41,729	13,597	19.6	28,102	40,271	13,121	20.1
Commercial	15,381	38,694	12,608	18.2	15,300	35,277	11,495	17.6
Industrial	356	4,350	1,417	2.04	247	3,617	1,179	1.8
Institutional 1*	1,392	14,487	4,721	6.80	1,845	10,905	3,553	5.4
Institutional 2**	1,715	13,528	4,408	6.34	1,822	11,596	3,779	5.8
Landscape	4,550	21,334	6,952	10.0	5,254	20,882	6,804	10.4
Other (outside city)	57	1,124	366	0.53	57	1,383	451	0.69
Total	259,666	213,047	69,420	100%	270,526	200,460	65,319	100%

*Military, University, and School
** City, Public, and Government

Water Rates, Rate Structure, and Sewer Charges

The City of San Diego bills its residential water and sewer customers monthly. The base rate for water is $15.87 per month; in addition there is a three-tiered rate structure. Customers pay $1.73 per CCF [119] for use between 0 and 7 CCF, $2.16 per CCF for use between 7 and 14 CCF, and $2.37 per CCF for use over 14 CCF.[120] The monthly base rate for sewer is $11.32. In addition customers pay $3.218 per CCF based on average winter consumption up to a maximum of 14 CCF.[121]

[118] http://www.sandiego.gov/water/pdf/uwmpfinal.pdf. . City of San Diego. 2005 Urban Water Management Plan. City of San Diego Water Department. Water Use By Customer-Type. *Table 2-5 Past, Current, and Projected Water Deliveries.* Accessed July 6, 2006.
[119] One CCF is equivalent to 748 gallons
[120] http://www.sandiego.gov/water/rates/rates.shtml. The City of San Diego. Water and Sewer Bill/Rates. *Single-FamilyDomestic Customers.* Accessed July 7, 2006.
[121] http://www.sandiego.gov/mwwd/residential/rates.shtml. Metropolitan Wastewater. Residential Concerns. *Sewer Rates.* Accessed July 7, 2006.

Water Conservation Programs[122]

The City of San Diego's Water Conservation Program has developed and implemented innovative approaches to water conservation that have resulted in savings of 30,000 acre-feet of potable water annually since its inception in 1985. The City has created policies, ordinances, education campaigns and other tools to reduce its use of potable water. The city's Water Department recently received Community Service/Resource Efficiency Award from the California Municipal Utilities Association for its conservation efforts in public outreach and education. They received another award from the EPA for developing the Landscape Watering Calculator, a tool that can be used by their customers to determine appropriate irrigation durations and amounts. The tool reduces over-watering of landscapes by providing weekly irrigation schedules based on the weather data, plants and soil in San Diego. Other innovative programs include Ms. Frizzle's™ World of Water, an educational program for young children and the Rinse n' Save Program for restaurants whereby nearly 1,400 water saving pre-rinse spray valves were installed in restaurants around the city.

The city continues to find innovative methods to reduce water use with a goal of reducing use by 60,000 AF by 2030. These include satellite imagery for developing water budgets for existing landscape, landscape requirements for new development including water budgets and irrigation schedules developed with the city's Watering Calculator and incentives for the installation of "smart" irrigation controllers.

Residential Conservation Programs

The City of San Diego's free Residential Water Survey Program is available for its entire single-family and small, multi-family customer base. Customers can schedule an appointment for a survey with a water conservation specialist. These surveys provide customers with information that will help them to reduce their household and irrigation water use. Where needed, customers will be provided with free faucet aerators, showerheads, hose nozzles, a drip gauge as well as literature and information that will reduce water use and water waste. Beginning in September 2009, residents of the City of San Diego can apply for rebates through the "Be WaterWise" program (http://www.bewaterwise.com/rebates01.html). Rebates are provided on a first-come first-served basis for high-efficiency clothes washers, high-efficiency toilets, weather-based irrigation controllers, rotating nozzles, and synthetic turf.

Commercial Conservation Programs

Commercial customers are eligible to receive rebates through the Save Water Save a Buck program. Funding for this program is used to provide conservation products such as cooling tower pH and conductivity controllers, central and weather-based irrigation controllers, water brooms, rotary nozzles, high-efficiency toilets and urinals, water brooms and air-cooled icemakers. The estimated annual savings from this program is 3,400 acre-feet of water.

Builders are also provided with financial incentives to install water-conserving devices as part of the California Friendly® Home Program (http://www.bewaterwise.com/CAF_brochure.pdf).

[122] http://www.sandiego.gov/water/pdf/uwmpfinal.pdf. The 2005 City of San Diego Urban Water Management Plan. 2005. Accessed December 18, 2009.

High-efficiency clothes washers and toilets, rotating nozzles, and synthetic turf are among the items eligible for rebates.

Long-term drought has resulted in permanent, mandatory restrictions that prohibit water waste from excess irrigation, hosing down impermeable surfaces, leakage, and single-pass cooling systems.

The City of San Diego began a commercial landscape survey program in 2003 that has provided landscape analyses to commercial accounts in the city's service area.

Las Virgenes Municipal Water District

Las Virgenes Municipal Water District (LVMWD) provides water service to a population of 71,000 over a 122 square mile service area. LVMWD is located in western Los Angeles County and includes portions of the Ventura County/Los Angeles boundary on the west and the north and the City of Los Angeles to the east. The service area (see Figure 93) includes the cities of Calabasas, Agoura Hills, Hidden Hills, and Westlake Village as well as unincorporated areas of Los Angeles County.[123]

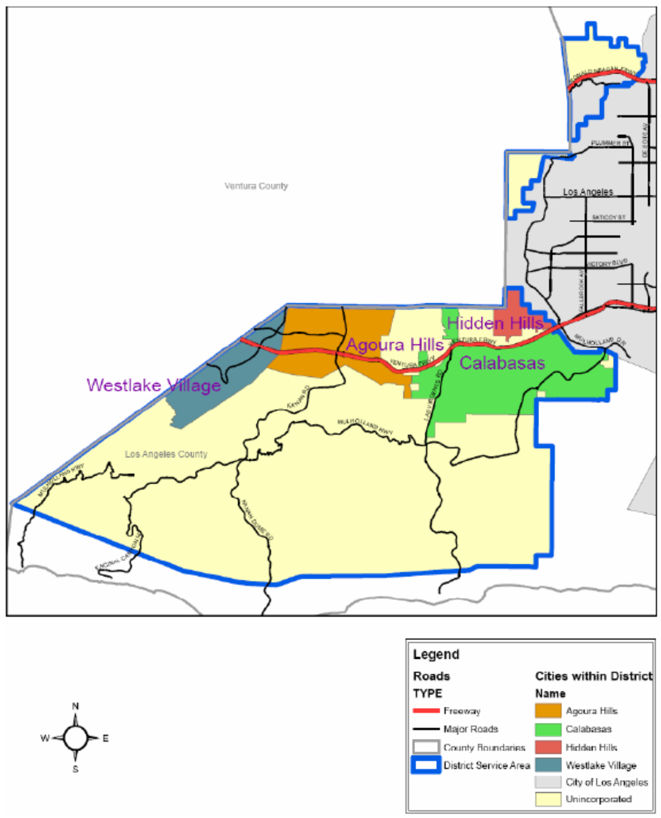

Figure 93: Graphic of Las Virgenes Municipal Water District service area[124]

[123] http://www.cityofcalabasas.com/pdf/documents/environmental-services/LVMWD-Urban-Water-Management-Plan-2005.pdf. LVMWD Water Service Area. *Location.* Accessed July 24, 2006.

[124] http://www.cityofcalabasas.com/pdf/documents/environmental-services/LVMWD-Urban-Water-Management-Plan-2005.pdf. Las Virgenes Municipal Water District 2005 Urban Water Management Plan. *Location.* Accessed July 24, 2006.

Demographics and Census Information[125]

Agoura Hills and Calabasas are the two largest water providers in the LVMWD service area. Demographic information is supplied for Agoura Hills, however, which seems to be the most typical of the demographics in the rest of the service area. The median age for Agoura Hills is 37.6 years. Of the population over the age of 25, 94.8% have a high school diploma or higher and 48.4% have a college degree or higher. The median annual household income of $87,000 is the highest in the study group, and only 3.5% of families live below the poverty level. The median home price is $366,600 and 86% of the homes are owner occupied with a median monthly mortgage of $2,138. Table 119 gives some additional information about the homes in Agoura Hills from the 2000 census.

Table 119: Demographic and household statistics for Agoura Hills

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$2,784	84.2	2.9	3.6	1981	7.0
Rental	$1,167	15.8	2.3	1.9	1985	4.5

Climate

The climate in the Las Virgenes MWD service area is described as semi-arid, with mild winters and warm summers. Most rainfall occurs between November and April; annual rainfall averages 16.5 inches and average annual ETo is 46.6 inches.[126] Currently, the closest CIMIS station is located in Camarillo which is further west than any of the sites in LVMWD and experiences cooler temperatures lower ETo, and higher precipitation. The weather data provided in Table 120 were obtained from the LVMWD 2005 Urban Water Management Plan.

[125] http://factfinder.census.gov/home/saff/main.html?_lang=en. U.S. Census Bureau. 2000 Census Data. Agoura Hills City, California. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed July 24, 2006.

[126] http://www.cityofcalabasas.com/pdf/documents/environmental-services/LVMWD-Urban-Water-Management-Plan-2005.pdf. Las Virgenes Municipal Water District 2005 Urban Water Management Plan. LVMWD Water Service Area. *Climate.* Accessed July 26, 2006.

Table 120: Las Virgenes Municipal Water District weather data

	Average High Temperature (F)	Average Low Temperature (F)	Average Precipitation (in)
January	68	38	3.3
February	71	40	2.9
March	72	42	2.9
April	77	44	1.0
May	81	48	0.3
June	87	54	0.0
July	95	57	0.0
August	95	58	0.3
September	91	55	0.3
October	84	48	0.5
November	74	44	2.5
December	68	38	2.1
		Total Rainfall	16.5

Source: [on-line] http://countrystudies.us/united-states/weather/

Customer Base

Table 121 shows that as of 2005, there were a total of 20,324 customer accounts served by LVMWD. These consisted of 18,282 residential connections (17,728 single-family and 554 multi-family), 676 commercial and industrial accounts, 247 landscape, 34 agricultural, 572 recycled and non-domestic, 336 detector check, and 177 temporary or other accounts.[127] Figure 94 shows the percentage of 2005 metered accounts by sector in LVMWD. Although residential customers make up 90% of the accounts in the water district they receive only 65% of total deliveries.

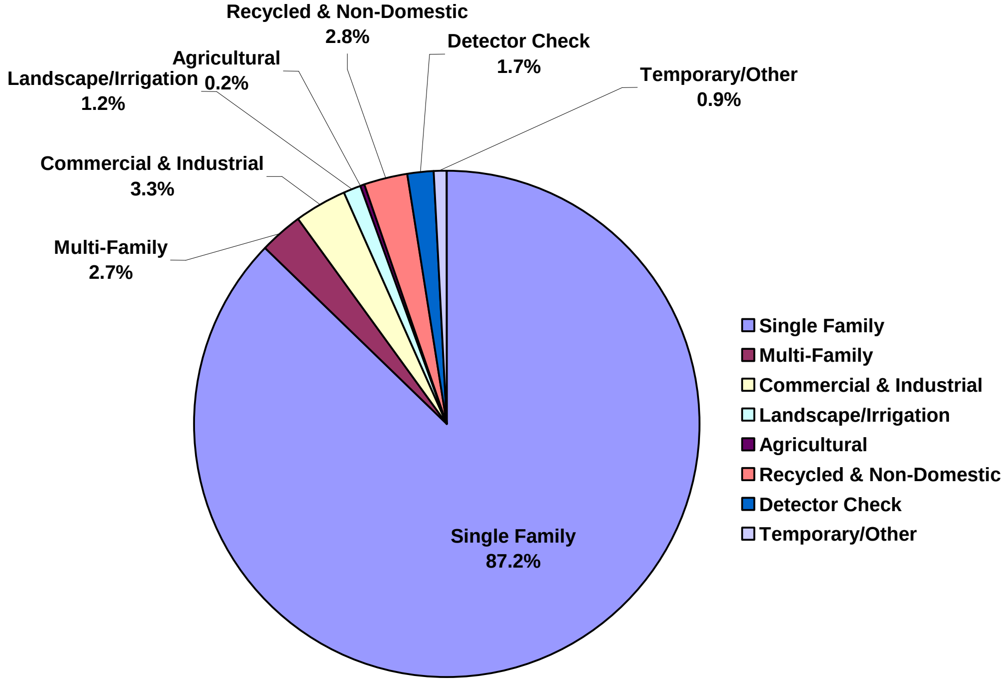

Figure 94: Percentage of 2005 metered accounts by sector in Las Virgenes Municipal Water District

Water Supply and Demand

Las Virgenes MWD stores potable water in the Las Virgenes Reservoir located in Los Angeles County. This 160 acre reservoir holds 9,600 acre-feet of water. This is a six month supply of water (at winter use levels) which provides a degree of protection against emergencies or in the event of service interruption by Metropolitan Water District. The stored water is imported from the State Water Project and the Colorado River and purchased wholesale from Metropolitan Water District. Recycled water from Tapia Water Reclamation Facility meets nearly 20 percent of the City's water supply and is used primarily for summertime irrigation.

Table 121 shows the number of metered water accounts in 2000 and 2005 and the amount of water delivered in each sector annually in both acre-feet and gallons. In 2005, the Las Virgenes

[127] http://www.cityofcalabasas.com/pdf/documents/environmental-services/LVMWD-Urban-Water-Management-Plan-2005.pdf. Las Virgenes Municipal Water District 2005 Urban Water Management Plan.

Municipal Water District supplied 27,734 acre-feet (9,037 MG) of water to 20,324 accounts. Residential customers accounted for 65% of the water deliveries (60% single-family and 5% multi-family), commercial and industrial customers received 6%, landscape customers used 4%, recycled and non-domestic customers received 17%; all other categories receive 8%.

It is interesting to note that while the number of connections increased between the years 2000 to 2005, the volume of deliveries decreased during the interval. The most notable change is in the recycled and non-domestic accounts sector which increased by 2% from 2000 to 2005 while water use decreased by 16%.

Table 121: Annual water delivery to accounts by sector for 2000 and 2005 in LVMWD[128]

Sector	Number of Connections 2000	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries	Number of Connections 2005	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single Family	17,512	16,716	5,447	58.7	17,728	16,575	5,401	59.7
Multi Family	529	1,603	522	5.6	554	1,380	450	5.0
Commercial & Industrial	658	1,964	640	6.9	676	1,700	554	6.1
Landscape/ Irrigation	240	1,054	343	3.7	247	1,060	345	3.8
Agricultural	23	NA	NA		34	195	63	0.70
Recycled & Non-Domestic	561	5,437	1,772	19.1	572	4,587	1,495	16.5
Detector Check	NA	NA	NA		336	32	10	0.11
Temporary/ Other	354	410	134	1.4	177	885	288	3.2
Unaccounted for Water		1,298	423	4.6		1,320	430	4.8
Total	19,877	28,482	9,281	100	20,324	27,734	9,037	100

Water Rates, Rate Structure, and Sewer Charges[129]

The bi-monthly service charge for single-family residential customers in LVMWD is $14.05. In addition, customers pay a potable water charge that is based both on their consumption and their elevation above the pumping station. Customers live in one of five service zones defined by their elevation or hydraulic gradient; ninety-five percent of customers live in zones 1 and 2. Table 122 shows the effect of both the elevation and water use on the cost per unit of water as of 2006[130]. Sewer rates range from $57.19 to $60.26 bi-monthly depending on where the sewage is treated and if it is necessary to pump the sewage to the treatment plant.

[128] http://www.cityofcalabasas.com/pdf/documents/environmental-services/LVMWD-Urban-Water-Management-Plan-2005.pdf. Water Use Provisions. *Past, Current and Projected Water Use Among Sectors.* Accessed July 24, 2006.

[129] http://www.lvmwd.dst.ca.us/cust/cust3rates.html#rates. Rates. Potable *Water Charge ~ Single-FamilyResidential, Sewer Rates.* Accessed July 24, 2006.

[130] A unit of water is defined as 1 CCF or 748 gallons.

Table 122: Water rate table for customers in LVMWD by hydraulic gradient

	Tier 1 (first 12 units)	Tier 2 (next 12 units)	Tier 3 (next 91 units)	Tier 4 (over 115 units)
Zone 1	$ 1.18 per unit	$ 1.31 per unit	$ 1.91 per unit	$ 2.48 per unit
Zone 2	$ 1.49 per unit	$ 1.62 per unit	$ 2.22 per unit	$ 2.79 per unit
Zone 3	$ 1.70 per unit	$ 1.83 per unit	$ 2.43 per unit	$ 3.00 per unit
Zone 4	$ 2.10 per unit	$ 2.23 per unit	$ 2.83 per unit	$ 3.40 per unit
Zone 5	$ 3.03 per unit	$ 3.16 per unit	$ 3.76 per unit	$ 4.33 per unit

Water Conservation Programs

Las Virgenes Municipal Water District is a signatory to the CUWCC's MOU and continues to implement the BMP program where economically feasible. Many of its conservation programs have been active since the early 1990s. LVMWD relies on imported water and as a result conservation plays an important role in reducing demand.

Residential Conservation Programs

LVMWD has been offering free residential surveys since 1991. These surveys provide customers with information that will help them to reduce their household and irrigation water use. Where needed, customers are provided with free low-flow showerheads and water-saving faucet aerators. Customers are given rebates of $60 for the replacement of one toilet with a ULF toilet and $40 for each additional toilet. By 1998 there had been 4,892 single-family and 1,657 multi-family toilet retrofits. To date LVMWD has provided rebates for as many as 8,000 ULF toilets.

LVMWD also has a rebate program for the purchase of high-efficiency clothes washers with a water factor of 9.5 or better. Rebates were $100 in 2002 and 2004 and $300 in 2003. As a result of this program rebates have been provided for 1,402 high-efficiency clothes washers. A four-tiered rate structure further encourages customers to reduce their water use and the district is very active in providing education in schools and for its water customers.

Customers can request free irrigation audits with recommendations on improving the efficiency of the irrigation system and a personalized irrigation schedule. Homeowners can request weekly phone calls from any of several local weather stations to further assist them in adjusting their irrigation schedule.

CII Conservation Programs

LVMWD provides free survey services for its large landscape customers. Surveys include a system check, distribution uniformity, measurement of irrigated area, irrigation scheduling, and follow-up. Many irrigation customers have dedicated irrigation meters and some are using voluntary water budgets to manage their water use. Customers with mixed use accounts can request ETo-based landscape budgets in lieu of a survey.

All large, non-residential landscapes that are located along the district's reclaimed water distribution lines are required to use reclaimed water for landscape irrigation. Currently 70% of dedicated irrigation accounts use reclaimed water.

Free water surveys are available to CII customers. Surveys provide customers with recommendations of ways to improve the efficiency of process water use, fixtures and appliances, agency incentives, and the payback period. Rebates are provided to CII customers for the installation of ULF toilets.

City of Davis

The City of Davis Utility is located in Yolo County in the Central Valley of Northern California 70 miles northeast of San Francisco and 15 miles west of Sacramento. The utility supplies water to approximately 66,000 customers in the City of Davis, El Macero, and additional areas to the north, south, east and west of the City. The Davis service area and its relationship to West Sacramento and the University of California at Davis are shown in Figure 95.

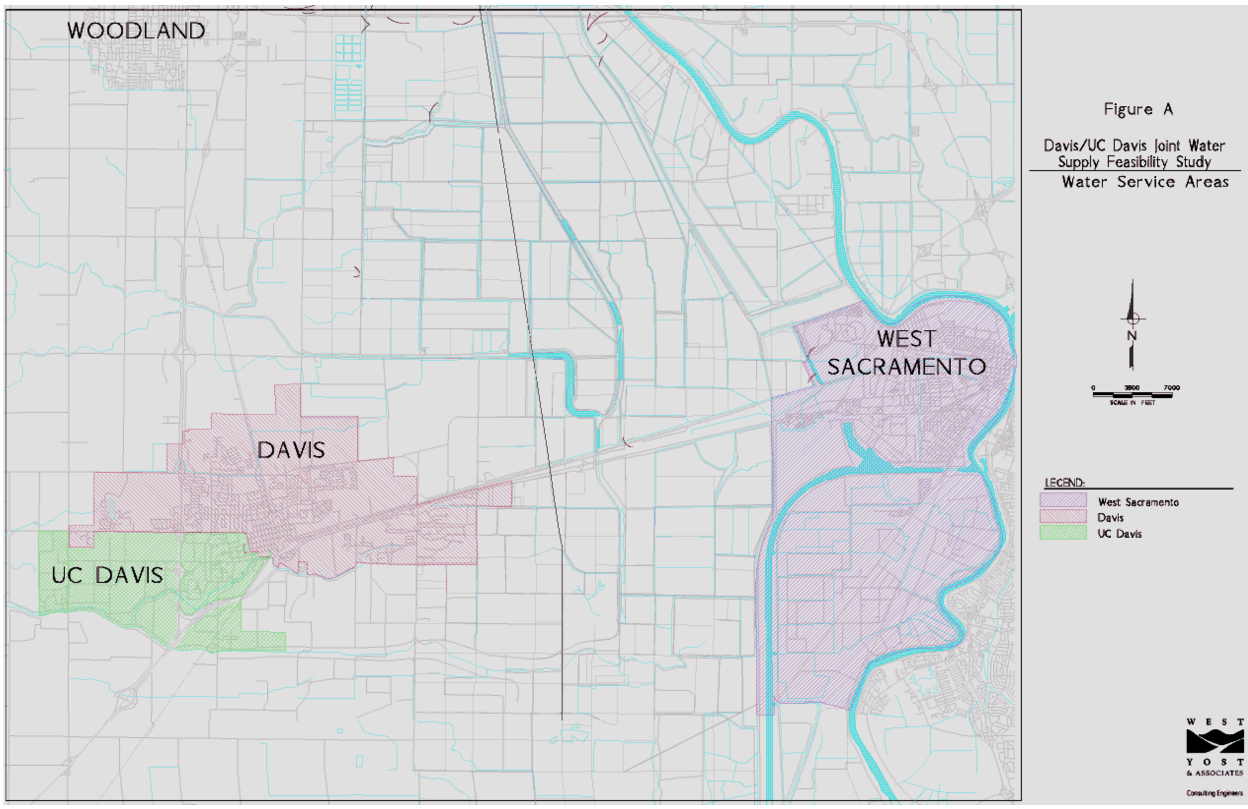

Figure 95: Graphic of City of Davis Utility service area. Provided courtesy of West Yost Associates for City of Davis 2005 Urban Water Conservation Plan[131]

Demographics and Census Information[132]

The City of Davis is a very young community with a median age of 25.2 years. Of the population over the age of 25, 96.4% have a high school diploma or higher and 68.6% have a college degree or higher. "Davis is a university-oriented city with a progressive, vigorous community noted for its small-town style, energy conservation, environmental programs, parks,

[131] http://www.city.davis.ca.us/pw/water/watersupply/index.cfm?topic=4. 2002 Water Supply Feasibility Study. Davis Water System. *Figure A Water Service Areas.*

[132] http://factfinder.census.gov/home/saff/main.html?_lang=en. U.S. Census Bureau. 2000 Census Data. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed June 13, 2006

preservation of trees, red double-decker London buses, bicycles, and the quality of its educational institutions."[133]

The median annual household income is $42,457; only 5.4% of families live below the poverty level. The median home price is $238,500 and only 44.6 percent of the homes are owner occupied with a median monthly mortgage of $1,897. Table 123 gives some additional characteristics about the homes in the City of Davis.

Table 123: Demographic and household statistics for the City of Davis[134]

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,547	44.6	2.64	3.3	1978	18.5
Rental	$775	55.4	2.39	1.9	1976	8.3

Climate

The City of Davis is characterized as having a Mediterranean climate because of its hot dry summers and mild wet winters[135]; it receives approximately 16" of precipitation annually with most of the precipitation falling between November and April. The average annual maximum temperature is 75.1 degrees and the average annual minimum temperature is 47.1 degrees. Snowfall in Davis is rare. The hottest month of the year is July with an average maximum temperature of 91.5 degrees and precipitation of 0.1 inches. According to the CIMIS ETo Zone Map, Davis is located in Zone 14, described as Mid-Central Valley, Southern Sierra Nevada, Tehachapi and High Desert Mountains with high summer sunshine and wind in some locations.

Weather and ETo information was obtained from CIMIS Station #6 located at the University of California, Davis campus. Table 124 compares the average monthly minimum and maximum temperatures, average monthly rainfall, and average monthly ETo from January 1987 to December 2005, with the same data from 2005. The table shows that although maximum and minimum temperatures in 2005 were very similar to the 20-year average, ETo was lower in 2005 than the 20-year average (56.37 inches vs. 59.02 inches) and rainfall was three inches above the 20-year average.

[133] http://www.city.davis.ca.us/aboutdavis/cityprofile/. Davis, California. Profile Welcome. *City of Davis Profile*. Accessed June 27, 2006.

[134] The City of Davis is the largest urban area serviced by the utility. Therefore census information and weather data is given for the City of Davis.

[135] http://www.city.davis.ca.us/aboutdavis/cityprofile/index.cfm?topic=weather. Davis. California. City of Davis Profile. *Weather.* Accessed June 27, 2006.

Table 124: Davis – #6 Lat 38°32'09" Long 121°42'32" – period of record July 1982 to December 2005[136]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	54.4	59.9	67.0	72.5	79.5	86.3	91.5	90.8	87.7	79.0	64.3	54.7	74.0
Avg. Max. Temp. 2005 (F)	50.5	60.5	67.1	69.7	77.6	81.9	95.2	93.2	83.7	77.0	66.4	56.4	73.3
Avg. Min. Temp. (F)	38.1	39.9	43.0	45.2	50.4	54.7	56.6	55.7	53.4	49.0	41.7	37.4	47.1
Avg. Min. Temp. 2005 (F)	37.8	42.4	43.6	42.7	50.2	53.4	58.4	55.8	50.5	48.4	41.3	40.9	47.1
Avg. Monthly Precip. (in)	1.1	4.1	2.4	0.9	0.7	0.3	0.1	0.1	0.2	0.7	1.7	3.6	15.9
Monthly Precip. 2005 (in)	0.7	3.1	2.6	0.8	0.8	0.4	0.0	0.0	0.0	0.0	1.4	9.2	19.0
Avg. Monthly ETo (in)	3.5	1.9	3.7	5.4	7.0	8.2	8.5	7.5	5.9	4.2	2.0	1.2	59.0
Monthly ETo 2005 (in)	3.5	1.6	3.6	4.9	5.9	7.5	8.5	7.8	5.7	4.3	2.3	0.9	56.4

136 http://wwwcimis.water.ca.gov/cimis/monthlyReport.do. California Irrigation Management Information System. Department of Water Resources. Office of Water Use Efficiency. *Monthly Report*. Sacramento – Davis – #6. Accessed June 27, 2006.

Customer Base

Table 125 shows that in 2005, there were approximately 16,680 customer accounts served by the City of Davis Water Department. These consisted of 15,062 residential connections (14,514 single-family and 548 multi-family), 646 commercial/industrial, 254 irrigation, 480 city facilities, and 238 for El Macero for a total of 16,680 connections. During the study period the number of connections is expected to increase by 1.57% annually.[137] This estimate was reduced to between 0.5% and 1% in 2010.

Water Supply and Demand

As of 2000, groundwater from the Sacramento Valley groundwater basin was the sole source of water for the City of Davis. Water was pumped from 22 wells (19 intermediate wells, depth 300-600 feet and three deep wells (700-1,500 feet) which supply 14,000 acre-feet of water annually.[138]

The utility sold 14,095 acre-feet (4,591 MG) of water in 2000 (Table 125); residential customers accounted for 66% of the total water demand (46% single-family and 20% multi-family), commercial and industrial customers used 11%, irrigation deliveries used 2.2%, water for construction 4.6%, deliveries to the El Macero service area 3.7% and unaccounted losses in the system an additional 5%. Unconstrained water use is expected to increase to 15,236 acre-feet (4,965 MG) in 2005 based on a projected increase of 1.57% annually.[139]

[137] http://www.sdcwa.org/manage/pdf/2005UWMP/Final2005UWMP.pdf. San Diego County Water Authority. 2005 Urban Water Management Plan. History and Description of the Water Authority. *Service Area*. Accessed July 27, 2006.

[138] http://www.city.davis.ca.us/pw/water/pdfs/2000_sample_plan1.pdf. City of Davis, California. July 2001. 2000 Urban Water Management Plan. *Groundwater.* Accessed July 7, 2006.

[139] http://www.city.davis.ca.us/pw/water/pdfs/2000_sample_plan1.pdf. City of Davis, California. July 2001. 2000 Urban Water Management Plan. *Past Current and Projected Water Use.* Accessed July 10, 2006.

Table 125: Actual and projected number of connections and deliveries in the City of Davis for 2000 and 2005 [140]

Sector	Number of Connections 2000	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries	Number of Connections 2005*	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single Family	13,427	6,472	2,109	45.9	14,514	6,996	2,280	45.9
Multi Family	507	2,805	914	19.9	548	3,033	988	19.9
Commercial/ Industrial**	602	1,604	523	11.4	646	1,734	565	11.4
Irrigation	235	310	101	2.2	254	335	109	2.2
City Facility	234	980	319	6.9	480	1,059	345	6.9
El Macero	480	564	184	3.7	238	564	184	3.7
Construction Water		655	213	4.6		708	231	4.7
Unaccounted Losses		704	229	5.0		807	263	5.3
Total	15,485	14,095	4,593	100	16,680	15,236	4,965	100

*Projected accounts and water use

** 535 connections are small Commercial/Industrial and 67 are large Commercial/Industrial

[140] http://www.city.davis.ca.us/pw/water/pdfs/2000_sample_plan1.pdf. City of Davis, California. July 2001. 2000 Urban Water Management Plan. *Past Current and Projected Water Use.* Accessed July 10, 2006.

Water Rates, Rate Structure, and Sewer Charges

The City of Davis customers are billed on a bi-monthly interval. The base rate for single family, residential customers is $6.22 per month and there is a two-tiered rate structure. The first tier is $0.77 per CCF for consumption from 0-36 CCF, $0.86 per CCF for consumption over 36 CCF. The base rate for sewer is $26.69 per month.

Water Conservation Programs[141]

The City of Davis has been a signatory to CUWCC's MOU since 1994. All BMPs have been implemented with the exception of BMP 2, the replacement of faucets and showerheads, and BMP 14 which provides rebates for the ULF toilets. The City has filed a request for exemption for these BMPs since they are no longer considered cost effective to implement.

Residential Conservation Programs

The City of Davis had a toilet rebate program that ended in 2001. In 1993, rebates of $75 were funded jointly by the City and Pacific Gas and Electric. The city provided rebates of $50 for toilet rebates from 1993-99 and then for the next few years increased the rebate to $100. Most of the rebates were distributed to single-family residential customers and were issued as a credit on the utility bill. Toilet rebates were discontinued at the end of 2001 because of the city's concern about free-ridership. The number of rebates being distributed was less than the expected number of toilet replacements that should occur through natural replacement.

The city provides rebates for high-efficiency clothes washers and plans to continue this program until funding runs out. Rebates of $150 and $225 were reported in the BMPs in 2003 and $100 and $150 in 2004. Matching rebates of $75 are being funded with grant funds through the Department of Water Resources Water Use Efficiency Program. This grant has been in place since 2002. Nearly 2,400 clothes washer rebates have been distributed since the beginning of the rebate program.

The city offers free residential surveys to its single-family and multi-family customers. As part of the survey the city provides toilet "leak" detection tablets and keeps customers informed of the rebate programs available to them. Currently showerheads and aerators are no longer provided through the survey program because these items are widely available and very affordable.

The city provides gpd usage for the current billing period which is compared to the same period the year before. The bill contains one year water-use history as well. There is a two-tiered rate structure for residential customers.

CII Conservation Programs

The city has water budgets for its parks. Large irrigation customers have dedicated water meters and the city has developed water budgets for some of their large irrigation customers. The city

[141] http://cityofdavis.org/pw/water/uwmp/pdfs/uwmp/10-Urban_Water_Management_Plan.pdf. City of Davis Urban Water Management Plan 2005 Update. Final Draft. Brown and Caldwell. March 2006. Accessed January 26, 2010.

assumes water budgets apply to accounts that are effectively ET controlled via a central irrigation control station, such that budgeted use equals actual use. It is assumed accounts with water budgets use approximately 15% less water than non-budgeted accounts. Therefore, irrigation meter accounts with water budgets use approximately is 85% of the proportion of budgeted irrigation meter accounts to total irrigation meter accounts.[142]

CII audits are provided at the request of the customer. However, many of the city's CII customers already have low water use and most are billed using a two-tier rate structure.

The city has high-efficiency clothes washer rebate program known as LightWash for its CII customers. At this time there are no industrial accounts in the City of Davis. The ULF toilet rebate program for CII customers was discontinued in 2001 because so few customers had taken advantage of the program.

The City will continue to investigate the effectiveness of programs that are aimed at reducing water use including:

- Regional ET Controller Pilot Program
- Regional Clothes Washer Rebate Program
- California SFR Water Use Efficiency Study
- Pre-rinse Spray Valve Program
- Water Loss "leak" Detection Survey
- Parks Water Budget Program
- Landscape Water Conservation Ordinance Update

[142] http://cityofdavis.org/pw/water/uwmp/pdfs/uwmp/10-Urban_Water_Management_Plan.pdf. City of Davis Urban Water Management Plan 2005 Update. Appendix D. BMP 05: Large Landscape Conservation Programs and Updates. Comments. Accessed January 26, 2010.

San Diego County

San Diego County is the third most populous county in California behind Los Angeles and Orange County. The San Diego County Water Authority (SDCWA) is a wholesale water provider for 24 member agencies and one military base in San Diego County serving nearly three million people. The population, and number and type of accounts served by each agency are shown in Table 126[143]. The member agencies include six cities, five water districts, three irrigation districts, eight municipal water districts, one public utility district, and one federal agency (military base). Figure 96 shows the area served by SDCWA, bordered by Riverside and Orange County to the north, the Pacific Ocean to the west and the Mexico border on the south. The service area encompasses 1,438 square miles in the western third of San Diego County.[144]

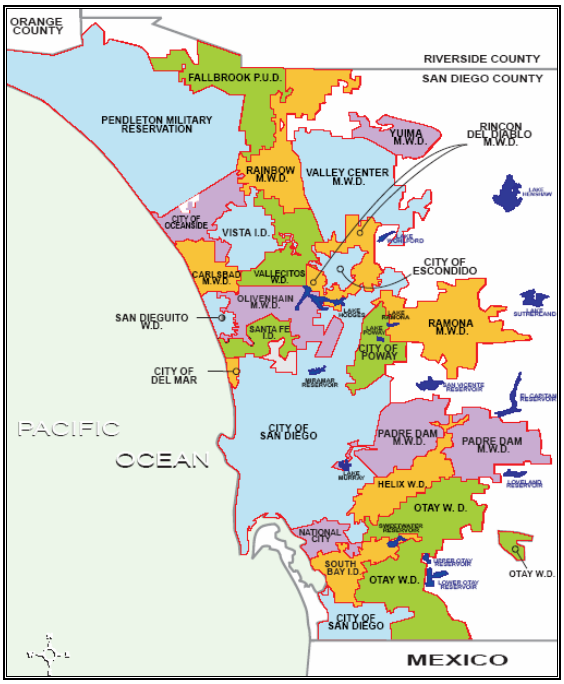

Figure 96: Graphic of San Diego County Water Authority service area[145]

[143] http://www.sdcwa.org/about/pdf/member-2005-rate-survey.pdf. San Diego County Water Authority, May 2006. Prepared by the Water Resources Department. Accessed December 16, 2009.

[144] http://www.sdcwa.org/manage/pdf/2005UWMP/Final2005UWMP.pdf. History and Description of the Service Area. *Service Area.* Accessed August 23, 2006.

[145] http://sandiegodialogue.org/pdfs/Water_Paper_Sept01.pdf#search=%22water%20agencies%20serving%20San%20Diego%20County%22. Briefing Paper prepared for San Diego Dialogue's Forum *Fronterizo* program on: Providing a Reliable Water Supply in the San Diego/Imperial Valley/Baja California. September 2001. Accessed August 23, 2006.

Table 126: Population and accounts served by San Diego County Water Authority in 2005

Water Provider	Population Served	Residential Accts	Agriculture Accts	Indus & Com Accts	Reclaimed Accts	Irrig Accts	Pub & Other Accts
Carlsbad MWD	80,874	22,790	40	1,422	209	1,105	229
City of Del Mar	4,555	1,567	0	106	0	128	17
City of Escondido	141,000	22,717	251	1,598	10	513	123
Fallbrook PUD	32,000	7,373	742	498	23	0	38
Helix WD	260,158	60,656	0	3,369	0	468	496
City of Oceanside	175,805	39,313	111	1,501	1	1,040	277
Olivenhain MWD	56,000	18,498	352	427	62	635	40
Otay Water District	186,000	43,220	33	1,225	549	1,137	222
Padre Dam MWD	130,199	20,512	11	888	172	237	112
City of Poway	50,675	12,632	77	563	195	237	179
Rainbow MWD	17,825	3,832	866	560	0	0	0
Ramona MWD	40,000	8,437	256	328	3	81	65
Rincon Del Diablo MWD	28,200	6,530	62	550	42	145	0
City of San Diego	1,305,736	246,482	NA	15,377	366	7,399	2,669
San Dieguito WD	38,295	10,103	169	510	50	193	112
Santa Fe Irrig	20,958	5,880	38	325	43	143	30
Sweetwater Auth.	177,000	29,401	8	2,570	0	652	281
Vallecitos WD	80,650	17457	212	912	0	690	84
Valley Center MWD	25,040	6,665	1,682	222	1	0	29
Vista Irrigation	119,916	23,098	721	1,431	0	663	68
Yuima MWD	1870	65	24	0	0	0	0
Total	2,972,756	607,228	5,655	34,382	1,726	15,466	5,071

Demographics and Census Information

The median annual household income is $47,064; 8.9% of families live below the poverty level. The median age of the population is 33.2 years. The median monthly mortgage is $1,541. Of the population over the age of 25, 82.6% have a high school diploma or higher and 29.5% have a college degree or higher. Table 127 gives some additional characteristics about the homes in San Diego County.

Table 127: Demographic and household statistics for San Diego County

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,541	55.4	2.78	3.0	1975	8.1
Rental	$710	44.6	2.68	1.7	1974	4.0

Climate

The climate along the coast of San Diego County is typically Mediterranean with mild year-round temperatures and low average rainfall (average 10 inches). Further inland weather is more variable with greater variation in temperatures; summer temperatures can exceed 90 degrees Fahrenheit and winter temperatures occasionally drop below freezing. Rainfall can exceed 33 inches in the inland mountain areas.[146] Currently there are five active CIMIS stations in San Diego County, three of which provide weather data for the City of San Diego. Weather data from three of the CIMIS stations is provided in Table 115,

[146] http://www.sdcwa.org/manage/pdf/2005UWMP/Final2005UWMP.pdf. San Diego County Water Authority. 2005 Urban Water Management Plan. Service Area Characteristics. *Climate.* Accessed July 27, 2006.

Table 116, and

Table 117. Weather data for the additional two CIMIS stations in San Diego County can be found in Table 128 and

Table 129. Both of these sites are inland sites and it is clear from the tables that the weather at these sites tends to be hotter and drier than the City of San Diego. This is reflected in the significantly higher annual ETo of 50.36 inches in Otay and 53.71 inches in Escondido.

Table 128: South Coast Valleys – Otay #147 Lat 32°37'48" Long116°56'18" – period of record April 1999 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	68.2	66.3	67.7	69.4	71.7	74.2	78.9	80.2	80.1	75.6	69.4	66.8	72.4
Avg. Max. Temp. 2005 (F)	68.3	65.1	67.4	69.6	72.7	72.8	79.9	80.8	79.2	74.8	74.6	68.8	72.8
Avg. Min. Temp. (F)	44.7	45.8	47.7	48.7	53.3	56.6	59.8	60.6	58.8	55.1	48.2	44.4	52.0
Avg. Min. Temp. 2005 (F)	48.0	48.9	49.9	49.0	54.9	57.4	60.8	61.7	57.6	55.5	50.8	46.0	53.4
Avg. Monthly Precip. (in)	0.4	2.4	1.1	0.5	2.4	0.3	0.1	0.0	0.2	0.3	0.5	0.4	8.6
Monthly Precip. 2005 (in)	0.3	4.2	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.2	7.2
Avg. Monthly ETo (in)	2.3	2.6	3.9	4.4	5.7	5.8	6.3	6.1	4.7	3.6	2.5	2.2	50.1
Monthly ETo 2005 (in)	1.9	2.0	3.7	4.7	5.9	5.4	6.5	5.9	5.0	3.5	3.0	2.2	49.7

Table 129: South Coast Valleys – Escondido SPV#147 Lat 32°37’48” Long116°56’18” – period of record February 1999 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg.. Max Temp. (F)	68.8	66.8	69.3	71.0	76.5	79.9	86.0	87.4	85.3	79.0	72.8	68.9	76.0
Avg. Max. Temp. 2005 (F)	67.2	65.2	69.0	72.4	77.4	78.5	88.3	88.4	84.7	77.8	76.0	70.7	76.3
Avg. Min. Temp. (F)	37.0	39.4	42.3	43.9	49.5	53.2	56.4	56.6	53.4	48.8	40.1	36.2	46.4
Avg. Min. Temp. 2005 (F)	41.3	43.4	45.6	42.4	50.5	53.8	57.8	57.6	49.2	47.9	40.6	36.9	47.3
Avg. Monthly Precip. (in)	1.4	2.5	1.1	1.1	0.7	0.1	0.0	0.0	0.0	1.0	0.6	0.9	9.4
Monthly Precip. 2005 (in)	6.3	5.1	1.6	1.3	0.7	0.0	0.0	0.0	0.0	1.1	0.0	0.2	16.2
Avg. Monthly ETo (in)	2.3	2.6	3.9	4.8	5.9	6.4	7.1	6.7	5.2	3.8	2.7	2.3	53.7
Monthly ETo 2005 (in)	1.9	1.9	3.7	5.0	6.0	6.0	7.3	6.7	5.3	3.7	2.9	2.1	52.5

Customer Base

Figure 97 shows the distribution of customers by sector served by San Diego County Water Authority in 2005. Just over half of the customers served are residential; industrial and commercial customers comprise 24% of the customer base, 13% are agricultural, and 8% are all other types of customers.

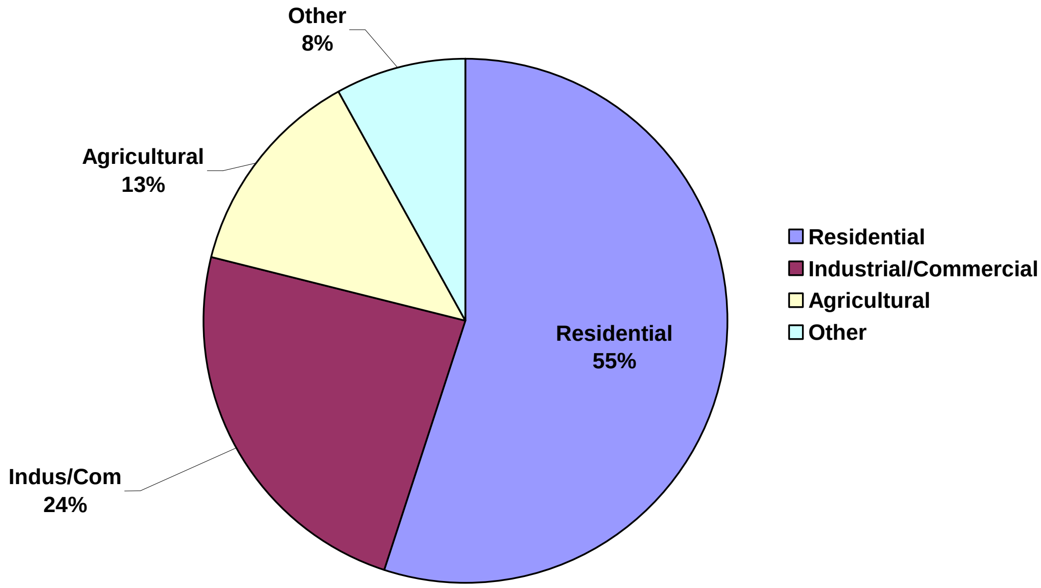

Figure 97: Water use by sector in San Diego County

Water Supply and Demand

As of 2005 as much as 90% of SDCWA water supply came from the Colorado River and the State Water Project, under contract with the Metropolitan Water District. "The rest comes from local water sources including groundwater, local surface water, recycled water, seawater desalination and conservation."[147] In addition to the water supplied by SDCWA, increasingly member agencies are developing and managing local sources of water to improve the diversity and reliability of their supply. Groundwater, surface water, and recycled water help to drought-proof supplies and reduce demand on imported water.[148]

San Diego County Water Authority sold 589,062 acre-feet (191,896 MG) of water in 2000 (Table 130) as shown in Table 114. Residential customers accounted for 57% of the total water demand, commercial and industrial customers used 21%, agricultural deliveries accounted for 16.1%, of the demand and water for public and other uses 6.4%. Water sales decreased by more than 36,000 acre-feet between 2000 and 2005 nearly all of which was in the residential sector.

[147] http://www.sdcwa.org/about/faqs.phtml#watercomefrom. About Us. Frequently Asked Questions. *Where does San Diego County's water come from?* Accessed July 27, 2006.

[148] http://www.sdcwa.org/manage/pdf/2005UWMP/Final2005UWMP.pdf. San Diego County Water Authority. 2005 Urban Water Management Plan. *Section 5 - Member Agency Supplies.*

Table 130: Annual water use by sector to SDCWA customers for 2000 and 2005

Sector	Water Use (AF) 2000*	Water Use (AF) 2000	% of Total	Water Use (AF) 2005**	Water Use (MG) 2005	% of Total Water Use
Single Family	396,311	129,139	57	355,799	115,938	55
Commercial/ Industrial	142,445	46,416	20.5	151,492	49,364	24
Agricultural	111,653	36,382	16.1	85,662	27,913	13
Public & Other	44,586	14,528	6.4	51,893	16,909	8
Total	694,995	226,465	100	644,846	210,125	100

*[on-line source] http://www.sdcwa.org/about/annual-2000ar.pdf

** [on-line source] http://www.sdcwa.org/about/annual_2005.pdf.

Projected Demand

The population served by SDCWA is projected to increase by 33,700 people per year (1.1 percent annually) resulting in a projected population of 3.7 million people by 2030.[149] As of 2005, water use was 642,152 AF, 87% of which is municipal and industrial. It is anticipated that by 2030 the demand will increase to 829,030 AF despite ongoing conservation measures. While conservation is expected to reduce demand by 108,396 AF much of this savings is offset by the increase in population and by the demands of various pending annexations to San Diego County.

Water Rates, Rate Structure, and Sewer Charges

Because SDCWA is a wholesale water provider, water rates, rate structures, and sewer charges are determined by each of the individual service providers. In order to comply with the CUWCC MOU, SDCWA and most of its member agencies must comply with BMP 11 which requires implementation of a conservation rate structure.

Water Conservation Programs[150]

SDCWA is a signatory to the CUWCC MOU and most of its member agencies are signatories to the MOU as well. SDCWA manages most of the BMP programs for its member agencies and provides approximately 20 percent of all of the conservation funding. To date, SDCWA has invested more than $12 million dollars towards conservation programs. During the 2005 fiscal year SDCWA and its member agencies budgeted nearly $6 million toward various conservation programs which are expected to save approximately 68,000 AF over the useful life of the conservation measures.

[149] http://www.sdcwa.org/manage/pdf/2005UWMP/Sections_1-9.pdf. Updated 2005 Urban Water Management Plan. San Diego County Water Authority. 1.6.3 Population. April 2007. Accessed January 15, 2010.
[150] http://www.sdcwa.org/manage/pdf/2005UWMP/Sections_1-9.pdf. Updated 2005 Urban Water Management Plan. San Diego County Water Authority. 3.2 Demand Management. April 2007. Accessed January 26, 2010.

Residential Conservation Programs

Many SDCWA providers offer free indoor and outdoor residential surveys to their customers. Residential conservation programs include rebates for installation high-efficiency clothes washers and various irrigation products. Since the inception of these programs SDCWA and member agencies have provided incentives for more than 90,000 high-efficiency residential clothes washers and installation of 528,000 ULF toilets. During this same time period more than 500,000 showerheads have been distributed as well.

Beginning in 2004, residential customers were provided with financial incentives for installing weather-based irrigation controllers to replace an existing controller. In order to qualify for the incentive, customers must have an irrigated area and an in-ground irrigation controller. Incentives are also provided for irrigation devices that improved the efficiency of residential irrigation. Funding was also provided for a demonstration Water Conservation Garden, conservation literature, and efficient irrigation training programs.

CII Conservation Programs

SDCWA provides conservation incentives for its commercial customers as well. To date, CII customers have installed 355 cooling tower conductivity controllers, 3,200 pre-rinse sprayers, and 7,600 coin-operated high-efficiency clothes washers.

CII customers are provided incentives for installing weather-based irrigation controllers. Irrigation customers, with dedicated irrigation meters, can request free water budgets.

Free surveys are also available with water-saving tips for both indoor and outdoor water use, provide an optimal watering schedule and review existing landscapes for irrigation system improvements. Availability of home surveys varies by water district.

Water budgets are also provided as a free service to water district customers, property managers and landscape contractors for commercial sites. Water budgets compare the amount of water used to the optimal amount of water that sites need. Water budgets are available as a stand-alone service upon request, for sites with dedicated irrigation meters.

East Bay Municipal Utility District

Demographics

East Bay Municipal Utility District comprises a large geographical area made up of several urban areas that lie both east and west of a range of hills running north to south from East Richmond down to the Castro Valley. The climate varies significantly from the east to west. The areas west of the hills (Walnut Creek, Lafayette, San Ramon and Dublin) are warmer and drier than the areas west of the hills (Richmond, Berkeley, and Oakland). In estimating the irrigation demands for the logging sample weather data were used from a range of weather stations. For this section climate and demographic information will be provided for Oakland, the largest of the cities in the service area. Because there are so many diverse communities in the EBMUD service area it was impossible to provide a properly weighted set of demographic and economic statistics for the area, and rather than provide misleading data, it was elected not to attempt to make a summary.

Climate[151]

Located across the bay from San Francisco, Oakland too has cool, mild weather year-round with very little fluctuation between summer and winter, or daytime and nighttime temperatures. Weather and ETo information were obtained from CIMIS Station #149 located on the campus of Mills College adjacent to a densely urbanized area. Table 131 compares the average monthly minimum and maximum temperatures, average monthly rainfall, and average monthly ETo from March 1999 to December 2005, with the same data provided for 2005. The table shows that although maximum and minimum temperatures in 2005 were very similar to the six-year average, ETo was lower in 2005 than the 6-year average (36.06 inches vs. 39.18 inches) and rainfall was six inches above the six-year average (30.81 inches vs. 24.75 inches). Most precipitation falls between October and May; precipitation in the summer months is rare. Oakland is in CIMIS Reference ETo Zone 1, described as Coastal Plains Heavy Fog Belt.

[151] http://wwwcimis.water.ca.gov/cimis/frontMonthlyReport.do. California Irrigation Management Information System. Department of Water Resources. Office of Water Use Efficiency. *Monthly Report*. Oakland Foothills #149. Accessed July 17, 2006.

Table 131: Oakland Foothills #149 Lat 37°46'51" Long 122°10'44" – period of record March 1999 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp.(F)	59.7	62.2	66.8	66.8	71.1	73.9	74.9	76.1	77.5	73.5	65.9	60.6	69.1
Avg. Max. Temp. 2005(F)	58.4	62.8	67.5	67.1	70.6	72.1	77.9	77.1	73.2	72.9	69.1	60.6	69.1
Avg. Min. Temp. (F)	41.9	43.5	44.5	45.5	49.7	52.2	55.0	55.6	53.6	50.2	45.4	43.1	48.4
Avg. Min. Temp. 2005 (F)	41.1	46.6	46.9	45.2	51.2	51.6	55.6	53.9	52.7	48.3	45.6	45.2	48.7
Avg. Monthly Precip. (in)	3.2	5.4	2.2	2.2	0.9	0.3	0.0	0.0	0.3	1.3	2.4	6.7	24.8
Monthly Precip. 2005 (in)	2.0	4.9	5.3	2.1	1.9	1.6	0.0	0.0	0.0	0.3	1.9	10.9	30.8
Avg. Monthly ETo (in)	1.0	1.4	2.7	3.9	5.1	5.6	5.8	4.9	3.8	2.6	1.4	1.0	39.2
Monthly ETo 2005 (in)	0.9	1.1	2.4	3.4	3.9	4.7	6.3	4.9	3.5	2.7	1.6	0.8	36.1

Customer Base

Residential customers make up 83% of EBMUD's customer accounts (81% single-family and 2% multi-family), commercial customers make up 13%, while industrial, institutional and irrigation customers are only 1% each of the billed accounts from the utility. Figure 98 shows the projected percentage of metered accounts by sector in East Bay MUD for 2005.

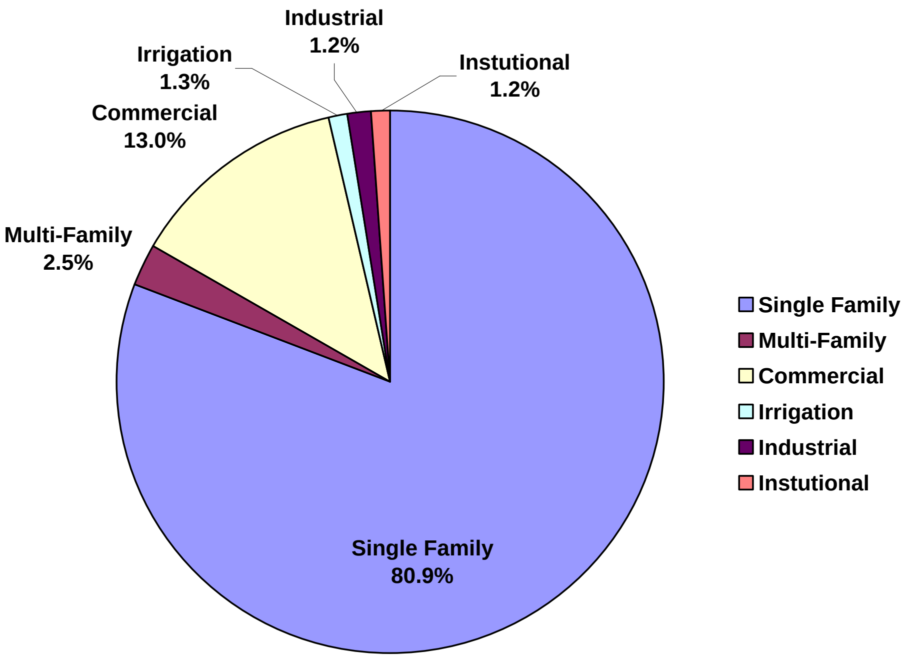

Figure 98: Percentage of 2005 metered accounts by sector in the East Bay MUD service area

Water Supply and Demand

East Bay Municipal Utility District supplies water to 1.3 million people in a 331 square mile service area (shown in Figure 99). The Mokelumne River in the Sierra Nevada provides 90% of the water supply for East Bay Municipal Utility District up to a maximum of 325 million gallons per day. There are two large reservoirs on the river: Comanche and Pardee. The remaining 10% of East Bay's water supply comes from runoff in the East Bay watershed area that fills San Pablo system on the north of State Highway 24 and San Leandro reservoir system on the south of the highway. The annual variability of rainfall and snowmelt, and the senior water rights of other users can adversely affect the supply.[152]

[152] www.ebmud.com/water_&_environment/water_supply/urban_water_management_plan/2005_uwmp/UWMP%20 2005%20Final%20Book.pdf. Water Supply and Water Supply Planning. *Water Supply System*. Accessed July 14, 2006.

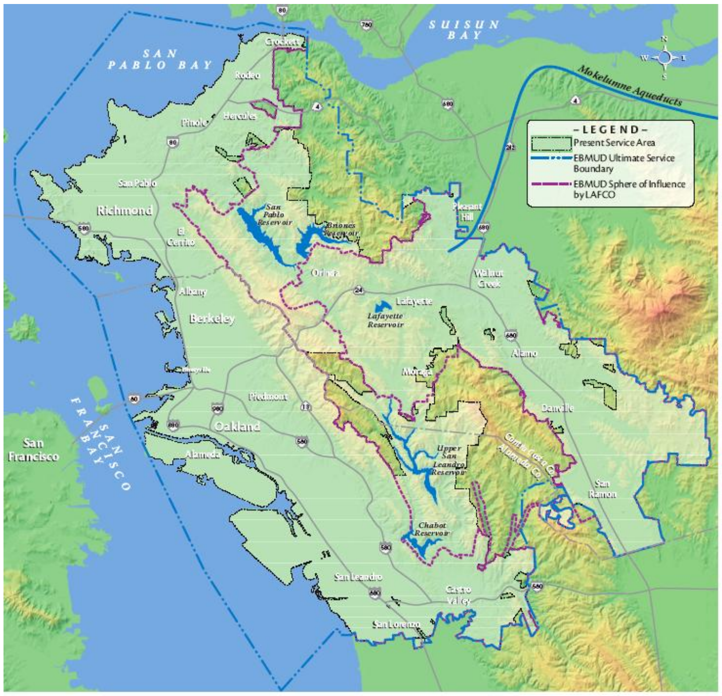

Figure 99: Graphic of East Bay MUD service area[153]

East Bay MUD sold 648.3 million acre-feet or 211MG of water in 2005 (Table 132); residential customers accounted for 42 % of the total water demand, commercial and industrial customers used 41%, irrigation deliveries accounted for nearly 5%, of the demand and water for institutional uses is less than 1%.

Table 132: Number of connections and deliveries in EBMUD for 2005[154]

Sector	Number of Accounts	Deliveries 2005 (MG)	% of Total Deliveries
Single Family	319,151	89.4	42.3%
Multi-Family	9,686	23.7	11.2%
Commercial	51,334	62.0	29.2%
Industrial	4,743	25.1	11.9%
Institutional	4,606	0.87	0.4%
Irrigation	4,950	10.0	4.7%
Total	391,216	211,251,539	100%

[153] http://www.ebmud.com/water_&_environment/water_supply/urban_water_management_plan/2005_uwmp/UWMP%202005%20Final%20Book.pdf. East Bay Municipal Utility District. 2005 Urban Water Management Plan. Chapter 1: General Information. EBMUD Service Area. Accessed September 1, 2006.

[154] Data provided by David Wallenstein, Associate Civil Engineer for East Bay Municipal Utility District

Water Rates, Rate Structure, and Sewer Charges

East Bay MUD single family, residential customers pay a base rate of $8.45 plus a $0.80 seismic improvement surcharge per month. Additionally, there is a three-tiered rate structure; customers are charged $1.65 per unit up to 172 gallons per day (a unit is one CCF or 748 gallons – 172 gpd is approximately seven units per month), $2.05 per unit for 173 gpd to 393 gpd, and $2.51 per unit for use in excess of 393 gpd.[155]

The minimum monthly service charge for wastewater for residential customers is $4.54. In addition there is a monthly San Francisco Bay Residential Pollution Prevention Fee of $0.07, a strength charge of $4.72, and a flow charge of $0.472 per unit of flow up to a maximum of 10 units of wastewater discharge per month.[156]

Water Conservation Programs[157]

EBMUD has been a signatory to the CUWCC MOU since 1993. They have implemented all 14 Best Management Practices with a goal of saving 33 MGD in the year 2020. The savings goal will result from natural replacement, financial incentives, educational programs, water surveys, and fixture replacement.

Residential Conservation Programs

Residential customers are offered free water use surveys that provide recommendations on ways that customers can reduce both their indoor and outdoor demand. Surveys can be provided by the utility or can be "self-guided," In an effort to make surveys cost effective, the utility targets high water use customers and customers with a significantly different summer and winter usage. The utility distributes free showerheads and faucet aerators to its customers primarily through its free water survey program. A study conducted in 2002 showed that the residential market has been saturated with efficient showerheads and faucet aerators.

Since the inception of the high-efficiency clothes washer rebate program in 1996, the utility has provided 32,500 rebates for high-efficiency clothes washers. Rebates are tiered to encourage customers to purchase clothes washers that meet efficiency standards expected to be released in 2007. Rebates of $50, $75, and $100 are provided depending on the efficiency rating of the clothes washer purchased. As a way to increase visibility of the clothes washer rebate program to both customers and retailers the utility partnered with other Bay Area water agencies to procure grant funding from the state.

Toilet rebates have been available to utility customers since the mid 1990s. The current, two-tiered rebate program, WaterSmart™ Toilet Replacement Program, provides rebates for ULF and

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[155] http://www.ebmud.com/services/account_information/understanding_my_account/rates_&_charges/water_rates/. Water Rates and Service Charges. Effective July 1, 2006. Accessed July 14, 2006.

[156] http://www.ebmud.com/wastewater/wastewater_rates/default.htm. Wastewater Rates, Charges and Fees. Effective July 1, 2005. *Single-FamilyMonthly Charges (BCC 8800).* Accessed July 14, 2006.

[157] http://www.ebmud.com/sites/default/files/pdfs/20080412%20-%20UWMP%202005%20Final%20Book.pdf. East Bay Municipal Utility District Urban Water Management Plan. November 2005. Chapter 6 Water Conservation. Accessed February 1, 2010.

high-efficiency toilets (HET). During the 2004 fiscal year 22% of the rebates provided were for HETs. In 2005, toilet rebates were provided for 1,030 single-family and 176 multi-family customers.

The utility promotes conservation by using a three-tiered inclining billing structure for water. There are several wastewater providers within the utility; not all wastewater providers use conservation billing rates.

CII Conservation Programs

The utility has provided a variety of water saving devices, primarily through surveys, to its CII customers including faucet aerators, showerheads, and toilet retrofit kits. In some cases CII customers could borrow devices to test in their business prior to purchasing them. As with residential customers, CII customers can be provided with a self-survey to improve their water efficiency. CII customers can also borrow water metering devices to determine the characteristics of their water use and allows the customer to implement the most cost-effective conservation measures.

There are nearly 5,000 irrigation accounts in the utility and water budgets have been established for more than 1,200 dedicated irrigation accounts. The utility uses presentations and targeting to encourage HOAs and irrigation accounts to reduce their water demand. Customers are provided with rebates that cover 50 – 100% of the cost of installing efficient irrigation equipment.

Rebates are provided as an incentive to CII customers who invest in equipment upgrades for processes such as cooling, water treatment, and washing. Rebates may cover as much as half of the cost of installing new hardware or changes processes and are based on an estimate of the savings. Rebates are also provided for high-efficiency clothes washers, HETs, ice machines, and x-ray machines. As with their residential customers, the utility has distributed free low flow faucet aerators and showerheads.

EBMUD is on the CUWCC task force designed to evaluate measures to improve the water use efficiency of both new and existing landscapes. The utility provides free landscape reviews to all of the cities and counties in their service area. The irrigation system efficiency and schedule, plant design and plant selection are included in the review.

Additional Conservation Programs

EBMUD is committed to ongoing conservation efforts and has participated in numerous conservation studies including:

- National Multi-Family Residential Sub-Meter Study
- Residential End-Use Study
- Market Penetration Study
- Water Closet Performance Testing
- Recycling Feasibility Study
- Oakland Zoo Conservation Study
- Irrigation Controller Pilot Study

Sonoma County Water Agency

The Sonoma County Water Agency was established in 1949 and currently provides "a functioning infrastructure and financial organization for regional water supply, wastewater management and flood control."[158] Sonoma County Water Agency manages and maintains a water transmission system that provides naturally filtered Russian River water to nine cities and special districts that in turn deliver drinking water to more than 600,000 residents in portions of Sonoma and Marin counties, including City of Cotati, Marin Municipal Water District, North Marin Water District, City of Petaluma, City of Rohnert Park, City of Santa Rosa, City of Sonoma, Valley of the Moon Water District, and Town of Windsor.[159]

Rohnert Park

Rohnert Park[160] is one of the earliest planned communities in the United States with each neighborhood designed around a park and elementary school. Located between Petaluma and Santa Rosa in the center of Sonoma County's business corridor, Rohnert Park is home to Sonoma State University; as a result education is one of Rohnert Park's largest industries and employers.

Demographics and Census Information

Rohnert Park is a relatively young community with a median age of 31.5 years. The median annual household income in Rohnert Park is $51,942. Of the population over the age of 25, 88.0% have a high school diploma or higher and 24.7% have a college degree or higher. Table 133 gives some additional characteristics about the homes in Rohnert Park.

Table 133: Demographic and household statistics for Rohnert Park

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,520	58.4	2.83	3.1	1979	5.8
Rental	$841	41.6	2.40	1.8	1980	6.2

158 http://www.envirocentersoco.org/SCWA/structure.htm. Sonoma County Water Agency Structure. Accessed August 22, 2006.

159 http://www.envirocentersoco.org/SCWA/structure.htm. Sonoma County Water Agency Structure. Accessed August 22, 2006.

160 http://www.rohnertparkchamber.org/. Welcome to Rohnert Park Chamber of Commerce. *A Community for Families.* Accessed July 21, 2006.

Customer Base

Rohnert Park has 8,717 customer accounts, 92% of which are residential accounts (87% single-family and 5% multi-family), 5% are commercial accounts, and 3% are irrigation and industrial accounts. Single family customers used 54% of the annual water deliveries in 2005 – the remaining 46% was used by commercial customers (multi-family, industrial, and irrigation were grouped in this category).

Table 134: Number of connections and deliveries in Rohnert Park for 2005[161]

Sector	Number of Accounts	Deliveries 2005 (MG)	% of Total Deliveries
Single Family	7,590	652.2	53.8
Multi-Family	413	Included in commercial	
Commercial	462	559.3	46.2
Industrial	2	Included in commercial	
Irrigation	250	Included in commercial	
Total	8,717		100

Water Rates, Rate Structure, and Sewer Charges

Residential customers of Rohnert Park are billed for water and sewer on a bi-monthly basis. The base monthly charge for water is $15.71. Customers are charged a uniform rate for water at $2.57 per kgal. Customers pay a base rate of $1.35 per month for sewer as well as $9.15 per kgal.

North Marin Water District

North Marin Water District (NMWD) serves the City of Novato in Marin County as well as several small districts in the West Marin area near the coast. In addition, service is also provided to Point Reyes Station, Olema, Bear Valley, Inverness Park, and Paradise Ranch Estates.[162] Since Novato is the largest community in the North Marin WD service area, demographic and census information are provided for Novato.

Demographics and Census Information

The median annual household income in Novato is $71,306. The median age of the population of 41.3 years is the highest of the study group. Of the population over the age of 25, 91.2% have

[161] Data provided by Carrie Pollard, Water Conservation Specialist for SCWA

[162] http://www.nmwd.com/index.html. About North Marin Water District. *Water Service.* Accessed August 22, 2005.

a high school diploma or higher and 51.3% have a college degree or higher. Table 135 gives some additional characteristics about the homes in Novato.

Table 135: Demographic and household statistics for Novato in North Marin Water District

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$2,344	65.7	2.42	2.8	1964	5.0
Rental	$1,105	34.3	2.21	1.7	1965	3.1

Climate

There are three climate zones in Marin County; the western half of the county is located in CIMIS Zone 1 known as Coastal Plains Heavy Fog Belt, the central section of the county is located in CIMIS Zone 4 known as South Coast Inland Plains and Mountains North of San Francisco and the eastern portion of the county is located in CIMIS Zone 5 known as Northern Inland Valleys.[163] Novato is located in Zone 5 and the weather data for the station that serves the Novato area is shown in Table 136. The comparison of 2005 weather data with historic data shows that 2005 was slightly cooler and wetter, with lower ET than previous years. It is important to note however that the station is very new and weather data has only been recorded since June 2003. The website for The City of Novato indicates that the weather is slightly warmer and drier that that found at the CIMIS station where the "mean annual temperature is 67 degrees, with an average minimum of 46 degrees and an average maximum of 71 degrees. Rainfall averages approximately 27.5 inches per year."[164]

[163] http://wwwcimis.water.ca.gov/cimis/info.jsp. California Irrigation Management System. Info Center. ET_o Zones Map. Accessed August 31, 2006.

[164] http://www.cityofnovato.org/about_nov.cfm. City of Novato. *Government and Utilities.* Accessed August 31, 2006.

Table 136: Black Point #187 Lat 38°05'28" Long 122°31'36" – period of record June 2003 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	51.5	57.9	67.7	68.3	71.9	77.1	80.2	79.6	78.9	72.6	61.9	54.0	68.5
Avg. Max. Temp. 2005 (F)	49.6	58.7	64.5	65.8	70.7	74.2	81.1	79.6	75.0	71.9	65.2	56.0	67.7
Avg. Min. Temp. (F)	36.7	40.2	41.0	39.8	44.7	47.8	50.8	50.8	47.5	43.5	38.6	36.5	43.2
Avg. Min. Temp. 2005 (F)	35.8	40.4	41.4	39.2	45.6	47.6	51.3	49.6	45.3	44.0	39.9	36.0	43.0
Avg. Monthly Precip. (in)	3.9	5.9	2.7	1.5	1.8	0.4	0.7	0.3	0.3	1.7	2.0	6.9	27.9
Monthly Precip. 2005 (in)	5.5	5.0	4.8	2.0	3.0	0.3	1.8	0.4	0.0	0.4	1.8	6.7	31.6
Avg. Monthly ETo (in)	1.0	1.5	3.6	4.9	5.9	6.0	7.1	6.1	4.9	3.5	1.8	1.0	47.3
Monthly ETo 2005 (in)	0.9	1.4	3.2	4.7	5.4	6.4	7.2	5.9	4.4	3.4	2.0	1.0	45.8

Water Supply and Demand

The North Marin WD service area, shown in Figure 100, covers approximately 100 square miles. NMWD receives approximately 80% of its water supply from the Russian River, provided by the Sonoma County Water Agency. The remaining 20% is from Stafford Lake which is used from late spring to early fall to supplement the supply from the Russian River.[165]

Table 137 is a breakdown of water deliveries supplied by North Marin Water District to its customers in 2000. Seventy-five percent of the deliveries were to residential customers (68.3% single-family and 6.9% multi-family). Commercial and irrigation customers each used approximately 11% and the remaining 2.3% was delivered to institutional and other customers.

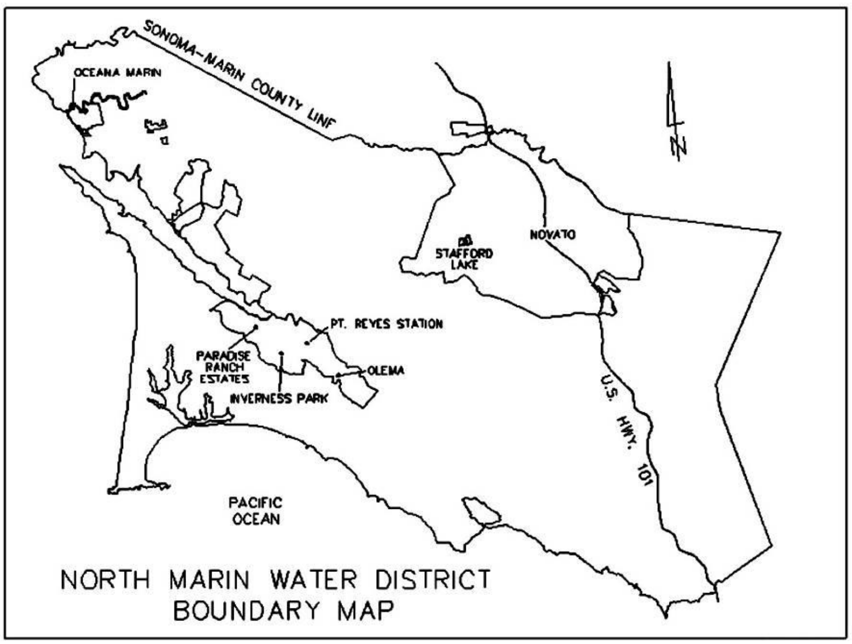

Figure 100: North Marin Water District Service Area[166]

[165] http://www.nmwd.com/novatowhere.html. North Marin Water District. Where Does My Water Come From And How Is It Treated? *Russian River Water*. *Stafford Treatment Plant.* Accessed August 22, 2006.
[166] http://www.nmwd.com/images/Boundary%20Map.jpg. About North Marin Water District. Territory. *Boundary Map.* Accessed August 22, 2006.

Table 137: Annual water delivery to accounts by sector for North Marin WD for 2005[167]

Sector	Number of Accounts 2005	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single Family	17,706	6,946	2,263	68.3
Multi-Family	647	704	229	6.9
Commercial	1,022	1,117	364	10.9
Irrigation	293	1,159	378	11.4
Institutional	102	231	75	2.2
Other	162	11	3.7	0.1
Total	19,932	10,168	3,313	100

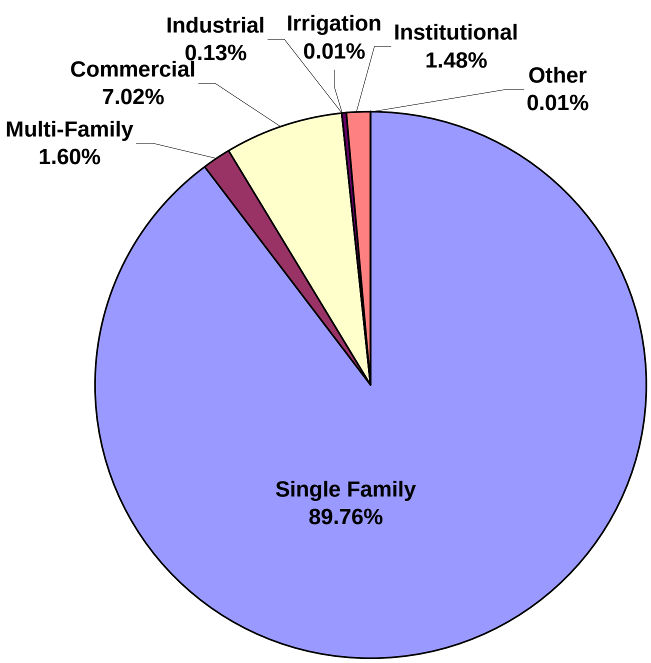

Figure 101: Percentage of 2005 metered accounts by sector in North Marin WD

Water Rates, Rate Structure, and Sewer Charges

Residential customers in North Marin WD are billed for water and sewer on a bi-monthly basis. The base monthly charge for water is $5.00. Customer rates are based on their elevation above the pumping station as well and an additional charge if they are located outside the improvement district as shown in Table 138. Customers who use water in excess of 15,000 gallons within the

[167] Data provided by Ryan Grisso, Water Conservation Coordinator for North Marin Water District, California

two-month billing period are charged an additional conservation fee of $3.00 per 100 cubic feet. Customers pay a base rate of $21.83 per month for sewer.[168]

Table 138: Residential commodity charge for customers in North Marin Water District[169]

Rate Zone	Elevation	Within Improvement District (per CCF)	Outside Improvement District (per CCF)
Zone A	0' – 60'	$1.70	$1.85
Zone B	61' – 200'	$1.90	$2.05
Zone C	201' – 400'	$2.35	$2.50
Zone D	401' +	$2.86	$3.01

Petaluma

Located on the Petaluma River, the City of Petaluma[170] is one of the oldest cities in California and on the National Register of Historic Places. "American Demographics magazine found this area to be America's number one choice among baby boomers in their mid-30s to mid-40s, who are affluent enough to choose where they settle."[171]

Demographics and Census Information

The median annual household income of Petaluma is $61,679. The median age of the population is one of the highest of the study groups at 37.1 years and is second only to the residents of North Marin Water District. Of the population over the age of 25, 85.9% have a high school diploma or higher and 30.1% have a college degree or higher. Table 139 gives some additional characteristics about the homes in Petaluma.

Table 139: Demographic and household statistics for Petaluma

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,622	70.1	2.75	3.2	1976	11.3
Rental	$870	29.9	2.59	2	1972	6

[168] http://www.studioefx.com/nsd/qanda.htm#generalrates. Novato Sanitary District. *Rates – General.* Accessed August 24, 2006.
[169] http://www.nmwd.com/novrates.html. North Marin Water District. *Novato Water Charges.* Accessed August 24, 2005.
[170] http://www.visitpetaluma.com/. Visit Petaluma. *Get Here.* Accessed July 21, 2006.
[171] http://www.petalumachamber.com/pages/livework.shtml. Petaluma Area Chamber of Commerce. *Affluent Baby Boomer Magnet.* Accessed July 21, 2006.

Climate

The Petaluma Chamber of Commerce describes Petaluma's "temperate climate is as close to perfect as possible without boredom."[172] Summers are dry and warm with temperatures ranging from the mid-60s to mid-80s and nighttime cooling from ocean breezes. Winter temperatures range from the mid-30s to 60 degrees. Average rainfall is 25 inches annually.

Table 140: Petaluma East #144 Lat 38°16'02" Long 122°36'58" – period of record August 1999 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	54.2	58.2	64.6	64.8	69.6	74.4	77.2	78.0	78.7	73.3	62.1	56.8	67.7
Avg. Max. Temp. 2005 (F)	48.3	57.3	60.8	62.4	63.8	68.8	75.8	73.4	75.6	72.9	67.1	58.0	65.4
Avg. Min. Temp. (F)	33.5	37.4	38.3	39.4	41.9	46.4	48.0	47.6	48.1	43.9	38.5	36.4	41.6
Avg. Min. Temp. 2005 (F)	30.7	35.0	35.8	35.1	38.9	42.6	42.4	40.4	47.4	44.9	39.6	39.7	39.4
Avg. Monthly Rainfall (in)	3.1	5.2	1.7	1.3	1.1	0.5	0.2	0.1	0.1	1.1	1.9	5.1	21.4
Monthly Rainfall 2005 (in)	3.9	4.2	3.0	1.9	3.1	0.3	0.0	0.0	0.0	0.3	1.9	12.1	30.6
Avg. Monthly ETo (in)	1.1	1.5	3.3	4.5	4.8	6.3	6.4	5.0	4.6	3.2	1.6	1.1	43.4
Monthly ETo 2005 (in)	0.9	1.4	2.9	4.4	4.7	5.6	6.4	5.1	4.1	3.1	1.8	0.8	41.2

[172] http://www.petalumachamber.com/pages/aboutpetaluma.shtml. Petaluma Area Chamber of Commerce. Petaluma's Voice for Business. *Climate.* Accessed September 1, 2006.

Table 141: Annual water delivery to accounts by sector for Petaluma for 2005[173]

Sector	Number of Accounts 2005	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single Family	17,014	5,614	1,829	58.5
Multi-Family	304	749	244	7.8
Commercial	1,330	1,982	646	20.8
Irrigation	2	457	149	4.8
Industrial	25	346	113	3.6
Institutional	280	417	136	4.3
Other	1	38	12	0.38
Total	18,956	9,603	3,129	100

Water Rates, Rate Structure, and Sewer Charges

Residential customers of Petaluma are billed for water and sewer on a bi-monthly basis. The base monthly charge for water is $3.79. Additionally, there is a three-tiered rate structure; customers are charged $2.16 per CCF for usage from 0-20 CCF, $2.37 per CCF for usage from 21-52 CCF and $2.61 per CCF for usage of 53 CCF or more on a bi-monthly basis. Customers pay $18.22 bi-monthly for sewer charges.

Santa Rosa

Located in the heart of Sonoma County wine country, Santa Rosa was called 'the chosen spot of all the earth' by well know botanist and horticulturalist Luther Burbank (March 7, 1849 – April 11, 1926). It was also home to cartoonist Charles M. Schultz, the creator of Peanuts and over the years numerous movies have been filmed there including Hitchcock's Shadow of a Doubt.[174]

Demographics and Census Information

The median annual household income in Santa Rosa is $50,931. The median age of the population is 36.2 years. Of the population over the age of 25, 85.2% have a high school diploma or higher and 27.6% have a college degree or higher. Table 142 gives some additional characteristics about the homes in Santa Rosa.

Table 142: Demographic and household statistics for Santa Rosa

	Median Monthly Payment ($)	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,490	48.5	2.56	2.9	1976	8.5
Rental	$862	51.5	2.57	1.8	1974	4.8

173 Data provided by Brian Lee, SCWA

174 http://www.visitsantarosa.com/didyouknow_all.asp. Santa Rosa Chamber of Congress. About Santa Rosa. *Did You Know?* Accessed August 21, 2006.

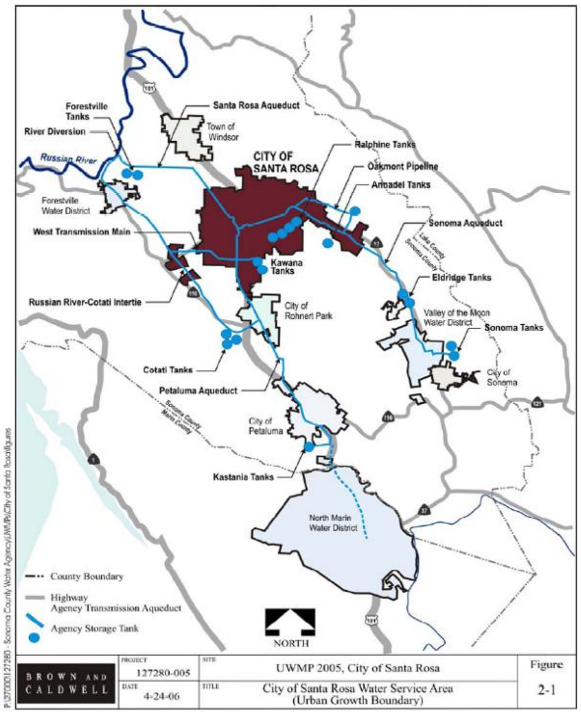

Figure 102: Service area for the City of Santa Rosa Utility from the 2005 Urban Water Management Plan[175]

Climate

Santa Rosa is located in Zone 5 on the CIMIS Reference Evapotranspiration Zones Map, described as Northern Inland Valleys (valleys north of San Francisco). It is clear from the data in Table 143 that 2005 had higher than average rainfall and lower than average temperatures resulting in ETo that was lower than average. Most of the rainfall occurs between November through the end of March and ETo is highest during the month of July. The average annual rainfall recorded from 1990 – 2005 is higher than that recorded for Santa Rosa during the period of 1952 – 2005. During that 52-year period the average annual precipitation was 29.63 inches.[176]

[175] http://ci.santa-rosa.ca.us/wc/pdf%20files/2005UWMPComplete.pdf. City of Santa Rosa. 2005 Urban Water Management Plan. Accessed June 30, 2006.

[176] http://ci.santa-rosa.ca.us/wc/pdf%20files/2005UWMPComplete.pdf. 2005 Urban Water Management Plan. City of Santa Rosa. Description of Existing Water System. *Climate.* Accessed August 21, 2006.

Table 143: Santa Rosa #83 Lat 38°24'04" Long 122°47'56" – period of record January 1990 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	56.8	60.6	64.6	67.2	71.5	76.6	79.7	83.9	79.7	75.6	65.0	57.0	71.0
Avg. Max. Temp. 2005 (F)	54.0	61.1	65.6	66.1	70.1	73.2	79.1	77.8	75.3	74.1	67.8	57.4	69.5
Avg. Min. Temp. (F)	37.1	38.1	39.2	39.1	43.3	46.7	49.1	49.0	46.6	42.2	38.5	35.8	42.6
Avg. Min. Temp. 2005 (F)	36.1	39.8	40.5	36.9	43.8	46.1	50.0	48.5	43.8	40.1	36.7	39.1	42.0
Avg. Monthly Rainfall (in)	6.8	6.5	4.1	1.9	1.7	1.3	0.5	0.7	0.3	1.6	3.7	7.4	36.6
Monthly Rainfall 2005 (in)	4.0	4.0	6.2	1.9	4.7	0.4	0.0	0.4	0.0	1.6	3.2	14.5	40.8
Avg. Monthly ETo (in)	1.0	1.6	3.2	4.4	5.6	6.2	6.5	5.9	4.6	3.2	1.5	1.0	44.6
Monthly ETo 2005 (in)	1.0	1.5	3.1	4.4	5.1	5.8	6.7	5.4	4.2	3.4	1.8	0.8	42.9

Customer Base

The City of Santa Rosa has 50,352 customers (connections). There are 41,839 single-family residential customers, 3,085 multi-family customers, 2,768 commercial customers and 939 accounts classified as other. Figure 103 is a graph of the percentages of each utility customer category. Single family connections make up 84% of the customer connections – clearly the largest category. When combined with multi-family accounts, residential customers make up 90% of the customer base for Santa Rosa.

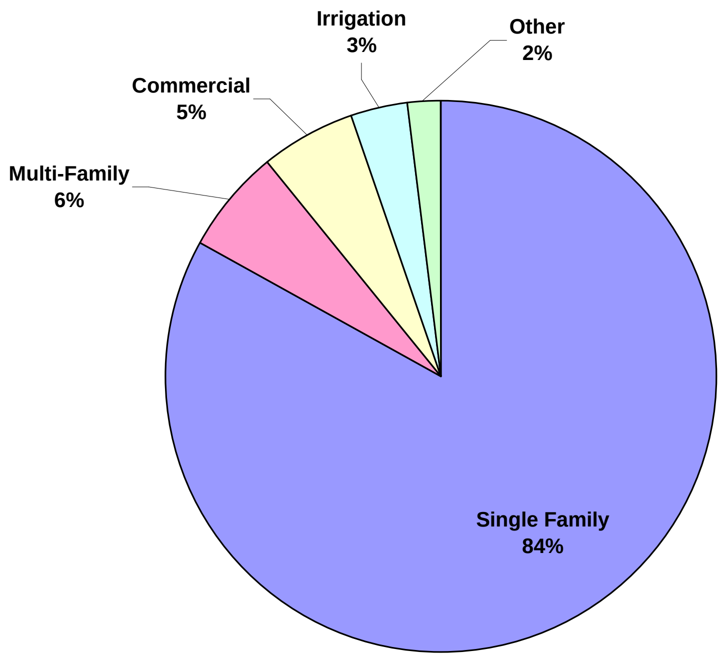

Figure 103: Percentage of 2005 connections by customer category in Santa Rosa

Water Supply and Demand

The City of Santa Rosa purchases water from Sonoma County Water Agency. Most of the water is surface water that is diverted from the Russian River, supplemented by groundwater from the Santa Rosa Plain.[177] Table 144 shows the number of accounts, by sector, in 2005 as well as the water deliveries to each sector. Single family customers make up 84% of the customer accounts and 57% of the water delivered.

[177] http://ci.santa-rosa.ca.us/wc/pdf%20files/2005UWMPComplete.pdf. 2005 Urban Water Management Plan. City of Santa Rosa. Water System Facilities Source Waters. *Surface Water System Facilities.* Accessed August 21, 2006.

Table 144: Annual water delivery to accounts by sector for 2005[178]

Sector	Number of Accounts 2005*	Deliveries (AF)	Deliveries (MG)	% of Total Deliveries
Single-Family	41,839	12,420	4,047	57.0
Multi-Family	3,085	3,345	1,090	15.4
Commercial	2,768	3,455	1,126	15.9
Irrigation	1,729	2,553	832	11.7
Other*	931			
Total	50,352		7,095	100

*These are fire accounts and don't have ongoing water use associated with them

Water Rates, Rate Structure, and Sewer Charges

Santa Rosa customers are billed monthly for water and sewer use. At the time of the study customers paid a fixed monthly charge of $5.53 for water and $12.82 for wastewater. In addition customers were charged $3.15 per kgal for water and $7.85 per kgal for sewer up to their "sewer cap." The "sewer cap" is the indoor allotment or average winter consumption calculated from average winter water usage in the months of December, January, and February where it is assumed that all usage during that period of time is indoors. In 2007 Santa Rosa implemented a three-tier rate structure. Details can be found on the city's website at http://ci.santa-rosa.ca.us/departments/finance/revenue/utilbill/Pages/CurrentResRates.aspx.

Water Conservation Programs[179]

The North Marin Water District and the cities of Rohnert Park, Petaluma and Santa Rosa are retail providers for Sonoma County Water Agency (SCWA). SCWA signed the CUWCC MOU in 1998 and is the first wholesale agency in California to have all of its water contractors sign the MOU. The Agency works with its retail providers to implement all economically feasible wholesale BMPs as well as some of the retail BMPs. In some cases contractors have implemented conservation measures that exceed the requirements of the BMP or have developed conservation measures in addition to the BMPs that SCWA has identified as Tier 2 BMPs.

SCWA has developed a model of savings projections and future water demand from four levels of conservation measures that include projected savings from implementing the current BMPs, projected savings from implementing Tier 2 BMPs, adoption of new development standards, and savings from future plumbing retrofits and required by plumbing code.

Residential Conservation Programs

In addition to the current BMPs, SCWA has developed a more aggressive list of BMPs which will be implemented in the future. These Tier 2 BMPs will require high-efficiency toilets, clothes washers, faucets and showerheads, a Cash for Grass program, rebates for irrigation upgrades, synthetic turf and Smart Irrigation Controllers, and financial incentives for water use below

[178] Information provided by Jennifer Burke, Senior Water/Wastewater Planner for the City of Santa Rosa, CA
[179] http://www.scwa.ca.gov/files/2005_uwmp_report.pdf. Sonoma County Water Agency 2005 Urban Water Management Plan. December 2006. Section 6.1 BMP Implementation. Accessed February 24, 2010.

water budget allotment. The BMPs will encourage increased water efficiency in new development with products such as Smart irrigation controllers and hot water on demand systems. Toilet replacement programs have been in place for more than ten years through rebates, direct installation and community-based organizations (CBOs).

Irvine Ranch Water District

The Irvine Ranch Water District is a special district formed in 1961 to provide potable water, wastewater service and recycled water. IRWD is located in the south-central portion of Orange County, and encompasses an area of approximately 181 square miles. Figure 104 is a map of Irvine Ranch Water District and its location within Orange County. Irvine Ranch Water District provides service to 316,287 customers in the City of Irvine, and portions of Tustin, Newport Beach, Costa Mesa, Orange, Lake Forest and unincorporated areas of Orange County.[180]

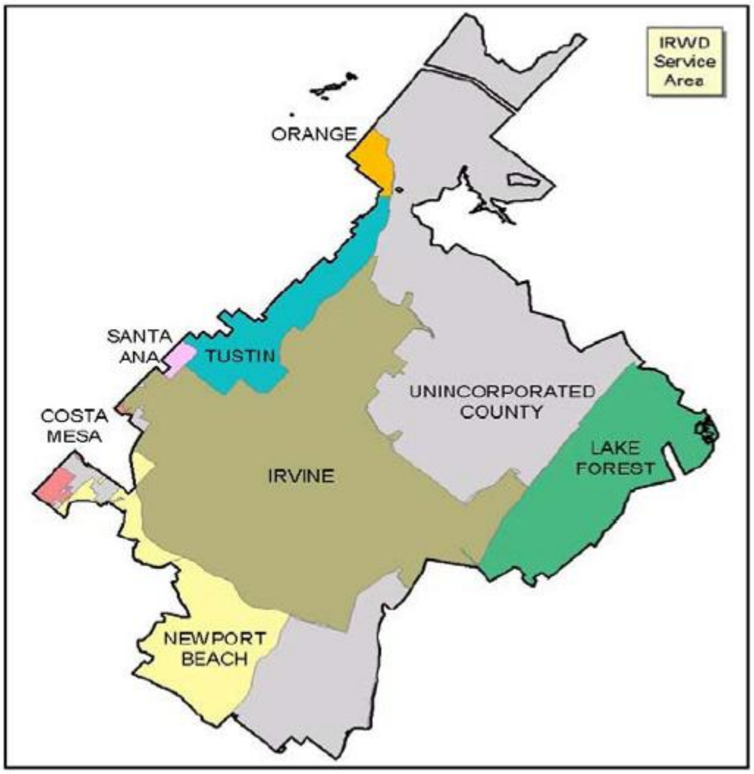

Figure 104: Map of Irvine Ranch Water District[181]

Demographics and Census Information

The following information on IRWD comes from the 2000 U.S. Census Bureau.[182] IRWD serves an affluent community with an average median household income of $72,057. Only 5% of families live below the poverty level. The median home price is $316,800 and 60% of the homes are owner occupied with an average monthly mortgage of $1,897. Table 145 gives some additional characteristics about the homes in Irvine. The median age of the residents in IRWD is

[180] http://www.irwd.com/AboutIRWD/servicearea.php. About IRWD. *Service Area.* Accessed June 26, 2006.
[181] http://www.irwd.com/BusinessCenter/UWMP-2005-F.pdf. Irvine Ranch Water District. 2005 Urban Water Management Plan. Section II-5: Contents of UWMP. Accessed June 14, 2006.
[182] http://factfinder.census.gov/home/saff/main.html?_lang=en. 2000 Census Data. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed June 13, 2006.

33 years. Of the population over the age of 25, 95.3% have a high school diploma or higher and 58.4% have a college degree or higher.[183]

Table 145: Demographic and household statistics for City of Irvine[184]

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,897	60%	2.78	3.1	1980	16.1%
Rental	$1,177	40%	2.46	1.8	1985	16.1%

Climate

There are three distinct climates or zones in the IRWD service area as defined by CIMIS (California Irrigation Management Information System). Zone 2 is described as a Coastal Mixed Fog Area and has an average annual ETo of 39 inches, Zone 4 is South Coast Inland Plains and Mountains North of San Francisco with an average annual ETo of 46.6 inches and Zone 6 is Upland Central Coast and Los Angeles Basin with an average annual ETo of 49.7 inches.

Weather and ETo information was obtained from CIMIS Station #75 located at the University of California Field Station near Irvine. Station #75 is located in ETo Zone 6. Table 146 compares the average monthly minimum and maximum temperatures, average monthly rainfall, and average monthly ETo from October 1987 to December 2005, with the same data from 2005. The table shows that although maximum temperatures in 2005 were slightly cooler than average, minimum temperatures were warmer than the 20-year average. However, ETo was slightly lower in 2005 than the 20-year average (48.12 inches vs. 49.12 inches) and rainfall was more than five inches above the 20-year average.

[184] The City Irvine makes up approximately 45% of the homes in the IRWD service area. Therefore weather and census information are given for Irvine.

Table 146: Irvine #75 Lat 33°41’19” Long 117°43’14” – period of record October 1987 to December 2005[185]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	66.6	66.3	68.2	70.6	73.3	75.8	80.8	82.6	81.5	76.4	71.2	66.3	73.3
Avg. Max. Temp. 2005 (F)	65.7	65.3	67.4	70.4	74.2	73.7	81.8	81.5	79.1	74.7	73.5	66.9	72.9
Avg. Min. Temp. (F)	44.5	45.6	47.2	49.2	54.0	56.2	59.7	59.8	58.4	54.6	48.1	44.0	51.8
Avg. Min. Temp. 2005 (F)	47.2	49.4	48.9	47.8	54.8	56.5	61.8	60.9	56.0	54.4	49.9	46.8	52.9
Avg. Monthly Precip. (in)	2.5	5.0	2.2	0.9	0.3	0.2	0.1	0.1	0.2	0.6	0.8	2.0	14.9
Monthly Precip. 2005 (in)	7.3	8.7	1.1	1.2	0.5	0.1	0	0	0.0	0.6	0.1	0.7	20.1
Avg. Monthly ETo (in)	2.3	2.5	3.7	4.7	5.2	5.7	6.4	6.1	4.6	3.4	2.6	2.2	49.4
Monthly ETo 2005 (in)	2.0	2.1	3.6	5.0	5.7	5.0	6.6	5.7	4.5	3.4	2.8	1.9	48.1

[185] http://wwwcimis.water.ca.gov/cimis/monthlyReport.do. California Irrigation Management Information System. Department of Water Resources. Office of Water Use Efficiency. *Monthly Report*. South Coast Valleys – Irvine – #75. Accessed June 26, 2006.

Customer Base

As of 2006 there were a total of 91,733 accounts served by IRWD. These consist of 77,797 residential connections (47,650 single-family and 30,147 multi-family), 3,973 commercial, 223 industrial, 1,757 landscape irrigation, 21 agricultural, 192 public authority, and 3,958 construction and temporary. In addition, IRWD provides recycled water to 3,812 connections. Based on overall water deliveries of 26,820 MG to 92,235 accounts average water delivery equates to 291 kgal/account.[186]

Water Supply and Demand[187]

Irvine Ranch Water District (IRWD) receives water from the State Water Project (California Aqueduct) and the Colorado River water imported by the Metropolitan Water District. Additional supply comes from the Dyer Road Wellfield, which pumps water from the Orange County Groundwater Basin. Annually, IRWD supplies approximately 53,572 acre-feet (17,464 MG) of treated or potable water, 6,301 acre-feet (2,053 MG) of untreated (non-potable) water, and 22,434 acre-feet (7,310 MG) of recycled wastewater, totaling 82,307 acre-feet or 26,827 MG. Residential water use is the largest sector and makes up 39% of the total use (33% single-family and 6% multi-family). This is followed by landscape accounts (29%), agriculture (11%), commercial (10%), industrial (7%), and institutional/government (4%). [188]

Water Rates, Rate Structure, and Sewer Charges

The IRWD uses a water budget based rate structure for all of its customers. Details can be found on the District web site.[189]

Residential Conservation Programs

IRWD has a five-tiered rate structure which is designed to encourage conservation and discourage water waste. Residential customers receive an individualized allocation of water based on the number of residents, landscape area, and local weather data. Water use with this allocation is billed at lower rates than water use that is deemed inefficient, excessive, or wasteful. The price of each tier doubles, which provides a strong incentive for customers to conserve. IRWD has shown the water allocation billing system to be "at least as effective as" surveys at reducing water use (landscape use in particular). Customers whose water use exceeds their allocation are encouraged to call IRWD. During a home survey customers are provided with free low-flow showerheads and faucet aerators, toilet displacement devices[190], "leak" checks, and information on irrigation scheduling. IRWD customers can request faucet aerators and showerheads that are provided free of charge. IRWD provides a rebate of $100 towards the purchase of a high-efficiency clothes washer. In 2004 the utility provided 1,084 customer rebates for clothes washers. Historically IRWD provided rebates on ULFTs, but these were discontinued.

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186 http://www.irwd.com/AboutIRWD/facts_figures.php. About Irvine Ranch Water District. *Facts and Figures*. Accessed June 26, 2006.
187 http://www.irwd.com/BusinessCenter/UWMP-2005-F.pdf. Irvine Ranch Water District. 2005 Urban Water Management Plan. Accessed June 14, 2006.
188 http://www.irwd.com/AboutIRWD/facts_figures.php. About IRWD. *Facts and Figures.* Accessed June 14, 2006.
189 http://www.irwd.com/customer-care/rates-charges/residential-rates.html
190 Toilet displacement devices were no longer distributed after 1995.

CII Conservation Programs

All CII customers are given a water allocation budget based on each business' unique demand for water. Water use above these tailored budgets sends a significant price signal to alert customers to potential water waste such as a leak or excessive irrigation. Water use in this sector decreased by only 2.3% from 1997 to 2004 however the number of accounts has increased by 55%. The per-account reduction during that same time period is 36%.

IRWD does not have a program in place to market surveys to large landscape customers. However, 84% of all dedicated irrigation meter accounts have water budgets in place. Conservation pricing has been an effective tool in reducing wasteful water use practices at these sites. In addition, IRWD offers landscape irrigation training and several hundred CII customers with mixed-use meters have been provided with water budgets for their landscape. A notice of water use is provided to accounts with water budgets each billing cycle.

Los Angeles Department of Water and Power

Los Angeles Department of Water and Power (LADWP) provides water service to the nearly 4 million residents of the City of Los Angeles and surrounding areas. The City of Los Angeles is the 10th largest economy in the world and the second most populous city in the United States, covering an area of 224 square miles. The residents of Los Angeles are ethnically diverse with 140 countries represented and 86 languages spoken. Los Angeles has one of the world's largest ports with exports that include aircraft and space craft, integrated circuitry, and computers. Los Angeles is also a leader in the fashion industry and is home to many institutions of higher learning.[191]

Demographics and Census Information

The following information on Los Angeles comes from the 2000 U.S. Census Bureau. The median annual household income in Los Angeles of $36,687 is the lowest of all the study sites and 9.2% of families live below the poverty level. The median home price is $221,600 and only 39% percent of the homes are owner occupied. The median monthly mortgage is $1,598. Table 147 gives some additional characteristics about the homes in Los Angeles. The median age of the residents in Los Angeles is 32 years. Of the population over the age of 25, 66.6% have a high school diploma or higher and 25.5% have a college degree or higher.

Table 147: Demographic and Household Statistics for the City of Los Angeles[192]

	Median Monthly Payment	Percent of Occupied Homes	Average Household Size	Average Number of Bedrooms	Median Yr. Structure Built	Percentage of Homes Built after 1995
Homeowner	$1,598	38.6	2.99	2.7	1956	0.4
Rental	$612	61.4	2.73	1.2	1964	0.5

Climate

Los Angeles has a Mediterranean climate due to its mild weather and 329 days of sunshine. The center of Los Angeles is located in CIMIS Zone 6 known as the Upland Central Coast and Los Angeles Basin described as a higher elevation coastal region. The western portion of Los Angeles is in Zone 4 known as the South Coast Inland Plains and described as having more sunlight and higher ETo than Zone 3. There are six CIMIS stations located in various areas around L.A. County; ET, temperature and precipitation data used in the 2005 Urban Water Management Report are shown in Table 148 and averages the weather data from an inland CIMIS station (Glendale) and a station located closer to the coast (Santa Monica). The data for these two stations are given in Table 149 and Table 150 respectively.

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[191] http://www.lachamber.org/. Los Angeles Area Chamber of Commerce. *Facts About LA.* Accessed August 23, 2006.

[192] http://factfinder.census.gov/home/saff/main.html?_lang=en. 2000 Census Data. Fact Sheet. Housing Characteristics. *Physical Characteristics. Financial Characteristics.* Accessed August 23, 2006

Table 148: Summary table of temperatures, rainfall and ETo for Los Angeles from the LADWP 2005 Urban Water Management Plan[193]

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Standard Avg. ETo (in) (1)	2.0	2.3	3.5	4.6	5.0	5.6	6.1	6.0	4.48	3.7	2.6	2.3	48.1
Avg. Rainfall (in)(2)	3.4	3.2	2.5	1.0	0.3	0.1	0.0	0.1	0.3	0.3	1.5	1.9	14.5
Avg. Max. Temp. (F)(2)	67.0	68.5	69.3	72.0	74.0	78.2	83.6	84.4	83.0	78.5	72.9	67.9	74.9

(1) Average of Glendale and Santa Monica ETo stations, as there are no active stations in Los Angeles
(2) Downtown Los Angeles (1948-2003)

193 http://www.ladwp.com/ladwp/cms/ladwp007157.pdf.

Table 149: Los Angeles – Santa Monica #99 Lat 34°02'28" Long 118°28'34" – period of record December 1992 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp. (F)	65.7	64.2	65.9	67.1	68.2	70.7	73.5	75.7	75.6	72.6	69.0	66.0	69.5
Avg. Max. Temp. 2005 (F)	65.4	65.2	65.3	67.4	69.8	69.7	74.1	74.8	73.9	71.6	72.0	66.5	69.6
Avg. Min. Temp. (F)	48.8	48.4	50.0	50.7	54.6	57.4	60.2	60.7	60.0	56.2	51.4	48.7	53.9
Avg. Min. Temp. 2005 (F)	51.2	51.4	51.8	51.4	56.0	56.3	61.3	61.2	57.2	55.8	55.2	50.3	54.9
Avg. Monthly Rainfall (in)	4.6	6.8	2.1	0.8	0.5	0.4	0.2	0.1	0.2	0.5	1.2	1.8	19.1
Monthly Rainfall 2005 (in)	8.9	9.4	2.3	1.0	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0	22.5
Avg. Monthly ETo (in)	2.1	2.3	3.6	4.7	5.1	5.3	5.6	5.6	4.2	3.3	2.5	2.2	46.7
Monthly ETo 2005 (in)	2.0	2.2	3.4	4.9	5.3	5.3	5.6	5.3	4.3	3.0	2.6	1.9	45.8

Table 150: Los Angeles – Glendale #133 Lat 34°11’59” Long 118°13’56” – period of record August 1996 to December 2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max. Temp (F)	64.9	63.3	67.3	68.0	73.0	75.4	82.0	84.0	81.7	75.4	69.1	65.1	72.4
Avg. Max. Temp. 2005 (F)	63.7	62.8	65.8	69.2	73.9	74.5	83.6	83.5	79.2	73.8	72.8	66.3	72.4
Avg. Min. Temp. (F)	43.7	43.0	45.3	46.3	51.7	54.8	58.5	59.5	58.1	52.7	46.3	42.8	50.2
Avg. Min. Temp 2005 (F)	45.0	46.4	45.9	46.4	52.0	53.4	60.2	59.6	54.7	53.1	48.9	44.7	50.9
Avg. Monthly Rainfall (in)	3.7	5.8	1.9	1.3	0.9	0.4	0.1	0.2	0.3	0.8	1.0	3.2	19.6
Avg. Monthly ETo (in)	2.0	2.1	3.3	4.0	4.7	4.8	5.7	5.7	4.4	3.3	2.2	1.8	43.9

Water Supply and Demand

LADWP provides water to the City of Los Angeles as well as parts of West Hollywood, Culver City, and minor portions adjacent to the city. The primary water supply for the 295,000 acre service area is a gravity-feed system that reaches Los Angeles via an aqueduct which extends 340 miles from Mono Basin to Los Angeles. The aqueduct is fed by late spring and early summer runoff from the eastern Sierra Nevada. Local groundwater is another source of water for the city and during dry years may provide as much as 30% of the water supply. When supplies of water from the aqueduct and groundwater are inadequate Los Angeles can purchase water from Metropolitan Water District to supplement its supply.[194]

[194] http://www.ladwp.com/ladwp/cms/ladwp007157.pdf. 2005 Urban Water Management Plan for Los Angeles Department of Water and Power. Executive Summary. Current Water Supply. Accessed August 24, 2006.

Table 151 shows the amount of water delivered by sector to Los Angeles in 2000 and projected water deliveries for 2005. In 2000, LADWP delivered 677 million gallons of water; single-family customers used 240 MG, multi-family customers 199 MG, commercial 112 MG governmental customers 41 MG, industrial 24 MG and non-revenue 60. Projected water use for 2005 was 661 million gallons; the most noticeable decreases were in the residential, industrial, and non-revenue sectors.

Table 151: Actual and projected annual water delivery to accounts by sector for 2000 and 2005 in Los Angeles[195]

Sector	Deliveries 2000 (MG)	% of Total Deliveries	Deliveries 2005 (MG)	% of Total Deliveries
Single-Family	240	35	231	35
Multi-Family	199	29	198	30
Commercial	112	17	119	18
Governmental	41	6	43	7
Industrial	24	4	20	3
Non-Revenue	60	9	48	7
Total	677	100	661	100

Water Rates, Rate Structure and Sewer Charges

LADWP's rate structure is unique among the utilities in the study; the complete rate structure is shown in Appendix A of this report. Customers are billed bi-monthly using a two-tier rate structure; Tier 1 is based on the number of residents in the home, the lot size, the zip code, and the ETo zone (low, medium, high). Tier 1 rates vary from low season to high season from $2.14 per CCF in the high season to $2.18 per CCF in the low season. The high season is from June 1 – October 31 and low season is from November 1 – May 31. Tier 2 is for any water use that exceeds the allotment and is $3.18 per CCF.[196]

Sewer charges are based on the customer's average daily winter consumption from the previous year, which is then multiplied by the number of days in the billing period to determine the number of CCF used in the billing period. Customers are charged $2.85 per CCF.[197]

[195] http://www.ladwp.com/ladwp/cms/ladwp007157.pdf. 2005 Urban Water Management Plan for Los Angeles Department of Water and Power. Executive Summary. Water Demand. *Water Demand Projections.* Accessed August 25, 2006.

[196] http://www.ladwp.com/ladwp/cms/ladwp001068.jsp. Understanding the LADWP Water Bill. Schedule A – Single Dwelling Unit Residential Customer. Accessed August 25, 2006.

[197] http://www.lacitysan.org/fmd/sscbill.pdf. City of Los Angeles Bureau of Sanitation. Financial Management Division. *Sample Bill.* Accessed August 25, 2006.

Conservation[198]

LADWP's conservation program is designed to increase awareness of and support for conservation from its customers. Demand-side management, infrastructure improvement, and conservation pricing serve to increase system reliability and efficiency. Despite a population increase of 750,000 residents in the past 20 years water usage has remained the same. Los Angeles consistently ranks among the lowest in per person water consumption when compared with California's largest cities.

Residential Conservation

In the early 1990s residents of Los Angeles reduced their water consumption by 30% in response to severe drought conditions and mandatory conservation measures. Because of ongoing conservation programs and measures LADWP customers have maintained much of the water savings achieved during the drought. Many of the conservation measures promoted by the city are designed to provide long-term savings through replacement of fixtures and appliances with more efficient models. Rebates, community-based organizations, and direct installation programs have resulted in the replacement of more than 1.24 million toilets through the Ultra-Low Flush Toilet Rebate Program since its inception in 1990. A Retrofit on Resale ordinance requires the installation of ULF toilets and efficient showerheads in all single and multi-family residences prior to the close of escrow. In 2003, the ULF toilet distribution program was supplemented with free installation of toilet flappers, showerheads, and faucet aerators.

The clothes washer rebate program has been popular with residential customers; 32,000 high-efficiency clothes washer were installed between 1998 and 2005. The minimum efficiency standards for high-efficiency clothes washers were increased in 2004 and will increase again in 2007.

More than a million water conservation kits have been distributed to customers since the drought and include toilet "leak" detection, toilet displacement bags, and conserving showerheads, all of which are provided to customers free of charge. Community involvement, customer education, and school programs are integral to LADWP's conservation efforts as is ongoing research to determine the effectiveness of various conservation programs. Pilot programs are currently underway to examine the effectiveness of toilet flapper replacement and the use of weather-based irrigation controllers.

Commercial Conservation

LADWP has partnered with Metropolitan Water District to promote conservation in its commercial customer sector. These customers, as well as industrial and institutional customers place some of the highest volume users served by LADWP. Financial incentives, packaged water efficiency measures, and rebates are available to the CII sector. Many conservation measures are tailored for specific businesses.

The Commercial Rebate Program began in 2001 and includes rebates for high-efficiency commercial clothes washers, ultra-low flow toilets and urinals, and cooling tower conductivity

[198] http://www.ladwp.com/ladwp/cms/ladwp007157.pdf. City of Los Angeles Department of Power and Water. 2005 Urban Water Management Plan. Chapter 2 Water Conservation. Accessed January 8, 2010.

controllers. By 2005 rebates had been provided for 15,500 toilets and 5,600 clothes washers. Retrofits of water intensive equipment has been funded through TAP (Technical Assistance Program). Site-by-site incentives are based on the water savings achieved through retrofits of water-intensive equipment such as cooling towers and x-ray processors.

Improving efficient landscape irrigation has significant potential for water conservation. Guidebooks, free training courses, demonstration gardens and surcharges are among the many tools used by LADWP to reduce demand. Other measures include examination of savings from weather-based irrigation controllers, irrigation system maintenance and upgrades, appropriate plant selection, and irrigation using storm water capture, cisterns, and other non-potable water sources.

APPENDIX C: Residential Water Use Survey

Household Water Use Survey

Indoor Water Fixtures

1. **Please indicate how many of each of the following types of water-using appliances or fixtures you have in your home. Please circle the appropriate number for each.**

	None	One	Two	Three	Four	Five	Six	Seven or more
Toilets	0	1	2	3	4	5	6	7+
Bathtub with shower	0	1	2	3	4	5	6	7+
Bathtub only	0	1	2	3	4	5	6	7+
Shower only (no bathtub)	0	1	2	3	4	5	6	7+
Indoor utility/garage sink	0	1	2	3	4	5	6	7+

2. **Please indicate whether you have any of the following in your home. Please check the appropriate box for each.**

	Yes	No
Garbage disposal	❑	❑
Top-loading clothes washing machine	❑	❑
Front-loading clothes washing machine	❑	❑
Dishwashing machine	❑	❑
Whirlpool bathtub with jets	❑	❑
Indoor spa or hot tub with jets (if hot tub is NOT usually filled with water, indicate "no")	❑	❑
Evaporative/swamp cooler	❑	❑
A built-in indoor water feature (like a water fountain or water pond)	❑	❑
A "whole house" water treatment system (like a water softener or a filter system) which is attached to water system, not just to a faucet	❑	❑

	None	One	Two	Three	Four or more	Don't Know
3. **How many of the toilets in your home are ultra-low-flush toilets (1.6 gallons per flush)?** *(If your home was built in 1994 or later, the toilets are probably ultra-low flush)*	❑	❑	❑	❑	❑	❑
4. **How many of the showers in your home have low-flow (water conserving*) showerheads?** **2.5 gallons per minute (gpm) or less, usually stamped on the showerhead*	❑	❑	❑	❑	❑	❑
5. **How many of the showers in your home have a hand-held sprayer?**	❑	❑	❑	❑	❑	❑

6. **Do any of the showers in your home have multiple showerheads?**

❑ Yes → **How many showerheads per shower?** ❑ 2 ❑ 3 ❑ 4 or more

❑ No

7. **Please indicate whether you have renovated or replaced any of the following since 1995. Please check the appropriate box for each.**

	Yes	No
Plumbing pipes (inside the house)	❑	❑
Bathroom fixtures	❑	❑
Kitchen fixtures	❑	❑

8. **Please indicate whether you have any of the following. Please check the appropriate box for each.**

	Yes	No
Leaking toilet (you can hear it running when not in use)	❑	❑
Dripping faucet	❑	❑
Leaks in your pool system	❑	❑
Leaks in your irrigation system	❑	❑
Other leaks in the water system	❑	❑

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Hot Water

9. What type is your water heater? (Please check all that apply.)
- ❑ Gas
- ❑ Electric
- ❑ Propane
- ❑ Solar
- ❑ Other ________________
- ❑ Don't know

10. Do you have or have you installed a remedy to eliminate or reduce "waiting for hot water"?
- ❑ Yes
- ❑ No → ***go to question #12***
- ❑ Don't Know → ***go to question #12***

11. What remedies are installed? (Please check all that apply.)
- ❑ Tankless water heater
- ❑ On-demand system (recirculating pump that goes on when I push a button)
- ❑ Other __________________________
- ❑ Recirculating pump installed on hot water system → **How does it work?**
  - ❑ It runs all the time
  - ❑ It is controlled by a timer clock
  - ❑ Don't know
  - ❑ Other _________________

12. Does hot water take longer to reach some places in your house than others?
- ❑ No, hot water reaches all fixtures in about the same amount of time
- ❑ Yes, some places take longer than others for hot water to reach → **Which rooms? (Check all that apply.)**
  - ❑ kitchen
  - ❑ master bathroom
  - ❑ other bathroom
  - ❑ other room ______________

13. Thinking of the place in the house where it takes hot water the longest to reach, how long would you say you have to wait for hot water?
- ❑ Almost no time at all
- ❑ Not very long, we just have to let the water run for a few seconds
- ❑ Pretty long, we have to let the water run a while before it runs hot
- ❑ Very long, we have to let the water run a long time before it runs hot

14. Does the wait for hot water bother you?
- ❑ Yes, very much
- ❑ Yes, a little bit
- ❑ No, not really

Outdoor Landscape

15. Do you water your outside landscape? ***(Include everything you apply water to, either by hand, or via an irrigation system or other method.)***
- ❑ Yes
- ❑ No → ***go to question #36***

16. Do you use a contractor for any part of your outdoor landscape maintenance?
- ❑ Yes
- ❑ No → ***go to question #19***

17. Is your contractor responsible for watering (irrigating) your outdoor landscape?
- ❑ Yes
- ❑ No

18. About how much of your outdoor landscape is <u>turf (lawn or grass)</u>?
- ❑ All of it (100%)
- ❑ Half or more
- ❑ About 20% to 50%
- ❑ About 10% to 20%
- ❑ About 5% to 10%
- ❑ Less than 5%
- ❑ None of it → ***go to question #21***

19. During the winter months of the year (generally December - February), how often do you usually water your turf?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

20. During the summer months of the year (generally June - August), how often do you usually water your turf?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

Household Water Use Survey (version 2006-11-01) *Page 2 of 5*

21. About how much of your outdoor landscape is garden (flower or vegetables)?
- ❑ All of it (100%)
- ❑ Half or more
- ❑ About 20% to 50%
- ❑ About 10% to 20%
- ❑ About 5% to 10%
- ❑ Less than 5%
- ❑ None of it → *go to question #24*

22. During the winter months of the year (generally December - February), how often do you usually water your garden(s)?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

23. During the summer months of the year (generally June - August), how often do you usually water your garden(s)?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

24. About how much of your outdoor landscape is other landscape plants (e.g., trees, shrubs, vines, ground covers, etc.)?
- ❑ All of it (100%)
- ❑ Half or more
- ❑ About 20% to 50%
- ❑ About 10% to 20%
- ❑ About 5% to 10%
- ❑ Less than 5%
- ❑ None of it → *go to question #27*

25. During the winter months of the year (generally December - February), how often do you usually water your other landscape plants?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

26. During the summer months of the year (generally June - August), how often do you usually water your other landscape plants?
- ❑ Never
- ❑ Twice a month or less
- ❑ A few times per month
- ❑ 1 day a week
- ❑ 2 days a week
- ❑ 3 days a week
- ❑ 4 days a week
- ❑ 5 days a week
- ❑ 6 days a week
- ❑ 7 days a week
- ❑ Not sure

27. In addition to the water purchased from your water utility, do you use any of the following sources of water for your outdoor water needs?
- ❑ No additional sources of water used
- ❑ Well water
- ❑ Canal/ditch
- ❑ Stream/river
- ❑ Cistern (rainwater harvesting)
- ❑ Landscaping or device which directs roof water toward plants in the yard
- ❑ Other: ____________________

28. Is any part of your outdoor landscape watered manually?

❑ Yes ❑ No → *go to question #31*

29. In what ways is the outdoor landscape watered manually? (Please check all that apply.)
- ❑ Hand-held garden hose (with or without a nozzle)
- ❑ Garden hose with sprinkler attached
- ❑ Soaker hose
- ❑ Drip irrigation or bubbler system
- ❑ In-ground sprinkler system without a timer

30. About how much of your outdoor landscape is watered manually?
- ❑ All of it (100%)
- ❑ Half or more
- ❑ About 20% to 50%
- ❑ About 10% to 20%
- ❑ About 5% to 10%
- ❑ Less than 5%

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31. Do you have an in-ground watering (irrigation) system?
❑ Yes ❑ No → *go to question #36*

32. Does your outdoor water system have any broken sprinkler heads?
❑ Yes ❑ No ❑ Don't know

33. Does your in-ground irrigation system have an automatic timer?
❑ Yes ❑ No

34. Does your automatic irrigation system have an override shut-off device such as a soil moisture sensor or rain sensor? (Please check all that apply.)
❑ No override shut-off device
❑ Yes, soil moisture sensor installed
❑ Yes, rain sensor installed
❑ Other ______________________
❑ Don't know

35. Does your automatic irrigation system have a weather-based irrigation controller (WBIC) or "smart" controller?
❑ No ❑ Yes ❑ Don't know

Outdoor Water Fixtures

36. Does your home have an outdoor spa or hot tub?
❑ Yes ❑ No → *go to question #38*

37. Is the outdoor spa or hot tub usually filled?
❑ Yes, all year round
❑ Yes, in the winter
❑ No, but it is sometimes filled
❑ No, it is never filled

38. Do you have an outdoor water feature like a fountain or pond? *(Note: do not include bird baths; only features that use a significant amount of water.)*
❑ Yes ❑ No

Swimming Pools

39. Does your home have a swimming pool?
❑ No → *go to question #44*
❑ Yes, outdoor pool only → *go to question #41*
❑ Yes, indoor pool only
❑ Yes, indoor AND outdoor pool

40. What type of filling system does the indoor swimming pool have?
(If your home ONLY has an indoor swimming pool, please check the appropriate box and then go to question #44.)
❑ Manual ❑ Automatic

41. What type of filling system does the outdoor swimming pool have?
❑ Manual ❑ Automatic

42. Do you have a swimming pool cover that you use when the outdoor pool is not in use?
❑ Yes ❑ No → *go to question #44*

43. What months of the year do you typically use the pool cover? (Please check all that apply.)
❑ January ❑ July
❑ February ❑ August
❑ March ❑ September
❑ April ❑ October
❑ May ❑ November
❑ June ❑ December

44. How do you feel about enforcement of local water waste ordinances?
❑ It is too lax ❑ It is too stringent ❑ Don't Know

45. Please indicate the extent to which you agree or disagree with each of the following statements. Please check the appropriate box for each.

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	Not Applicable
Without looking at past bills, I know about how much my average (typical) household water bill was (in dollars) last year	❑	❑	❑	❑	❑
Without looking at past bills, I know about how much water my household used in an average (typical) billing period last year	❑	❑	❑	❑	❑
The cost of water is an important factor for me when deciding how much water to use indoors (e.g. for washing dishes, washing clothes, showering/bathing, etc.)	❑	❑	❑	❑	❑
The cost of water is an important factor for me when deciding how much water to use outdoors (e.g., for watering the lawn or garden, etc.).	❑	❑	❑	❑	❑
I conserve water mainly for environmental reasons	❑	❑	❑	❑	❑
I take into account the cost of wastewater (sewer) service when deciding how much water to use*	❑	❑	❑	❑	❑

*If you are charged a flat rate for wastewater/sewer service, mark "not applicable."

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These last few questions are about your house and your household. This information will only be used to group responses.

46. Is your house on a septic system?
- ❑ Yes ❑ No ❑ Don't Know

47. Is your household responsible for paying the water bill, or is it paid by a landlord or homeowners' association?
- ❑ Household pays
- ❑ Landlord or a homeowner's association → *go to question #49*
- ❑ Don't know → *go to question #49*

48. Are wastewater (sewer) charges included on the bill you receive for water service?
- ❑ Yes ❑ No ❑ Don't Know

49. About when was your home built?
- ❑ Before 1940
- ❑ In the 1940s
- ❑ In the 1950s
- ❑ In the 1960s
- ❑ In the 1970s
- ❑ In the 1980s
- ❑ Between 1990 and 1994
- ❑ Between 1995 and 2000
- ❑ 2001
- ❑ 2002
- ❑ 2003
- ❑ 2004
- ❑ 2005
- ❑ 2006

50. In what year did you move to this home? .... ___________ *year*

51. How many bedrooms does this house have?
- ❑ 1 ❑ 3 ❑ 5
- ❑ 2 ❑ 4 ❑ 6 or more

52. Do you have a garage?
- ❑ No
- ❑ Yes, attached to the house
- ❑ Yes, detached from the house

53. How many people, including yourself, live full-time at this address?

______ Adults, including yourself (age 18+)

______ Teenagers (age 13-17)

______ Older Children (age 6-12)

______ Younger Children (age 3-5)

______ Infants or Toddlers (under age 3)

54. What number of adults living at this address are employed full-time OUTSIDE the home?
- ❑ None (0) ❑ 2 ❑ 4
- ❑ 1 ❑ 3 ❑ 5 or more

55. Do you rent or own your residence?
- ❑ Rent →

About what is your monthly rent payment?
- ❑ Less than $300 per month
- ❑ $300 to $449 per month
- ❑ $450 to $600 per month
- ❑ $600 to $799 per month
- ❑ $800 to $999 per month
- ❑ $1,000 to $1,249 per month
- ❑ $1,250 to $1,499 per month
- ❑ $1,500 to $1,749 per month
- ❑ $1,750 to $2,000 per month
- ❑ $2,000 to $2,249 per month
- ❑ $2,250 to $2,499 per month
- ❑ $2,500 or more per month

- ❑ Own →

About what is the market value of your home?
- ❑ $Less than $100,000
- ❑ $100,000 to $149,999
- ❑ $150,000 to $199,999
- ❑ $200,000 to $249,999
- ❑ $250,000 to $299,999
- ❑ $300,000 to $349,999
- ❑ $350,000 to $399,999
- ❑ $400,000 to $449,999
- ❑ $450,000 to $499,999
- ❑ $500,000 to $599,999
- ❑ $600,000 to $699,999
- ❑ $700,000 to $799,999
- ❑ $800,000 to $899,999
- ❑ $900,000 to $999,999
- ❑ $1,000,000 to $1,249,999
- ❑ $1,250,000 to $1,499,999
- ❑ $1,500,000 or more

56. What is the last grade of formal education the primary wage earner has completed?
- ❑ Less than High School
- ❑ High School degree
- ❑ Some College or Associate's degree
- ❑ Bachelor's degree
- ❑ Master's degree
- ❑ Doctoral degree

57. About how much do you estimate your household's total income before taxes was last year? Please check the appropriate box below.
- ❑ Less than $30,000
- ❑ $30,000 to $39,999
- ❑ $40,000 to $49,999
- ❑ $50,000 to $59,999
- ❑ $60,000 to $69,999
- ❑ $70,000 to $79,999
- ❑ $80,000 to $89,999
- ❑ $90,000 to $99,999
- ❑ $100,000 to $119,999
- ❑ $120,000 to $139,999
- ❑ $140,000 to $159,999
- ❑ $160,000 to $179,999
- ❑ $180,000 to $199,999
- ❑ $200,000 to $224,999
- ❑ $225,000 to $249,999
- ❑ $250,000 to $274,999
- ❑ $275,000 to $299,999
- ❑ $300,000 or more

58. If you have any comments about how your household uses water, or about your water service, please write them in the space below or include them on your own paper.

____

____

____

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APPENDIX D: Complete End-Use Model Results

Terms used in this Appendix:

r^2 is the Pearson correlation coefficient squared. This is commonly described as the fraction of variance explained by a given model, and is the most common indicator of goodness-of-fit. Values observed in these models range from 0.29 – 0.46 and the only end use without an r^2 is leakage, which has no regression model.

p-value is the test probability for a given statistical procedure. To test the independent effect of a given factor, if the p-value is lower than 0.10, then the model assures a less than 10% chance that the effect occurred by chance alone. For each model, the p-value is calculated from the observed variable against the model prediction for each data point. For categorical factors, the p-value reported is calculated from the sample size and properties of the effect itself. More frequently, an arbitrary p=0.05 value is used. A p-value of 0.10 is reported here with the assumption that, if more samples are added to the dataset, the direction of each effect will probably not change, while the size of the effect will likely change.

Log-Log regression coefficients are used as exponents in the log-log regression prediction equation:

$$\text{Predicted}\,y = a_0 \cdot x_1^{a_1} \cdots x_n^{a_n}$$

Where:
Predicted y is often compared to observed y
Constants $a_1 \ldots a_n$ are the output of regression, labeled Unstandardized Coefficients in SPSS output
Variables $x_1 \ldots x_n$ are quantities for which log is defined; 0 cannot be a meaningful value for these variables.
Constant a_0 can be considered a scale or unit conversion scalar. The constant (a_0) and any coefficients for categorical variables are calculated using the antilog of coefficients determined through regression.

One of the properties of log-log regression versus linear regression is that the regression equation is forced to intercept 0. All regression models detailed in this report use water use as the dependent variable, so an intercept of 0 is more intuitive than a nonzero intercept.

Clotheswasher

r^2:	0.30		
Factor	Coeff	p-value	Base-10 coeff
(Constant)		0.60	1.31
log_Res_No	0.58	0.00	
Log_CW_GPL	0.70	0.00	

Factor	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
q45A_agree	0.80	0.73	370	92
q45B_agree	4.19	0.04	372	164
q45C_agree	-1.07	0.60	374	137
q45D_agree	-2.46	0.27	371	99
q45E_agree	2.98	0.25	368	61
q45F_agree	3.57	0.08	367	148
survey_leaks	2.20	0.44	383	53
Survey_ULF	0.50	0.83	349	251
Youth	4.59	0.02	426	162
At Home	-1.39	0.50	421	297
significant_leak	1.31	0.74	426	25
renter	5.52	0.13	421	31
Pay4Wtr	-18.73	0.05	421	417
Survey Softener	1.57	0.61	392	44
Survey Cooler	13.21	0.16	387	4
CW_Front	-2.13	0.35	343	105
renovations	3.79	0.11	379	289
Survey Plumbing Renovated	3.53	0.10	364	144
Survey Bathroom Renovated	3.52	0.09	374	235
Survey Kitchen Renovated	1.64	0.43	372	236
Survey Other Leaks	-1.40	0.86	371	6
Survey wastewater included in bill	4.30	0.32	279	258

Faucet

r^2:	0.29		
Factor	coeff	p-value	Base-10 coeff
(Constant)		0.00	5.54
Log_FlushesPerDay	0.46	0.00	
log_Res_No	0.44	0.00	

Factor	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
q45A_agree	-1.65	0.53	389	99
q45B_agree	-7.85	0.00	391	174
q45C_agree	-6.34	0.01	392	143
q45D_agree	-3.21	0.22	389	104
q45E_agree	2.03	0.49	386	61
q45F_agree	-7.16	0.00	386	158
survey_leaks	-1.44	0.66	402	56
Youth	-4.11	0.06	448	168
At Home	1.34	0.56	441	313
significant_leak	0.64	†	448	25
renter	1.97	0.61	443	35
Pay4Wtr	-9.33	0.40	442	438
wait	-2.16	0.35	382	163
Survey Softener	-5.93	0.10	412	45
renovations	1.99	0.46	397	305
Survey Plumbing Renovated	1.99	0.40	379	150
Survey Bathroom Renovated	3.16	0.18	392	250
Survey Toilet Leaking	3.19	0.51	402	23
Survey Faucet Drips	4.41	0.46	400	15
Survey Pool Leaks	-7.38	0.43	377	6
Survey Irrigation Leaks	-3.85	0.43	390	23
Survey Other Leaks	28.50	0.00	389	6
Q10	0.78	0.83	370	41
pool	-5.35	0.07	385	75
Survey Indoor Spa	-1.95	0.76	372	13
Spa_out	-7.71	0.00	444	89
Survey Garbage Disposal	-13.08	0.00	403	347
Survey Dishwasher	-14.17	0.00	398	330
Survey Cooler	8.78	0.31	407	7

† Significant “leak” is determined from Trace Wizard, and shown only for reference.

Leaks

Factor	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
Pool	17.51	0.086	396	78
Spa_out	4.15	0.795	456	91
Survey Indoor Spa	-1.08	0.834	382	13
Wait	-1.23	0.577	394	165
Survey Garbage Disposal	2.51	0.109	416	356
Survey Cooler	24.77	0.452	419	7
Survey Water Feature	-15.05	0.146	383	11
Survey Softener	7.47	0.011	425	47
Survey Plumbing Renovated	1.54	0.797	391	157
Survey Bathroom Renovated	-0.79	0.770	405	261
Survey Kitchen Renovated	5.91	0.586	401	256
Survey Toilet Leaking	10.58	0.064	415	23
Survey Faucet Drips	-13.74	0.980	413	15
Survey Pool Leaks	10.10	0.111	389	6
Survey Irrigation Leaks	0.33	0.457	403	23
Survey Other Leaks	-7.57	0.610	402	6
Q10	12.11	0.048	380	42
Q14	19.69	0.915	394	*
Survey Irrigator	13.34	0.269	410	396
Survey Landscaping Contractor	10.31	0.218	394	174
Survey Landscaping Contractor Responsible for Watering	0.42	0.896	215	31
Pay4Wtr	8.46	0.590	451	447
Renter	-9.90	0.531	451	35
other_sources	3.88	0.684	461	*
Survey Manual Irrigation	-4.29	0.070	393	284
in-ground	-4.82	0.614	438	303
Q35	22.73	0.834	225	9
outdoor_pool_automatic	55.35	0.499	76	17
pool_cover_months	*	0.255	18	*
Renovations	8.77	0.522	410	317
survey_number_leaks	*	0.224	415	*
survey_leaks	2.27	0.040	415	56
Income_Hi	-2.26	0.377	379	141
Income_Low	-10.76	0.388	379	35
Youth	-8.67	0.356	461	170
At Home	-0.28	0.394	444	316
OwnHome	9.90	0.531	451	416

Fount_Out	8.18	0.247	733	59
Fount_In	-16.03	0.124	733	11
significant_leak	188.13	†	733	48
IrrigationController	-4.51	0.977	733	51
SprinklerSystem	8.35	0.009	733	246

* Multiple-choice question with more than one distinct affirmative answer
† Significant "leak" is determined from Trace Wizard, and shown only for reference.

Shower

r^2:	0.29		
Factor	coeff	p-value	Base-10 coeff
(Constant)		0.01	3.49
log_Res_No	0.84	0.00	
Log_household_income	0.27	0.01	

Factor	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
q45A_agree	-0.31	0.91	329	84
q45B_agree	-1.82	0.44	331	150
q45C_agree	-1.39	0.57	333	126
q45D_agree	-3.10	0.24	331	90
q45E_agree	-2.51	0.44	326	52
q45F_agree	-0.02	0.99	327	135
survey_leaks	-0.86	0.79	338	49
Youth	-0.72	0.76	372	145
At Home	-4.51	0.08	371	256
significant_leak	0.71	0.90	372	18
Renter	13.35	0.00	369	29
Pay4Wtr	-14.39	0.27	367	364
Wait	-0.69	0.78	320	139
Survey Softener	-4.00	0.30	343	39
Renovations	5.20	0.07	335	259
Survey Plumbing Renovated	2.05	0.41	321	130
Survey Bathroom Renovated	3.97	0.12	330	214
Survey Other Leaks	9.75	0.32	327	5
Survey Whirlpool	-3.68	0.31	312	43
Pool	-4.43	0.15	322	62
Survey Indoor Spa	-0.50	0.94	312	12
Spa_out	-5.52	0.06	368	72

Hydra	-0.96	0.84	372	23
Survey Shower Wands	*	0.67	406	*

* Multiple-choice question with more than one distinct affirmative answer. Survey Shower Wands represents the number of shower wands. It is included in this analysis as a multiple-choice answer.

Toilet

r^2:	0.46		
Factor	Coeff	p-value	Base 10 Coeff
(Constant)		0.69	0.69
log_Res_No	0.61	0.00	
Log_Toilet_GPF	0.86	0.00	
Log_IndoorSQFT	0.32	0.01	

Factor	Change in Mean Daily Use (gphd)	p-value	Total Responses	Total Positive Responses
q45A_agree	5.53	0.11	186	44
q45B_agree	2.96	0.32	187	92
q45C_agree	-1.07	0.73	187	70
q45D_agree	-0.24	0.95	185	41
q45E_agree	9.59	0.01	186	34
q45F_agree	-0.23	0.94	187	74
survey_leaks	-3.04	0.47	194	26
Survey_ULF	-3.12	0.32	178	114
Youth	-6.79	0.02	212	93
At Home	7.06	0.02	208	137
significant_leak	-2.55	0.81	212	4
renter	1.22	0.79	212	22
Pay4Wtr	-1.49	0.90	209	206
renovations	4.43	0.18	191	142
Survey Plumbing Renovated	2.62	0.43	183	54
Survey Bathroom Renovated	5.46	0.07	188	115
Survey Toilet Leaking	-0.98	0.87	194	12
Survey Other Leaks	-4.39	0.83	187	1
Survey septic	-6.31	0.50	185	5

APPENDIX E: Results of Independent Landscape Area Verification

As mentioned in CHAPTER 5, the IRWD and EBMUD independently measured the irrigated areas for the study lots within their service areas, and performed field verifications of these measurements. The results of the analysis for IRWD are shown in Table 152. The top portion of the table shows the original irrigated area measurements performed by Aquacraft from the photos we were able to obtain from around 2005. These were relatively poor quality and low resolution. The average irrigated area for the 102 lots measured was 1816 sf. When IRWD did their verification using newer, higher resolution photos they produced an estimated irrigated area of 2209 sf. Since the Aquacraft estimate was 18% lower than the IRWD estimate it was decided that Aquacraft would repeat the measurements using copies of the new photos provided by IRWD. The issue with the analysis was that IRWD believed that Aquacraft had not counted all of the areas as irrigated that should have been. The middle portion of the Table 152 shows that when the analysis was repeated by different individuals using the new photos and copies of the field notes, but without reference to the IRWD results, the Aquacraft results were within 2% of the IRWD results.

Similar results were obtained from the reassessment of the EBMUD irrigated areas. Table 153 compares the EBMUD estimates of irrigated area for their study group to the revised assessment done by Aquacraft. There were large variations for the categories with small areas, but for the three large categories, turf, non-turf and total irrigated areas the differences between the two estimates was 5% or less. For the final analysis the Aquacraft V2 areas were used.

Table 152: Comparison of independent assessment of irrigated areas in IRWD

COMPARISON OF IRRIGATED AREA ASSESSMENTS						
Aquacraft Irrigated area assessment based on original photos ~2005						
	turf	non-turf	non-irrigated	Xeriscape	pool	Irrig. Area
Total	70668	86760	0	27817	4645	185245
Count	87	98	0	9	14	102
Average	812	885	0	3091	332	1816
Percent of IRWD Assessment						82%
Aquacraft Irrigated area assessment based on 2010 photos from IRWD						
	turf	non-turf	non-irrigated	Xeriscape	pool	Irrig. Area
Total	78661	146822	6803	4533	3976	230015
Count	101	102	97	98	11	102
Average	779	1439	70	46	361	2255
Percent of IRWD Assessment						102%
IRWD assessment from 2010 photos						
				Total		223135
				Count		101
				Average		2209
NOTE: Irrigated area equals turf + non-turf + Xeriscape only Averages are based on totals/count of lots with category present						

Table 153: Comparison of EBMUD Irrigated areas estimates

	Aquacraft Areas V2	EBMUD Area	Diff.	Diff. as % of Aquacraft
Non-Turf Plants	108992	114860	5868	5%
Pool or Fountain	2643	4104	1461	55%
Turf	64335	67219	2884	4%
Vegetable Gardens	288	875	587	204%
Xeriscape	36985	19820	-17165	-46%
Total Irrigated Area	210600	206878	-3722	-2%

In response to comments from the Las Virgenes staff, Aquacraft inspected each of the aerial photos for the study group customers in their service area to double check that no irrigated areas were excluded from the calculations. After careful review of the Las Virgenes photos, Aquacraft could not see significant areas that should have been included as irrigated, but were not.

The City of San Diego performed an estimate of the landscape areas using photos in their GIS system. When comparing these to the original Aquacraft estimate we noticed that our original tabulation of areas had incorrectly listed non-irrigated areas as xeriscape. This led us to review all of the photos for the City of San Diego and San Diego County and make appropriate adjustments, which have been included in the final version of the report.

The fact that the averages of irrigated areas for IRWD and EBMUD agreed closely gives confidence about the overall agreement of the data. There were still some substantial differences, however, in estimates of irrigated areas on individual lots. This was due to the fact that the two sets of photos were taken in different years, there were differences in resolutions and exposures, and the analysts who reviewed them, and visited them in the field had differences in opinions about how plant covers should be classified. To demonstrate this, the irrigated area data for the lots were plotted as a scatter diagram in Figure 105. In this diagram the X co-ordinate of each point is the irrigated area estimated by EBMUD and the Y co-ordinate is the area for the same lot estimated by Aquacraft. If both estimates agreed perfectly the points would all lie along a straight line with a slope of 1.0 going through the origin. The best fit line of the actual data, in fact, do lie along this line, but the data points are scattered around the line with significant variances. This scatter in the data leads one to apply the relationships with caution. When a large number of lots are involved the estimates will tend to agree well, but as the number decreases the chances of errors between the actual area and the estimates increases. As is the case with all similar analyses the data should not be used for purposes for which they are not intended, and should be confined to analyses of populations and general trends rather than making predictions for individual sites. Additional work needs to be done to determine why there is so much variance in the analysis of aerial photos for the same lots and see how this can be reduced.

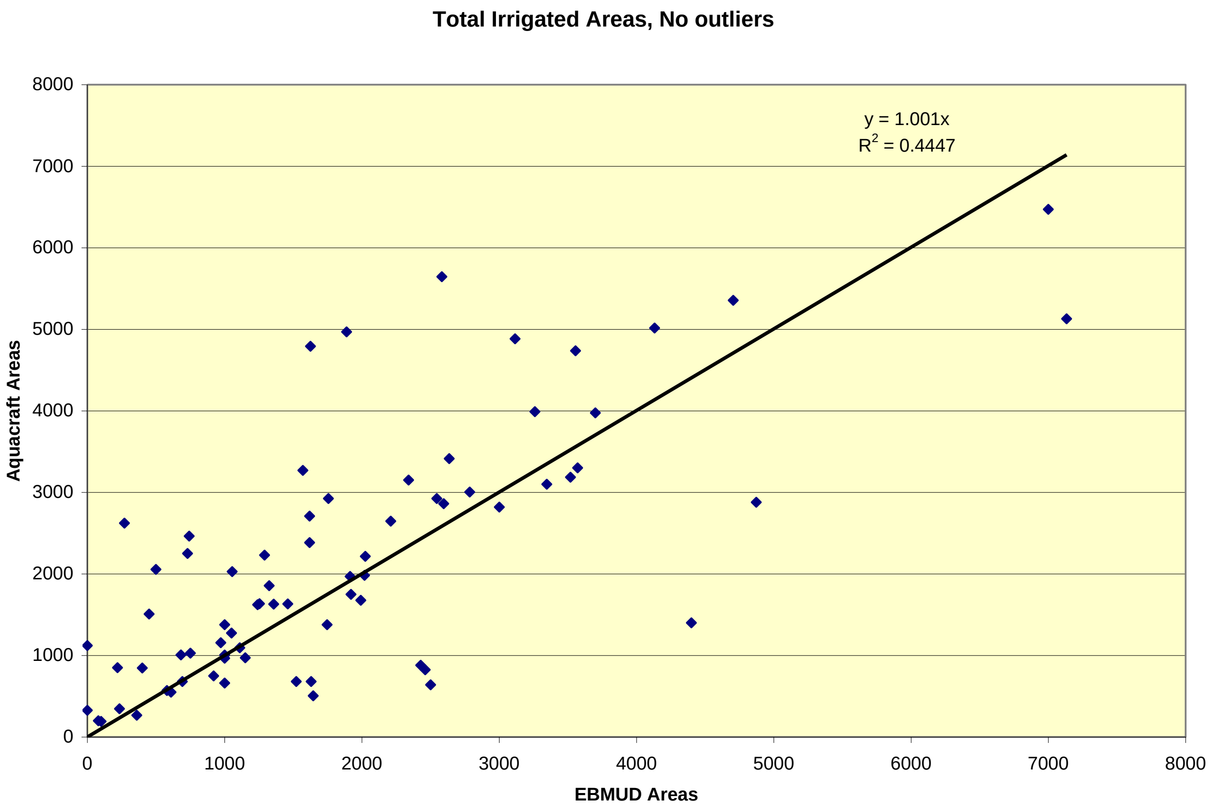

Figure 105: Comparisons of estimates of irrigated areas between EBMUD and Aquacraft

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