EVALUATION OF CALIFORNIA WEATHER-BASED "SMART" IRRIGATION CONTROLLER PROGRAMS

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FOREWARD

Irrigation demand is the single largest end use of water in the urban sector in California. Irrigation demands typically account for 50% or more of the total water used in many California homes and businesses. As water utilities pursue options for new supplies, one option involves capturing savings from water conservation programs. This process also includes continually searching for additional water conservation opportunities through new measures and new technologies. Water agencies, wastewater utilities, the utility customer, and the environment all benefit from improved efficiency.

In support of the goals of water conservation and environmental sustainability, the California Department of Water Resources funded two large-scale regional efforts to improve urban irrigation efficiency and reduce runoff through the installation of smart controllers.

Automatic clock driven in-ground irrigation systems were developed with the goal of delivering water to urban landscapes effectively and efficiently. In well designed, built, maintained, and operated systems this goal is often achieved. In less ideal situations, irrigation systems provide inefficient and excessive water delivery. At the core of the irrigation system is the controller or "clock" where irrigation run days and times are set and where electronic signals that turn on and off irrigation valves are generated. The controller is also the key interface between the irrigation system and person in charge of operating that system – the homeowner, property manager, or landscape contractor.

Smart controllers (commonly referred to as ET controllers, weather-based irrigation controllers, smart sprinkler controllers, and water smart irrigation controllers) are a new generation of irrigation controllers that utilize prevailing weather conditions, current and historic evapotranspiration, soil moisture levels, and other relevant factors to adapt water applications to meet the actual needs of plants.

The irrigation controller is important, but only one piece of the puzzle. Even the best, most water efficient controller cannot make up for poor system design, installation, and maintenance. The focus of this report is on irrigation controllers, but a holistic approach to irrigation systems and landscape design and maintenance is required to achieve the full potential of water savings in the urban irrigation sector.

This report presents an evaluation of the California Weather-Based Irrigation Controller programs. This project presents empirical data on the performance of smart controller products distributed and installed through different methodologies in a wide variety of settings. This report is intended to fulfill a key requirement of the DWR grants and provide information and guidance for future smart controller and landscape conservation programs.

This report reflects the results of an effort that began over four years ago in cooperation with the California Department of Water Resources, the California Urban Water Conservation Council, the Metropolitan Water District of Southern California and their 26 member agencies, and a consortium of six water agencies in northern California led by the East Bay Municipal Utility District. It is hoped that the information presented in this report will be found timely, useful, and objective; will add to the current body of knowledge; and that the appropriate organizations, including water utilities and the California Department of Water Resources, will consider adopting and implementing the study's recommendations.

Innovations in any field involve risk. In the case of this new irrigation technology, weather-based irrigation controllers, people across California have taken the risk of investing their time, money, and expertise to explore the possibility of improving the efficiency of water use in California's urban landscapes. As this report demonstrates, the risks have been justified and the investments are resulting in significant water savings.

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EXECUTIVE SUMMARY

Irrigation demand is the single largest end use of water in the urban sector in California. Irrigation demands typically account for 50% or more of the total water used in many California home and businesses (Mayer et. al. 1999, 2000) (DeOreo 2007). Improving irrigation efficiency is perhaps the single most important goal for water conservation professionals in the coming years. In support of this goal, the California Department of Water Resources (DWR) funded two large-scale regional efforts to affect urban irrigation efficiency and reduce runoff through the installation of smart controllers.

Smart controllers (commonly referred to as ET controllers, weather-based irrigation controllers, smart sprinkler controllers, and water smart irrigation controllers) are a new generation of irrigation controllers that utilize prevailing weather conditions, current and historic evapotranspiration, soil moisture levels, and other relevant factors to adapt water applications to meet the actual needs of plants.

As a relatively new technology, water utilities have had only limited experience with smart controllers. The potential of smart controllers to reduce urban irrigation demands has only been measured through a limited number of studies. The California installation programs represent the largest coordinated effort to implement this technology and as such provide an important opportunity to evaluate the performance of smart controllers in the field and to determine if this is a tool that should be broadly pursued as a conservation measure.

New technology must be proven effective at reducing water demands in laboratory and field settings before it can be responsibly adopted into local, regional, statewide, and national water conservation programs. Research studies over the past 8 years have measured statistically significant water savings and runoff reduction achieved through the implementation of smart irrigation control technology (Bamezai 2004), (DeOreo, et. al. 2003), (IA, 2006, 2007, 2008), (Jakubowski 2008), (Kennedy/Jenks 2008), (Mayer, et. al. 2008), (MWDOC, IRWD 2004), (SCWA 2005), (US DOI 2007, 2008). Over that time nearly 20 smart control product developers and manufacturers have emerged and weather-based irrigation control has become a strategic focus of the irrigation industry.

The controller is important, but only one piece of the irrigation puzzle. Even the best, most water efficient controller cannot make up for poor irrigation system design, installation, and maintenance. The focus of this report in on irrigation controllers, but a holistic approach to irrigation systems and landscape design and maintenance is required to achieve the full potential of water savings in the urban irrigation sector.

Research Approach

The California Proposition 13 Smart Controller programs are the largest scale efforts to date to distribute and evaluate the impacts of weather-based irrigation control technology. This report presents an evaluation of the California weather-based irrigation controller programs in northern and southern California. This project presents empirical data on the performance of and satisfaction with smart controller products distributed and installed through different methodologies in a wide variety of settings.

This executive summary presents key study findings and results summarized concisely and without explanation or reference to the methodologies implemented by the research team. The full body of the report includes detailed explanations of the research approach, all participating agencies and organizations, data sources and analytic and statistical methods employed. Please refer to the Research Methodology chapter and the subsequent results chapters for full details. The Appendices include detailed information about each smart controller technology and brand as well as copies of survey instruments, fully enumerated survey results, and other supporting documentation.

Smart Controller Programs and Installation Summary

Through this program more than 6,342 smart controllers have been installed in southern and northern California. This report presents results of the impact of 3,112 smart controllers (49.1% of the total) installed at 2,294 sites in northern and southern California. These sites met the fundamental data requirements established for inclusion in this study – 1 full year of pre- and post-installation billing data, corresponding climate data, a measurement of the landscape area at the site, and basic information about the site, controller, and installation.

The fundamental unit of analysis for this smart controller evaluation study was on the site level. A site is a property where one or more smart controllers were installed. A single-family residential property with a single smart controller is a site as is a multi-family housing complex with 20 smart controllers installed. Only sites for which sufficient data were provided could be included in the analysis portion of this study. Utility partners were able to provide the necessary data for 2,294 sites encompassing 3,112 smart controllers to be included.

The southern California smart controller programs were made up of a large number of distribution programs developed and implemented by more than 20 water agencies. MWD's member agencies invested significant time and resources to implement and market their smart controller programs, tried various approaches, and made mid-stream adjustments because of lack of participation. Three fundamental smart controller distribution program methodologies were implemented in southern California: rebate and voucher programs, exchange programs, and direct installation. While some agencies tried to target the smart controllers to historically high irrigators, by and large, the southern California program effort was a general distribution program that provided smart control technology to interested and motivated customers.

The northern California Smart Controller programs were made up of rebate, voucher and direct installation programs at five participating agencies under the leadership of the East Bay Municipal Utility District. In an effort to maximize potential water savings, agencies in northern California targeted customers with historically high outdoor water use demands through an analysis of historic billing data.

Table ES.1 presents a summary of the smart controller installations evaluated in this study. A total of 411 controller sites (17.9%) were located in northern California and 1,883 sites (82.1%) were located in southern California. The northern California smart controller sites were located in the San Francisco Bay region including Oakland and the various East Bay cities, Santa Clara County to the south, and Sonoma County to the north. The southern California sites were located in the Los Angeles and San Diego metropolitan area starting from Santa Barbara in the north (outside the MWD service area) and stretching south to San Diego County and the Mexico border.

Table ES.1: Summary of smart controller installations in study

Category	All Sites	Northern Sites	Southern Sites
Total	2,294 (100.0%)	411 (17.9%)	1883 (82.1%)
Customer Category			
Single-Family Residential	1,987 (86.6%)	295 (12.9%)	1,692 (73.8%)
Multi-Family, Commercial, and Other Non-Residential	296 (12.9%)	105 (4.6%)	191 (8.3%)
Irrigation only	11 (0.5%)	11 (0.5%)	
Installation Method			
Self-Installed*	1,374 (59.9%)	182 (7.9%)	1193 (52.0%)
Professional/Utility**	919 (40.1%)	229 (10.0%)	690 (30.1%)
Climate Zone			
Coastal	655 (28.6%)	67 (2.9%)	588 (25.6%)
Intermediate	1,444 (62.9%)	330 (14.4%)	1114 (48.6%)
Inland	195 (8.5%)	14 (0.6%)	181 (7.9%)
Smart Controller Brand			
Acclima	1 (0.0%)	1 (0.0%)	0 (0.0%)
Accurate WeatherSet	342 (14.9%)	3 (0.1%)	339 (14.8%)
Aqua Conserve	288 (12.6%)	52 (2.3%)	236 (10.3%)
Calsense	17 (0.7%)	0 (0.0%)	16 (0.7%)
ET Water	94 (4.1%)	93 (4.1%)	1 (0.0%)
Hunter	44 (1.9%)	44 (1.9%)	0 (0.0%)
HydroEarth	2 (0.1%)	0 (0.0%)	2 (0.1%)
HydroPoint	537 (23.4%)	52 (2.3%)	485 (21.1%)
Irritrol	37 (1.6%)	34 (1.5%)	3 (0.1%)
LawnLogic	1 (0.0%)	1 (0.0%)	0 (0.0%)
Nelson	3 (0.1%)	1 (0.0%)	2 (0.1%)
Rain Master	22 (1.0%)	5 (0.2%)	17 (0.7%)
Toro	68 (3.0%)	42 (1.8%)	26 (1.1%)
Weathermatic	838 (36.5%)	82 (3.6%)	756 (33.0 %)

*Customer was responsible for installing the controller. They could have hired someone else to do it, but this information is not known.

**Controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer

Fourteen different brands of controller were included in the analysis portion of this study. Three brands, HydroPoint, Toro, and Irritrol are the same technology with a different box and face plate, and these were combined into a single category for the impact analysis. Controllers installed at fewer than 15 sites were included in the overall impact analysis, but not in analysis by brand because of the lack of sample size and hence statistical validity. This limitation excluded only 7 controller sites from the brand analysis.

Customers (also referred to as "participants") were responsible for installing about 60% of the smart controllers in this study (referred to simply as "self-installation"). They could have hired someone to perform the installation for them, but that level of detailed information is not known. At about 40% of the sites the controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer (referred to as "professional installation").

In reviewing and comparing the performance of the controllers in this study it is important to keep in mind that water savings is only one evaluation measure. An important evaluation parameter to consider is the post-application ratio (post-AR). A primary goal of smart irrigation technology is to reliably match the actual irrigation application to the theoretical irrigation requirement, (to achieve a post-application ratio of 1.0). Controllers that match actual applications to the theoretical requirement can be considered successful even if they do not reduce (or even increase) water use, because they are performing as designed.

Research Findings

Summary of Key Results.

The evaluation of research described in this report provides strong evidence for the following findings and conclusions:

- Weather-based "smart" irrigation controllers, while a valuable tool, are not a "magic bullet" for achieving perfect irrigation control and water savings.
- On average smart controllers are a moderately effective measure for reducing the amount of water applied by automatic irrigation systems, while maintaining the health, and appearance of landscapes.
- When seeking irrigation water savings, the pre-existing level of excess irrigation at the site is the most important factor to consider.
- The water savings achieved through installation of smart controllers can be maximized by targeting the technology to irrigators with historically high irrigation application rates, not simply customers with high irrigation use.
- The many irrigators who historically apply less than the theoretical irrigation requirement for their landscape are likely to *increase* their irrigation application rate after installing a smart controller.
- Survey results indicate that smart controllers are likely to achieve a high degree of customer acceptance once they more broadly penetrate the consciousness of irrigation contractors and the general public.

- The utility programs implemented through the DWR grant have succeed in raising public awareness of this technology, but survey results suggest most consumers have no knowledge of smart irrigation control.
- Smart controllers can achieve cost effective water savings for utilities and irrigators under some cost and pricing scenarios, however this technology will not be cost effective for all utilities and customers.
- Most of the smart control brands and technologies evaluated in this study reduced irrigation demands on average, but not all of these reductions were statistically significant.

A more detailed summary of the findings from this study are presented below.

Weather-Normalized Change in Irrigation Volume

The total weather-normalized volumetric change in outdoor usage for each study site and region is presented in Table ES.2. This table includes the results from the 2,294 smart controller sites included in the impact analysis. In this study, the smart controllers sites changed water use by -108,418,500 gallons (-144,942 hcf, -330 acre-feet) across California in one year. All but one participating water agency achieved overall water savings. Sites in northern California reduced demand of -152.8 af (46.3% of the total savings), and sites in southern California reduced demand by -177.1 af (53.7% of the total savings).

The average weather-normalized change in water use per smart controller site is presented in Table ES.3. Overall, outdoor water use was reduced by an average of 47.3 kgal per site (-6.1% of average outdoor use) across the 2,294 sites examined in this study as part of the California Weather-Based Irrigation Controller Programs. This reduction was found to be statistically significant at the 95% confidence level. At smart controller sites in northern California the average change in outdoor use was a reduction of 122.2 kgal per site (-6.8% of average outdoor use). This change was not statistically significant at the 95% confidence level, but was significant at the 90% confidence level. At smart controller sites in southern California the average change in outdoor use was a reduction of 30.9 kgal per site (-5.6% of average outdoor use) and this was statistically significant at the 95% confidence level.

Table ES.2: Weather-normalized total change in water use estimated in study (1 year of data)

Site Location	Weather-Normalized Total Change in Water Use		
	kgal	hcf	acre-feet
All Sites	-108,418.5	-144,941.9	-330.0
Northern Sites	-50,215.0	-67,131.2	-152.8
Southern Sites	-58,203.4	-77,810.7	-177.1
Coastal ET Zone	-27,864.8	-37,251.7	-84.8
Intermediate ET Zone	-75,440.9	-100,855.0	-229.6
Inland ET Zone	-5,112.9	-6,835.3	-15.6
Professional Installation	-35,233.0	-47,102.1	-107.2
Self Installation	-73,185.5	-97,839.8	-222.7
Commercial	-67,751.9	-90,575.8	-206.2
Irrigation Only	1,191.2	1,592.5	3.6
Residential	-41,857.8	-55,958.6	-127.4
Alameda County WD	-418.1	-558.9	-1.3
Burbank	-1,442.5	-1,928.5	-4.4
Contra Costa WD	-484.2	-647.3	-1.5
Eastern	-9,625.3	-12,867.9	-29.3
EBMUD	-23,299.0	-31,147.8	-70.9
Foothill	-1,899.5	-2,539.4	-5.8
Glendale	-579.2	-774.4	-1.8
Goleta	-846.6	-1,131.8	-2.6
Inland Empire	-11,463.3	-15,324.9	-34.9
LADWP	-12,100.1	-16176.3	-36.8
Pasadena	-6,010.6	-8,035.5	-18.3
Santa Barbara	-6,584.5	-8,802.6	-20.0
Santa Monica	401.8	537.1	1.2
Santa Clara Valley	-23,627.7	-31,587.2	-71.9
Sonoma County WA	-2,386.1	-3,190.0	-7.3
San Diego County WA	-2,974.9	-3,977.1	-9.1
Western	-5,078.5	-6,789.3	-15.5

Table ES.3: Weather-normalized change in water use volume (kgal)

Site Locations	Weather-Normalized Change in Outdoor Use Descriptive and Validatory Statistics					
	N	Mean	Std. Deviation	95% Conf. Boundary	Statistically Significant Reduction?	% Change
All Sites	2294	-47.3	669.5	27.4	Yes	-6.1%
Northern Sites	411	-122.2	1305.2	126.2	No	-6.8%
Southern Sites	1883	-30.9	416.5	18.8	Yes	-5.6%
Coastal ET Zone	655	-42.5	399.3	30.6	Yes	-7.6%
Intermediate ET Zone	1444	-52.2	756.7	39.0	Yes	-5.8%
Inland ET Zone	195	-26.2	707.4	99.3	No	-4.5%
Pro. Installation	920	-38.3	599.0	38.7	No	-3.6%
Self Installation	1374	-53.2	712.8	37.7	Yes	-9.0%
Commercial	296	-228.9	1783.8	203.2	Yes	-5.6%
Irrigation	11	108.3	231.1	136.6	No	10.9%
Residential	1987	-21.1	197.0	8.7	Yes	-7.3%
Alameda County WD	5	-83.6	81.2	71.2	Yes	-18.5%
Burbank	76	-19.0	49.1	11.0	Yes	-18.4%
Contra Costa WD	32	-15.1	268.3	93.0	No	-2.1%
Eastern	87	-110.6	284.5	59.8	Yes	-18.7%
EBMUD[1]	333	-70.0	499.0	53.6	Yes	-5.8%
Foothill	245	-7.8	34.6	4.3	Yes	-10.2%
Glendale	109	-5.3	12.9	2.4	Yes	-18.0%
Goleta	26	-32.6	230.2	88.5	No	-3.3%
Inland Empire	186	-61.6	93.7	13.5	Yes	-41.6%
LADWP	477	-25.4	600.9	53.9	No	-5.5%
Pasadena	17	-353.6	956.2	454.6	No	-8.5%
Santa Barbara	73	-90.2	259.2	59.4	Yes	-14.7%
Santa Monica	71	5.7	41.3	9.6	No	3.9%
Santa Clara Valley	34	-694.9	4254.5	1430.1	No	-8.1%
Sonoma County WA	7	-340.9	753.9	558.5	No	-10.9%
San Diego County WA	401	-7.4	117.7	11.5	No	-4.4%
Western	115	-44.2	1007.4	184.1	No	-1.0%

The overall impact of smart controllers installed in this study was to reduce irrigation demands, but the results suggest that those who historically apply less than the theoretical irrigation requirement for their landscape are likely to increase water use after installing a smart controller. The Application Ratio is a measure of how closely irrigation applications at a site matched the theoretical irrigation requirement determined from proximal ET weather stations. The level of excess or under irrigation (pre-AR) prior to the installation of the smart controller was the most important factor in determining if a site increased or reduced water use with the

[1] In 2007, EBMUD requested a voluntary 10% cutback in usage from customers in response to drought conditions. Some of the post-installation water use data from EBMUD came from this time frame. It was not possible to determine if this effort impacted water savings in this study.

smart controller. In this study, a total of 1,300 (56.7%) of the 2,294 study sites had a statistically significant reduction in weather-normalized irrigation application ratio while 959 (41.8%) sites had a statistically significant increase in application ratio. For 35 (1.5%) of sites, there was not a statistically significant change in application. These results are shown in Table ES.4

Table ES.4: Number of smart controller sites and change in application ratio

Statistically significant change in water use?	# of Sites	%
Increase	959	41.8%
No change (+ or – 0.6%)	35	1.5%
Decrease	1300	56.7%

While the overall findings show reductions in outdoor water use through the installation of smart controllers, it should not be ignored that 41.8% of study sites experienced an increase in weather-normalized irrigation application ratio after the installation of a smart controller. Differences between sites that increased and decreased weather-normalized irrigation application ratio were examined and results are presented in Table ES.5.

Sites that increased application after installation of a smart controller had a mean pre-AR of 131% and a median of 95%. The median indicates that more than half of these customers were applying less than the theoretical irrigation requirement prior to the installation of the smart controller. Since smart controllers are designed to adapt irrigation to match the theoretical requirement, it would be expected that installing a smart controller at a site with a history of applying less than the theoretical irrigation requirement will result in increased demand.

Sites that decreased their application ratio after installation of a smart controller had a mean pre-AR of 182% and a median of 137%. The median here indicates that more than 50% of these sites were irrigating in excess of the theoretical requirement prior to installation of the smart controller. The water savings achieved through installation of smart controllers can be maximized by targeting the technology to irrigators with historically high irrigation application rates.[2] As shown in Table ES.5, residential sites were more likely to increase irrigation applications after installing a smart controller than non-residential sites.

Table ES.5: Comparison of sites that increased and decreased irrigation application ratio with statistical significance after installation of a smart controller.

Category	Sub-Category	Increased Application	Decreased Application
Customer Category	Non-Residential Sites	32.9%	67.1%
	Residential Sites	43.0%	57.0%
Landscape Area (sf)	Mean	22,084	28,505
	Median	6,286	5,698
Pre-Application Ratio (%)	Mean	131%	182%
	Median	95%	137%

[2] Irrigation application rates can be calculated using two pieces of data: (1) Landscape area at the site; and (2) Annual outdoor water use at the site.

Factors that Influenced Water Savings

Multiple regression analysis was used to determine the factors that did and did not influence changes in application ratio. This analysis methodology allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and application ratio after adjusting for factors known to influence savings such as the application ratio prior to installation of the smart controller.

The following factors were examined and determined to have a statistically significant impact on the change in application ratio:

- Pre-smart controller Application Ratio – the application rate relative to the calculated theoretical irrigation requirement
- Installation method (self vs. professional)
- Participating agency (sometimes significant)

Factors that Did Not Influence Water Savings

The following factors were examined and determined not to have a statistically significant impact on the change in application ratio:

- Site classification (residential vs. non-residential)
- Region (northern vs. southern California)
- Climate zone (coastal, intermediate, inland)
- Smart irrigation control methodology (historical ET, on-site readings, remote readings, soil moisture sensor)
- Landscape area

Water Savings by Smart Controller Brand

The data assembled in this project allowed for a comparison of the field performance achieved by each brand of controller installed at the study sites. Controller brands installed at fewer than 15 sites were not included in this analysis (the total number of sites in this category = 7). Controller brand names were made anonymous during the analysis process and were only exposed at the conclusion. This analysis did not attempt to adjust for factors shown to influence water savings such as differences in installation method.

Seven of eight controller brands included in the analysis saved water on average, however the overall variability of the data resulted in broad 95% confidence bounds. When the 95% confidence boundary spans zero (i.e. the upper bound is greater than zero), the water savings associated with brand is not statistically significant. Of the eight manufacturers evaluated here, only two achieved statistically significant water reductions – Accurate WeatherSet and ET Water. Accurate WeatherSet achieved an average weather-normalized per site savings of 50.5 kgal which represented a 33.2% reduction. ET Water achieved an average weather-normalized per site savings of 185.4 kgal which represented a 6.2% reduction.

For five of eight manufacturers, statistically significant reductions in weather-normalized water use were not found. This result means that the water savings measured for these three brands was not statistically different from zero (the confidence boundary crossed zero).

Consequently, no statistically "reliable" finding of water savings can be made for these three brands (Hunter, Weathermatic, Calsense, Rain Master, and Aqua Conserve). As additional years of post-installation data become available and/or with an increased sample size it is possible that these technologies could achieve statistically significant water use reductions.

The HydroPoint/Toro/Irritrol controller was the only technology that did not achieve water savings in this analysis, but this technology performed better over time as discussed in the multi-year analysis.

Water savings is only one evaluation measure. An important evaluation parameter to consider for smart controllers is the post-application ratio (post-AR). A primary goal of smart irrigation technology is to reliably match the actual irrigation applications to the theoretical irrigation requirement, (to achieve a post-application ratio of 1.0). Controllers that match actual applications to the theoretical requirement can be considered successful even if they do not reduce (or even increase) water use, because they are performing as designed.

Persistence of Savings – Multi-Year Analysis

The primary results for smart controller sites presented in this study compare a single year of pre-installation data against a single year of post-installation data. While these results are encouraging and show that smart controllers can reduce weather-normalized outdoor use on average, the longer-term performance of smart controllers in the field is of critical importance. Do water savings persist over time after the installation of a smart controller? Do the water savings decay? In the three years of post-installation data examined in this study for 384 study sites, water savings were not found in the first year, but savings were found in year 2 and year 3 and actually increased over time. More than 90% of the controllers in this analysis were HydroPoint/Irritrol/Toro so this analysis largely reflects the performance of this technology over time.

Three years of post-installation data were available for more than 384 smart controller sites. The results show that the controllers in this sample did better over time and in particular in the third year following installation. During post-installation year 1, weather-corrected percent change in water use increased by 6%. In year 2, the weather-corrected percent change water use showed a decrease 7.8% vs. the pre-install year. In year 3 the weather-corrected percent change in water use showed a decrease of 16.4% vs. the pre-install year.

Cost Effectiveness Analysis

Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. For the customer perspective, cost-effectiveness analysis was used to determine the level of investment that would be reasonable for a customer to make in a smart controller given the anticipated water and cost savings achievable through installation of the device.

A water utility with an annual avoided cost for water of $150/acre-foot that implements a smart controller program aimed at the residential sector and small landscapes (~4,000 sf) would likely achieve cost-effective water savings for a per-site incentive of up to $26. If the same agency implemented a program aimed at large landscapes (~25,000 sf), a $164 incentive would likely result in cost-effective water savings.

Utilities with higher annual avoided costs for water may find smart irrigation control technology to be a cost effective method of reducing demand in new and existing customers. At an annual avoided cost of $1000 per acre-foot a utility could provide nearly a $500 per site incentive for sites averaging 12,000 sf in size. The economics of smart controller incentives will differ between water agencies. But if average water savings as found in this study are achieved, then some utility programs that incent smart control technology will be cost effective.

For a residential customer with a 4,000 square foot landscape who pays $3/hcf for irrigation water who achieves average water savings with a smart controller would be justified in spending up to $229 to purchase, install, and maintain a smart controller over the 10-year expected life of the product. A customer with a 12,000 square foot landscape who pays $2/hcf for irrigation water would be justified in spending $458 on a smart controller. These results indicated that customers who achieve average water reductions can realize cost-effective savings from installing a smart controller.

Each water utility is unique. Each utility normally has its own distinct avoided cost for water and system of water rates and charges, developed over many years through complex processes. In water conservation planning, each utility may place a different value on conserved water. This poses challenges for developing cost-effectiveness analysis for smart controllers that will be broadly applicable across the diverse range of utility agencies that participated in this study and the even larger group that may utilize the results. It is most likely that utilities will use the water savings and percentage decrease estimates from this study and apply them to their own cost-effectiveness models. However, the research team was able to develop an approach to cost-effectiveness analysis that provides information for a broad range of agencies and systems of rates and charges.

Water utilities and customers may wish to promote and install smart irrigation control technology for other reasons besides potential water and cost savings. For water utilities, smart irrigation control offers a number of potential additional benefits including:

- Reduced runoff from urban landscape
- Adaptation of customer demands to calculated water budget allotments
- Potential for peak demand reduction (through coordinated irrigation "brown outs" similar to energy utility peak shaving)
- Improved health and condition of urban landscapes through more proper irrigation applications

For customers and end users, smart controllers offer some of the same potential benefits, but also a few others.

- Convenience – many participants in this study reported appreciating the convenience associated with smart control technology.
- Improved landscape appearance and health. Applying the proper amount of water usually improves landscape quality.
- Better feedback about other problems with the irrigation system. Many smart controllers offer diagnostic tools not available on traditional controllers. Applying the proper amount of water to a zone often reveals distribution uniformity problems or other system deficiencies that may have been masked by excess application in the past.

Conclusions and Recommendations

Process Analysis of Utility Smart Controller Program Design and Implementation

- **Program Design and Efficiency.** The California Prop. 13 Smart Controller Programs set out to test a variety of distribution methods and technologies to determine which approach makes the most sense moving forward. In both northern and southern California a regional approach was attempted, but in many cases each agency chose to follow its own chosen course while cooperating as much as possible with neighboring agencies. These programs benefited from the more efficient unified regional approach adopted for this study and this effort should be expanded. Leveraging common program elements such as design, marketing, and evaluation, stretched funds for program implementation and evaluation funds and increased regional recognition and public awareness.

- **Marketing.** Smart controller programs must be marketed if they are to attract interest. Smart controllers are a relatively new technology and very few people know what they are and what they do. Customers and landscape professionals alike need to be educated about these products and why they are desirable. Marketing materials should explain how the technology works and what benefits it offers. EBMUD found the readily available SWAT marketing materials to effective at explaining the technology and generating interest. Once educated, the public appears quite interested in smart control technology and is willing to give it a try. Customers may need help choosing the smart controller product that best suits their needs. The differences in operation and performance between a signal-based, sensor-based, and historic ET controller are not obvious to the typical customer. Targeted marketing approaches that identify customers with high irrigation demands and focus distribution efforts may be an effective method of placing smart controllers at sites that offer the greatest potential for water savings.

- **Getting Smart Controllers Into the Field.** Public information is critical to success of any utility sponsored smart controller program. Information provided should be clear and concise. A complicated message spanning multiple pages will not be successful. Information provided at the point of sale (e.g. the irrigation supply outlet or retail home and garden center) can be beneficial. Availability of product is essential. It cannot be assumed that smart controllers are easily available. Partnerships with the landscape industry are an excellent way to promote smart controller technology and can be beneficial to customers and landscape professionals alike. Smart controller programs should include a strong education element that focus on proper installation and most importantly programming. Manufacturers and distributors can help educate irrigation contractors and provide incentives for installation of smart controllers. Manufacturers and distributors can also increase marketing efforts in areas where water agencies are offering financial incentives programs that encourage installation of smart controllers. Follow-up inspections can be helpful for assuring maximum benefit, but also increase utility program costs.

- **Market Transformation –** The overall smart controller distribution program design and marketing materials and distribution methodologies developed have the potential to achieve longer lasting impacts on the market. In both southern and northern California, the marketing efforts succeeded in raising public awareness about the technology, although much work remains to be done on this front. Efforts that educate irrigation and landscape contractors can result in increased adoption of the technology, even after the program has ended.

- **Costs.** The type of distribution program a utility chooses to implement impacts program costs tremendously. Direct installation programs are typically the most expensive to implement as professionals are contracted to perform installations and programming. Exchange programs are typically less expensive and place responsibility for installation and programming with the customer. This study found that self-installation resulted in greater water savings compared with professional installation.

  The cost of rebate programs varies depending upon the design. Rebates can be set to match expected utility cost savings/avoided costs. Follow-up visits and inspections can be beneficial, but also add to the overall cost of a program. Agencies with prior experience implementing rebate programs for toilets, clothes washers, and other efficiency measures may have an easier time getting a smart controller rebate program underway. If water savings are the desired outcome, targeting program efforts at customers that historically irrigate in excess of the theoretical irrigation requirement is an essential key to success.

- **Irrigation Systems.** The controller is just one piece of a much larger irrigation system. Performance of the controller is limited by the capabilities of the irrigation system. The most water efficient smart controller cannot operate optimally on an irrigation system with poor head spacing and inadequate distribution uniformity. A systems approach is required to achieve maximum water savings. Some agencies incorporated system repair and upgrades into their smart controller program out of recognition that maximal water savings may not be achieved from poorly designed, maintained or improperly programmed systems.

- **Residential and Commercial Differences.** When implementing a smart controller program it is important to recognize the distinct differences between irrigation sites and to plan accordingly. Small sites such as residential and small commercial properties are distinct from large commercial and institutional sites. At a small site, the financial decision maker and the person in charge of operating and maintaining the landscape and irrigation system are often one and the same. At a large site they are almost always different people who seldom communicate with each other. The smart controller technologies for small and large sites are also different as are the irrigation systems and management arrangements. Smart controller programs targeted at commercial and institutional customers will typically require distinct marketing materials, resources, training, and other program elements. Cost differences and varying potential water savings must be accounted for as well.

- **Program Evaluation.** Effective evaluation of a smart controller program requires fundamental data including: make and model of controller, date of installation, installation method, sufficient water use data (pre- and post-installation), a measurement (or estimate) of the irrigated area, climate data corresponding to the same period as the water billing data, and other data as well. Good program design includes a method for collecting these and other data such as shading as part of the distribution and installation effort.

- **Signaling Fees.** Some controller technologies require the customer to pay an annual fee to receive a signal that adapts irrigation applications to prevailing local conditions. Nearly 48% of the mail survey respondents indicated that they would not continue to pay the signaling fee for their smart controller after the conclusion of the utility program. The failure to pay the signaling fee would transform a signal-based smart controller into a conventional controller. Although this result is only based on a total of 46 survey respondents, the high percentage of customers indicating they will not continue to pay the signaling fee after the program ends is of concern and this should be the subject of follow-up research during the on-going program monitoring effort.

Impact Evaluation of Smart Controller Programs

- **Maximize Water Savings.** Smart controllers can save water. Smart controllers are far more likely to effect savings when they are installed at sites that have historically applied excess irrigation applications. Water providers seeking significant volumetric savings should target smart controllers at these customers in particular. To do this a utility must have three critical pieces of data: (1) Estimated outdoor water use at the site; (2) A measurement (or estimate) of the irrigated landscape area at the site; and (3) The specific (or average) evapotranspiration rate for the locale.

  In this study, 41.8% of the study sites *increased* their irrigation water use after installation of the smart controller. Irrigators who historically apply less than the theoretical irrigation requirement for their landscapes are poor candidates for smart controllers and should be pre-screened from utility distribution programs. Most water utilities have the electronic tools required to calculate which customers are good candidates for smart controllers and which are not. A geographical information system (GIS) linked to historic water billing data are the perfect system for calculating historic application rates. Not all agencies have such tools readily available.

  To maximize water savings, the installation and programming of the smart controller is of critical importance. Landscapes are unique. Experience has shown that the initial or default settings used to program a smart controller will likely need to be fine tuned over the first few weeks or even months of operation to ensure optimal performance. This is not a technology that can simply be installed and forgotten, adjustments are often required during the initial set up to calibrate the controller default settings to the specific conditions of the site. Once the controller is properly adjusted for the site few if any adjustments should be needed. Manufacturers, irrigation contractors, water agencies, and consumers must be made aware of this need for fine tuning. Training and tools should be developed to improve the installation and adjustment process to help ensure that the smart controller performs optimally and does not end up unnecessarily increasing water use.

- **Factors that Influence Water Savings**. This study has identified only a few factors that have a statistically significant influence on water savings. Specifically, the pre-Application Rate at the site, the installation method (self vs. professional), and the participating agency (sometimes a significant factor). Aside from the importance of targeting based on historic application rate (not just volume), these findings offer limited guidance for utility smart controller programs.

  - ***Installation and Programming.*** Remarkably, self-installed smart controllers performed better than professionally installed controllers in this study. It is unclear exactly why this is the case, but a reasonable hypothesis is that customers who installed their own controller were more familiar and comfortable with the technology and hence better able to fine tune the programming to maximize efficiency at their site. Irrigation experts, landscape professionals, and knowledgeable water conservation staff agree that proper installation, programming, and fine tuning are critical to a successful smart controller installation. In northern California utility personnel conducted an inspection of nearly all smart controller sites during which programming adjustments were made. This approach appears to have improved savings for some northern California agencies, but it is unclear if the benefits of these efforts outweigh the additional program costs associated with conducting site inspections. Post-installation inspections are a good idea, but the results from this study show that smart controller programs can achieve significant water savings without conducting site inspections.

  - Customer training programs at distribution and exchange events in southern California proved that a little training goes a long way. Participants were required to bring their old controller to the exchange event or class and were taken through exercises with the new controller to help familiarize them with the technology and to demonstrate the differences from the old controller. The research finding higher water savings from self-installed controllers bears out the efficacy of this training concept. The verbatim customer survey responses indicate that not all self-installations were successful, and in some cases professional assistance was sought. Because of the relatively low cost of implementing an exchange program, other agencies may opt for this distribution method as a reasonable way to promote smart irrigation control technology. An approach that is able to target customers with a history of applying water in excess of ET and then distributing the smart controllers with the low cost and ease of implementation of an exchange event could be an excellent hybrid program solution.

- **SWAT Testing.** Seven of the eight controller brands included in this study[3] have published SWAT test results. Only Accurate WeatherSet has chosen not to participate in the SWAT testing process, but still this technology achieved statistically significant water savings. All of the published SWAT scores were above 95% for adequacy. The results from this study indicate that the SWAT testing protocol may be a predictor of reasonable field performance, but is not a guarantee of water savings. The SWAT testing protocol was not designed as a way to assess water savings, but rather is a method to try and ensure controllers apply the right amount of water based on current ET formulation.

  Testing is essential. If water efficiency is the primary goal of the testing regime, then a conservation-oriented testing criteria perhaps derived from the current SWAT protocol should be considered. Maintaining acceptable landscape appearance and health while minimizing the amount of water used should be the objective of water conservation-oriented smart controller bench testing. Achieving this objective might require an entirely new testing protocol including modifications to the way ET is currently formulated as discussed below.

- **Cost-Effectiveness – Depends on Avoided Costs and Water Rates.** Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product. Programs targeted customers who historically irrigate in excess of the theoretical requirement are far more likely to be cost effective under any avoided cost and pricing scenario. Utilities seeking cost-effective demand reductions should focus their efforts on identifying sites that stand the best chance of reducing demands through installation of a smart controller.

  Smart controllers will be cost-effective for many end users, but not all. Utilities could easily provided simple cost-effectiveness calculations for customers to assist them in determining if a smart controller makes sense given their historic outdoor water demands. For some customers, factors besides water and cost savings such as convenience and a desire to enhance landscape health and appearance may convince them to install a smart controller.

- **Long-Term Performance Data Required.** More data on the long-term performance of smart controllers is required. The limited multi-year analysis presented in this report which showed increasing savings over time indicates the potential for long-term water savings from smart controllers is promising, but it is certainly not the final word on this subject. The DWR contract with the participating water agencies in northern and southern California specifies that post-installation water use must be tracked over a five

[3] Eight smart controller technologies were installed at 15 or more sites in the study, the minimum required for inclusion in the analysis by manufacturer/technology.

year period. The participating water agencies should take full advantage of this opportunity to continue to monitor the impacts of smart controllers over the coming years and to track the persistence and/or decay of water savings over that time.

- **Long-term landscape health and appearance should also be considered.** Water use data included in this study was from monthly or bi-monthly billing records. Consequently, this study was not able to examine of how the controllers distribute irrigation events through time (i.e. frequency and duration or irrigation run times over a given period of time). With such coarse data it is possible that a controller might apply an amount of water close to the theoretical irrigation requirement over the course of a month or two, but within a given week the irrigation run times might not be distributed properly. While the distribution of irrigation events through time could not be examined in this study, it is potentially significant in the way smart controllers can affect overall plant health over time and should be the subject of further investigation. Some smart controller technologies only adjust run times and not water days which could result in frequent shallow waterings. Data on the long term appearance and health of landscapes irrigated with smart controllers should be collected.

- **CIMIS Data for Urban Irrigation.** Accurate, consistent, and continuous climate, evapotranspiration, and precipitation data will be increasingly important for effective urban water management in the future. The California Irrigation Management Information System (CIMIS) was originally created to provide critical data to agricultural water users in the state. More recently the system has been adapted to provide evapotranspiration data for urban irrigation management. The researchers relied heavily on CIMIS data to develop the analyses presented in this report and the experience of working closely with these data leads to a series of recommendation for improving the CIMIS system to better serve the needs of urban irrigators.

    - ***More CIMIS Stations Needed in Urban Areas.*** California needs more CIMIS ET stations in urban areas. Los Angeles and the surrounding metropolitan area in particular would benefit from additional CIMIS stations. The research team for this study was forced to obtain supplementary climate data for much of the analysis conducted on sites in the Los Angeles area when problems were detected at the few CIMIS stations located in the LA basin.

    - ***Continuous Data are an Important Goal.*** CIMIS stations are regularly removed from service for repairs and maintenance. When this occurs, climate data during the outage is unavailable and those seeking climate that data must use alternative, often less ideal, CIMIS stations. In this study, discontinuous data proved problematic and in many cases a particular CIMIS station could not be used because of discontinuity during the pre- or post-installation year. Repairs and maintenance are essential to assuring the quality and accuracy of CIMIS data, but there might be ways to complete repairs while still recording data from that location. One idea would be to temporarily replace station components with substitutes while others are removed for servicing.

- ***Formulate ET for Acceptable Landscape Appearance and Health Using the Least Amount of Water.*** There is a bright future for the use of evapotranspiration data to help manage urban irrigation. The essential goal of this effort will likely be maximizing water efficiency. Currently, CIMIS evapotranspiration data must be modified with various crop and landscape coefficients to adapt it to urban water requirements. There is general agreement on how this is done, but in the long run, something different is needed.

  The research team believes in thinking big, and our recommendation is that research be conducted to develop a new urban ET factor designed to maximize water efficiency while maintaining landscape health and appearance. Several recent landscape studies, including this one, have found the current ET formulation with a *Kc* value of 0.8 or even 0.7 is simply too high for many urban landscapes which contain a mixture of turf, trees, and plants (Sovocool, et. al. 2006, White, et. al. 2007). The revised urban ET factor should be developed by agronomists, horticulturalists, and landscape experts from around the country with the goal of developing an ET value designed for the efficient irrigation of urban landscapes. A water conservation-oriented ET factor should be based not on maximizing the growth of plants, as many current ET formulations are, but instead should be developed with the goal of *acceptable landscape appearance and health using the least amount of water*. The new factor must be formulated for different parts of the country, different soils, different plant materials appropriate to the setting, and different climates, but with the same goal of acceptable landscape appearance using as little water as possible. Ideally the new water conservation ET factor could be developed in the university environment at different locations across the country. Many universities already have facilities and programs that could be enlisted in this effort which will probably require federal funding to move forward. If urban landscape water conservation is expected to help stretch and support water supplies, this fundamental tool to help manage water use should be developed.

  Once developed, the water conservation ET factor could be incorporated into smart controller scheduling engines[4] and algorithms to improve water savings.

[4] Scheduling engines are the internal software programs in smart controllers that develop and adjust irrigation run times.

INTRODUCTION

Irrigation demand is the single largest end use of water in the urban sector in California. Irrigation demands typically account for 50% or more of the total water used in many California home and businesses (Mayer et. al. 1999, 2000) (DeOreo 2007). Improving irrigation efficiency is perhaps the single most important goal for water conservation professionals in the coming years. In support of this goal, the California Department of Water Resources (DWR) funded two large-scale regional efforts to affect urban irrigation efficiency and reduce runoff through the installation of smart controllers. Smart controllers (commonly referred to as ET controllers, weather-based irrigation controllers, smart sprinkler controllers, and water smart irrigation controllers) are a new generation of irrigation controllers that utilize prevailing weather conditions, current and historic evapotranspiration, soil moisture levels, and other relevant factors to adapt water applications to meet the actual needs of plants.

According to the Irrigation Association's Smart Water Application Technology (SWAT) information, "*Smart controllers estimate or measure depletion of available plant moisture to operate an irrigation system that replenishes water as needed while minimizing excess. A properly programmed smart controller makes irrigation adjustments throughout the season with minimal human intervention.*"

Automatic clock driven in-ground irrigation systems were developed with the goal of delivering water to urban landscapes effectively and efficiently. In well designed, built, maintained, and operated systems this goal is often achieved. In less ideal situations, irrigation systems provide inefficient and excessive water delivery. At the core of the irrigation system is the controller or "clock" where irrigation run days and times are set and where electronic signals that turn on and off irrigation valves are generated. The controller is also the key interface between the irrigation system and person in charge of operating that system – the homeowner, property manager, or landscape maintenance worker.

Many people desire the convenience and flexibility of an automatic in-ground irrigation system and large properties often cannot be effectively manually irrigated without a substantial amount of labor. A properly designed, installed, maintained, and operated automatic irrigation system can provide appropriate applications of water across a landscape as well as convenience to the residents. The controller is fundamental to the operation of the irrigation system and the amount of time each zone operates and consequently the amount of water applied to the landscape.

As a relatively new technology, water utilities have had only limited experience with smart controllers. The potential of smart controllers to reduce urban irrigation demands have only been measured through a limited number of studies. The California smart controller programs represent the largest coordinated effort to implement this technology and as such provide an important opportunity to evaluate the performance of smart controllers in the field and to determine if this is a tool that should be broadly pursued as a conservation measure.

New technology must be proven effective at reducing water demands in laboratory and field settings before it can be responsibly adopted into local, regional, statewide, and national water conservation programs. Research studies over the past 8 years have measured statistically significant water savings and runoff reduction achieved through the implementation of smart irrigation control technology (Bamezai 2004), (DeOreo, et. al. 2003), (IA, 2006, 2007, 2008), (Jakubowski 2008), (Kennedy/Jenks 2008), (Mayer, et. al. 2008), (MWDOC, IRWD 2004), (SCWA 2005), (US DOI 2007, 2008). Over that time nearly 20 smart control product developers and manufacturers have emerged and weather-based irrigation control has become a strategic focus of the irrigation industry.

The irrigation controller is important, but only one piece of the puzzle. Even the best, most water efficient controller cannot make up for poor irrigation system design, installation, and maintenance. The focus of this report in on irrigation controllers, but a holistic approach to irrigation systems and landscape design and maintenance is required to achieve the full potential of water savings in the urban irrigation sector.

Purpose of Report

This report presents results in the following areas of the California smart controller programs funded through DWR grants:

- **Process Evaluation of Program Implementation**
  - Customer satisfaction with smart controller products and smart controller distribution programs.
  - Participating agency program implementation methods, results, successes and lessons learned.
- **WBIC Program Descriptive Statistics**
  - What smart controller technologies were installed? Where were they installed? How were they installed? What were the climate conditions during the pre- and post-installation periods? What was the water use before and after installation of the smart controller?
  - Key data are presented by agency, region, and statewide.
- **Impact Evaluation**
  - What water savings resulted from the installation of the smart control technology? What factors influenced water use? How did different smart controller technologies perform in the field?
  - Given the water savings achieved, what is the cost effectiveness of smart controller technology? What amount of water utility rebate is justified to encourage adoption of this technology? What level of customer investment in smart controller technology is reasonable given the measured water savings?

This project is the largest field study to date of smart controller technologies, and presents empirical data on the performance of smart controller products distributed and installed through different methodologies in a wide variety of settings. This report is intended to fulfill a key requirement of the DWR grants and provide information and guidance for future smart controller and landscape water conservation programs.

This report was prepared by Aquacraft, Inc., National Research Center, Inc. (NRC), and statistician Dr. Peter Bickel, the consulting team contracted to conduct the evaluation study of the Proposition 13 smart controller programs. East Bay Municipal Utility District (EBMUD) and the Metropolitan Water District of Southern California, project leads for the northern and southern California study sites, contracted with the California Urban Water Conservation Council (CUWCC) to act as project manager for the statewide smart controller evaluation. CUWCC Associate Marsha Prillwitz and her predecessor Karl Kurka managed the project and coordinated activities between the northern and southern California study sites.

Participating Agencies

There were two large regional smart controller programs implemented in California. The northern California smart controller program involved a consortium of five utility agencies lead by the East Bay Municipal Utility District. Each participating agency was responsible for its own program development and implementation. Invoices for installed controllers were funneled through EBMUD. The northern California agencies included:

East Bay Municipal Utility District – lead agency

- Alameda County Water District
- Contra Costa Water District
- Santa Clara Valley Water District
- Sonoma County Water Agency

The City of Davis was initially slated to participate in the study, but ultimately chose not to take part.

The southern California smart controller program involved a consortium of agencies and sub-agencies, not all of whom had an active smart controller distribution program. The Metropolitan Water District of Southern California was the coordinating agency for the project. MWD is primarily a wholesale supplier of water and all member agencies were invited to participate in the smart controller program and receive DWR grant funds. Initially, each agency was responsible for developing and implementing its own program. Agencies were reimbursed from the DWR grant for installed smart controllers. Not all agencies took up the offer to participate in this project. As the program evolved, MWD implemented a series of controller distribution events that cut across agency boundaries and superceded individual utility program efforts. The list of southern California participants included:

Metropolitan Water District of Southern California – lead agency

- City of Burbank

- Calleguas Municipal Water District
- Central Basin Municipal Water District
- Eastern Municipal Water District
- Foothill Municipal Water District
- City of Glendale
- Inland Empire Utilities Agency
- Las Virgenes Municipal Water District
- City of Long Beach
- Los Angeles Department of Water and Power
- City of Pasadena
- San Diego County Water Authority
- City of San Fernando
- City of Santa Monica
- Three Valleys Water District
- West Basin Municipal Water District
- Western Municipal Water District
- City of Beverly Hills
- City of Torrance
- Upper San Gabriel Valley Municipal Water District

Santa Barbara and Goleta

Additional data were provided by the cities of Santa Barbara and Goleta which also implemented smart controller distribution programs at about the same time as the MWD efforts, although they were not part of the MWD program. These additional data increased the sample size and breadth of the study and helped to improve the overall reliability of the results, without increasing research costs. The addition of these data were done at the request of the original project manager Karl Kurka of the CUWCC in an effort to take maximum advantage of the evaluation effort and to increase the sample size as much as possible

Overview of Smart Controller Programs and DWR Grant funding

The State of California, Department of Water Resources provided grant funding to the Metropolitan Water District of Southern California and the East Bay Municipal Utility District for the purpose of saving water through installation of weather-based irrigation controllers. The Urban Water Conservation Capital Outlay Grants were provided under Proposition 13, the California Safe Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act. The MWD grant was agreement number 4600003098 executed on 2/27/04. The EBMUD grant was agreement number 4600003099 executed on 4/27/04. Table 1 below outlines some of the important goals and features of each grant.

Table 1: DWR Smart Controller Grant Information

Grant Information	**MWD – S. California**	**EBMUD – N. California**
Grant amount	$1,778,700	$1,660,725
Cost share amount	$1,072,933	$441,957
Smart controller installation goal*	5,514 controllers	2,605 controllers
Estimated 10-year potential water savings over useful lifetime of device**	27,500 AF	30,477 AF

* The installation goal is a maximum ("up to") target number to be achieved.

** Estimated savings were included in the original grant proposal and reflect various individual agency assumptions and rough estimates based on the types of controllers to be installed and the water demand in each area. Actual savings are anticipated to differ substantially.

The contracted California smart controller project deliverables for northern and southern California include:

- Installed smart controllers
- Tracking of water consumption data
- Quarterly progress reports
- Annual program evaluation
- Final report at the end of the 3-year program life (this report)
- Annual water savings reported for five years (post implementation)
- Dissemination of project results via conferences, web sites, CUWCC, green industry events, organizations such as the WaterSmart Innovations Conference, California Landscape Contractors Association, Irrigation Association, American Society of Irrigation Consultants, American Society of Landscape Architects,

Green Industry Council, Participating Agency Boards of Director's , MWD member agencies, and press releases.

Smart Controller Technologies

Smart controllers are a relatively new and emerging technology that has only been available to consumers since 2001. The concept of adjusting irrigation application to meet prevailing climate and weather conditions is as old as irrigated agriculture. The technology to control irrigation application automatically has been included in large-scale commercial systems for some time, but is relatively new to the residential and small commercial sectors. Over the past seven years the number of smart controller products on the market has increased dramatically with different manufacturers opting for different control technology solutions.

Two fundamental irrigation control technologies have been implemented to manage water use. One type of control relies on atmospheric weather data, while the other type of control measures the soil moisture level. Very few soil-moisture controllers were part of this study. The majority of controllers in this study relied on atmospheric weather data. Among the weather-based controllers that rely on weather data there are two primary technologies – (1) onsite sensor based control; or (2) signal based control.

Onsite Sensor Based Controllers

A sensor-based controller uses real-time measurements of one or more locally measured factors to adjust irrigation timing. The factors typically considered include: temperature, rainfall, humidity, and solar radiation. A sensor-based system often has historic weather information (i.e. an ET curve) for the site location programmed into memory and then uses the sensor information to modify the expected irrigation requirement for the day.

Signal Based Controllers

A climate signal-based controller receives a regular signal of prevailing weather conditions via radio, telephone, cable, cellular, web, or pager technology. The signal typically comes from a local weather station (or series of weather stations) and usually updates the current evapotranspiration rate to the controller. A climate signal based controller may also have an on-site sensor such as a rain sensor.

Smart Water Application Technology (SWAT) Initiative

Smart irrigation controllers are a relatively new technological innovation and have garnered national attention. There is tremendous interest in the potential of these devices to improve irrigation water management and a broad coalition of partners have come together in an effort to ensure that the technology performs to expectations and is successfully introduced into the market. The "Smart Water Application Technology" project is an international utility/irrigation industry initiative to achieve exceptional landscape water use efficiency through the application of irrigation technology. SWAT identifies, researches, and promotes technological innovations and related management practices that advance the principles of efficient water use. Led by the Irrigation Association (IA) in partnership with leading water purveyors, the SWAT process also includes industry professional associations and irrigation equipment suppliers.

The SWAT initiative currently has two working groups: a technical team and a market transformation team. The technical team has developed conservation testing protocol for climate- and sensor-based control systems. The Center for Irrigation Technology (CIT) has assisted the Irrigation Association in developing the protocol. CIT (located at California State University, Fresno) conducts irrigation equipment testing and evaluation for both public agencies and private businesses. Through grants and donations, CIT has developed a state-of-the-art hydraulics laboratory for testing irrigation equipment.[5] The testing protocol is available to any public or private institution through the Irrigation Association and additional SWAT test facilities at the University of Florida and elsewhere are being explored. Manufacturers may submit their products for testing and may elect to publish the testing results, otherwise they are considered confidential. To date seventeen smart controller products have released their test results for review.

Some of the agencies in the California smart controller program have required a published performance report from the SWAT protocol be published on the SWAT web site, http://www.irrigation.org/gov/default.aspx?pg=swat_perf-reports.htm&id=214 for a technology to be included in their program. Support such as this from water agencies has encouraged smart controller manufacturers to submit (and revise and re-submit) their products for testing and to publish the results. Agencies with this requirement believe that independent testing provides a safe guard that ensures a smart technology will provide adequate irrigation to landscapes without excessive waste.

EPA WaterSense

The US Environmental Protection Agency (EPA) has created a voluntary water efficiency marketing enhancement program known as WaterSense. This program is essentially the water efficiency version of the Energy STAR program at EPA. The WaterSense program has expressed an interest in efficient irrigation and in particular in smart irrigation controllers. Preliminary product research has been conducted and some public meetings held. The EPA has filed its intent to apply the WaterSense label to smart controller products, but has not advanced any proposed testing protocol or methods as would be required. It is anticipated that the results of this study could assist decision makers in moving forward with a WaterSense smart controller program.

California AB 2717 Task Force and AB 1881

In 2004, AB 2717 was passed, it requested the California Urban Water Conservation Council (CUWCC) to convene a stakeholder task force, composed of public and private agencies, to evaluate and recommend proposals by December 31, 2005, for improving the

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[5] The CIT lab is not a certified test facility and should EPA choose to test smart controllers for the WaterSense program, the tests will almost certainly be performed elsewhere.

efficiency of water use in new and existing urban irrigated landscapes in California. Based on this charge, the Task Force adopted a comprehensive set of 43 recommendations, essentially making changes to the AB 325 of 1990 and updating the Model Local Water Efficient Landscape Ordinance. The recommendation of the bill charges DWR to update the Model Efficient Landscape Ordinance and to upgrade CIMIS.

The Water Conservation in Landscaping Act of 2006 (AB 1881) enacted many, but not all of the recommendations reported to the Governor and Legislature in December 2005 by the CUWCC Landscape Task Force. AB 1881 required the California Energy Commission, in consultation with DWR, to adopt, by regulation, performance standards and labeling requirements for landscape irrigation equipment, including irrigation controllers, moisture sensors, emission devices, and valves to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy or water.

As part of this effort the California Energy Commission has held a series of workshops to examine potential performance standards for smart controllers. It is anticipated that the results of this study will be utilized in this process to better understand the impact of smart controllers and to help determine what performance standards are most sensible.

Smart Controller Technologies

Brief descriptions of the smart controller technologies installed in the California Weather-Based Irrigation Controller programs are presented below. More details can be found in Appendix A.

Weathermatic controllers use onsite weather monitoring to adjust watering. Parameters used to calculate ET are rain fall, temperature (both collected from the onsite station) and solar radiation (determined as a function of latitude) (DOI 2007). These controllers comprise approximately 37% of controller sites evaluated in this study.

HydroPoint Data Systems' WeatherTRAK controllers use ET data from public and private stations as the bases for weather-responsive irrigation. HydroPoint controllers do not use a base schedule for irrigation. Rather, user entered site data are combined with ET data to create dynamic irrigation schedules. HydroPoint's weather service is ET Everywhere (DOI 2007). HydroPoint WeatherTRAK controllers account for about 23% of the controllers in this study. Toro and Irritrol controllers utilize identical technology.

Accurate WeatherSet's weather-based irrigation controller is the Smart Timer. These controllers account for about 15% of the controller sites in this study. The Smart Timer uses onsite weather sensors to determine ET values. These sensors include Accurate WeatherSet's solar radiation sensor and a rain sensor. Once ET values are determined, the controller adjusts base schedule run times on a zone-by-zone basis. Accurate WeatherSet's residential controllers entered the market in 2001. Accurate WeatherSet offers the most economical controller in the study (DOI 2007).

Aqua Conserve uses historical ET data to modify user-entered irrigation schedules. Historical ET curves are based on data from various public weather station networks. These data correspond to 17 geographical regions. The historical ET data are adjusted by onsite temperature readings. Models range from six zones to 66 zones. This makes Aqua Conserve one of the largest capacity controllers in this study. Twelve percent of the controller sites in this study were Aqua Conserve controllers.

Toro / Irritrol controllers use ET data from public and private stations as the bases for weather-responsive irrigation. These controllers do not use a base schedule for irrigation. Rather, user entered site data are combined with ET data to create dynamic irrigation schedules. Toro / Irritrol controllers use HydroPoint's ET Everywhere service to manage ET data. Toro partners with HydroPoint Data Services. Also, Toro owns Irritrol and manufactures Irritrol Smart Dial weather-based irrigation controllers. Toro also owns Rain Master. However, Rain Master's controllers are manufactured separately and have different functionality (Starr 2008).

ETwater Systems uses ET and precipitation data from more than 10,000 public and private weather stations. A major feature of ETwater's irrigation control is a Web-based interface that controls and monitors irrigation. The web interface collects site information, determines start times based on ET data from weather station networks, provides users with detailed watering history and tracks controller information. Obviously, these features require the user to have a computer with an Internet connection. ETwater Systems controller sites account for about 4% of the sites in this study.

Hunter manufactures a weather-based control system that works with existing Hunter irrigation controllers. The weather-based irrigation product, the ET System, consists of an onsite weather station and an ET module that is added on to a previously installed Hunter irrigation controller. The weather station includes a solar radiation sensor, temperature sensor and a relative humidity sensor. An optional wind sensor can be added for increased accuracy (DOI 2007). Hunter controllers account for about 2% of controller sites in this study.

Rain Master controllers offer a wide variety of methods for weather-based irrigation. Daily ET can come from public weather stations via Internet connection. Rain Master's Weather Center II weather station is another option for obtaining onsite ET data. ET data can be directly inputted into the controller (DOI 2007). It should be noted that Toro owns Rain Master. However, the two companies use different methods for weather-based irrigation control (Starr 2008). Rain Master controllers account for 0.9% of controller sites in this study.

Calsense controllers can receive ET data from a variety of sources. Onsite measurements of ET or weather conditions can be used. CIMIS data may also be used. Soil moisture sensors also provide additional control of the irrigation system. As a company, Calsense's primary market is larger institutions such as universities or transportation departments. They do not make a product tailored for the typical residential customer. Calsense accounts for 0.7% of controller sites in this study.

Table 2 shows the list of the smart controller manufacturers and products that have been included in at least one of the California smart controller projects. Table 2 also indicates if the controller is signal or sensor based and if the manufacturer has released SWAT testing results. Detailed descriptions of each smart controller technology are provided in Appendix A.

Table 2: Smart controller technologies included in California projects

Manufacturer	Weather data source	Station or zone capacity	SWAT test performance report available
Accurate WeatherSet	On-site solar and rain sensors	8-48	No
Aqua Conserve	Historic ET curves with onsite temperature sensor	6-66	Yes
Calsense	Onsite ET sensor. Soil moisture sensor	8-48	Yes
ETwater Systems	Public and ETWS weather station data managed by centralized computer	1-48	Yes
Hunter Industries	On-site weather station with full set of sensors	1-48	Yes
HydroPoint Weather TRAK	Public and Private Weather stations managed by central computer and wireless delivery	6-48	Yes
Irritrol Systems	Public weather stations data managed by centralized computer server	6-24	Yes
Rain Master	Automatic, historic or manually entered ET or optional on-site weather station	6-36	Yes
Toro Company	Public weather station data managed by central computer server	6-24	Yes
Weathermatic	On-site temperature and rain sensors and solar radiation estimated based on location	8 to 48	Yes
Various: Acclima, HydroEarth, Lawn Logic, Nelson*	Various	Various	Acclima – Yes Others - No

*Only a small number of these products were installed as part of the study

RESEARCH METHODS

The project evaluation research team of Aquacraft, Inc., National Research Center, Inc., and Dr. Peter Bickel was selected early on in the project process, even before many of the smart controller programs had been implemented. This early selection allowed the evaluation team to observe the implementation process and to make recommendations for data collection activities required for conducting the impact evaluation at the conclusion of the project. Research team members, participating utilities, and the CUWCC project manager held regular teleconferences and worked closely to develop interim work products such as the preliminary process evaluation report for DWR submitted in 2007, a statistical sampling and analysis memo, and database specifications and data requirements for both northern and southern California programs.

The evaluation team was asked to complete two fundamental research tasks for this project: (1) a process evaluation of the program implementation conducted by the participating agencies; and (2) an impact evaluation of the water savings achieved through the installation of smart controllers in a variety of California settings. The evaluation team developed methodology to accomplish both of these critical, but distinct tasks and implemented a variety of surveys and data collection efforts over the more than three-year study period.

Process Evaluation Methodology

The key goals of the process evaluation were to:

1. Compare program implementation results to projected results based on original program design
2. Evaluate effectiveness of the following:
    a. Targeting methodology
    b. Method of intervention (direct vs. self install)
    c. Disbursement method (voucher, rebate, exchange, direct install)
3. Identify key elements of successful smart controller distribution programs for the benefit of future implementations
4. Survey participating customers to determines their satisfaction level with the technology and the utility distribution program

The process evaluation involved interviews and surveys of all participating agencies in the DWR smart controller grant program, discussions with utility implementation teams in northern and southern California, and a detailed customer satisfaction survey sent to every person who received a smart controller as part of the DWR grant program.

The willingness of the participating agencies to critique, evaluate, and evolve their smart controller programs was essential to the success of the process evaluation. Participants were completely forthright about their experiences – both good and bad - with the smart controller distribution programs. The differing emphases, goals, and philosophies of the various programs were evident from the outset, but all participants had a sense of the strengths and weaknesses of the approach chosen for their implementation.

Participating customers were similarly willing to share their experiences with the smart controllers. Survey response rates were good and in spite of a lengthy survey instrument, most of the returned surveys included complete answers.

Agency Survey Methodology

A survey of agencies was conducted about two years after the grant had been awarded for the purpose of obtaining information about program implementation and the overall utility experience with controller distribution methods. The results of this survey were the basis of the process evaluation presented later in this report.

The survey consisted of two parts: 1) a series of mostly open-ended questions designed to elicit information about the programs being designed or implemented by each agency, and 2) a worksheet in which the agency was to report mostly numeric information about the installation process and agency investment. A copy of the agency survey instrument is provided in Appendix E and completed responses are presented in Appendix F.

The agency survey and worksheet were developed through an iterative process by National Research Center with review by the project team. The survey questions with worksheet were sent to each agency in advance. Interviews with agency representatives were conducted by an NRC staff member. The worksheets were sometimes completed on the phone with the interviewer, other times returned via fax or e-mail. All the information was recorded in a database for analysis. Table 3 presents information on the completion schedule of agency interviews.

In some cases, additional information was needed, and follow-up contacts were made with a number of the agencies to clarify the information garnered. The results were reported in the Interim Process Evaluation Report On Prop. 13 Smart Controller Programs.

Participating Customer Survey Methodology

National Research Center (NRC) was responsible for implementation of the customer survey. A generic version of the questionnaire was crafted for participants in the various smart controller programs of the utilities.

The purpose of the survey was to learn about customers' perspectives about and experiences with the smart irrigation control technology and utility program. NRC developed the questionnaire through an iterative process with review by the project team. An accompanying cover letter was also drafted. The questionnaire was created for either residential or commercial (non-residential) customers.

NRC then contacted each participating utility to customize the materials for each utility using their logos, letterhead, signatories, etc. Each survey was printed with the utility logo and/or some introduction by an official in order to improve response rates. For a few utilities, the option was chosen for the questionnaire to be sent using NRC letterhead. NRC printed and mailed the surveys using participant lists provided by the utilities or a coordinating agency.

Table 3: Agency survey interview dates

Agency	Interview Date
Southern California	
Las Virgenes Municipal Water District	1/12/2006
San Diego County Water Authority	1/13/2006
Pasadena Water and Power (PWP)	1/17/2006
Rancho California Water District	1/18/2006
Eastern Municipal Water District	1/19/2006
Western Municipal Water District	2/22/2006
Foothill Municipal Water District	4/04/2006
Long Beach Water Department	5/19/2006
Central Basin Municipal Water District	5/31/2006
West Basin Municipal Water District	5/31/2006
Los Angeles Department of Water & Power	5/31/2006
Santa Monica	5/31/2006
Santa Barbara	7/25/2006
Burbank Water and Power	8/21/2006
Inland Empire Utilities Agency	9/12/2006
Three Valleys	9/12/2006
Central Basin	9/20/2006
Northern California	
Contra Costa Water District	1/23/2006
Alameda County Water District	4/10/2006
Sonoma County Water Agency	4/26/2006
East Bay Municipal Utility District	2/22/2006
Santa Clara Valley Water District	*
Davis Water	*

* Information gathered through means other than interview

The survey packet contained a questionnaire, cover letter and postage-paid reply envelope (addressed to National Research Center, Inc.). Each customer eligible for the survey was contacted two times. About a week after the first mailing, a second packet was sent, with a different cover letter explaining if the recipient had already responded, they did not need to do so again, but if they had not, their participation would be greatly appreciated.

For some agencies, two sets of mailings were conducted: the first was conducted with southern California exchange event customers (a control distribution program method detailed later in this report), the second with non-exchange event customers. Table 4 delineates the number of surveys sent in each mailing, with the corresponding response rate. Overall, a total of 3,445 surveys were mailed; completed questionnaires were received from 1,401 customers for an overall response rate of 41%.

Table 4: Customer survey mail dates and response rates

Agency	Number of Surveys Sent	Approximate Mail Date (1st Wave)	Number of Surveys Data Entered	Response Rate
Southern California				
Beverly Hills	11	5/12/2008	11	100%
Burbank	92	3/2007	43	47%
Calleguas	17	4/14/2008	6	35%
Central Basin	20	7/2007	7	35%
Central Basin 2nd Batch	147	3/24/2008	10	7%
Eastern	16	5/26/2008	3	19%
Foothill	346	2/2007	111	32%
Foothill 2nd Batch	22	2/18/2008	4	18%
Glendale	165	4/2007	76	46%
Goleta	25		7	28%
Inland Empire	283	4/2007	125	44%
Inland Empire 2nd Batch	87	3/24/2008	33	38%
Las Virgenes	11	5/12/2008	3	27%
Long Beach	324	4/21/2008	105	32%
Los Angeles	120	4/2007	58	48%
Los Angeles 2nd Batch	137	5/19/2008	40	29%
Pasadena	81	5/12/2008	22	27%
San Diego	680	3/2007	308	45%
San Diego 2nd Batch	19	3/31/2008	20	105%
San Fernando	7	3/24/2008	0	0%
Santa Barbara	81		43	53%
Three Valleys	132	2/2007	64	48%
Three Valleys 2nd Batch	24	3/24/2008	10	42%
West Basin	44	3/24/2008	11	25%
Western	217	5/19/2008	45	21%
Southern Cal. Total	3108	NA	1165	37%
Northern California				
Alameda	23	3/31/2008	16	70%
Contra Costa	69	5/12/2008	32	46%
East Bay Municipal Utility District	222	5/26/2008	130	59%
Santa Clara Valley	59	3/31/2008	25	42%
Sonoma County	80	5/12/2008	33	41%
Northern Cal. Total	453	NA	236	52%
TOTAL	3455	NA	1401	41%

Customer Survey Analysis Methodology

Once the surveys were received at NRC, staff opened and examined each survey for preparation for data entry. Survey responses were entered into an electronic dataset. This dataset was subject to a data entry protocol of "key and verify," in which survey data were entered twice into an electronic dataset and then compared. Discrepancies were evaluated against the original survey form and corrected. Range checks (examination of the data for invalid values) as well as other forms of quality control were also performed.

NRC staff analyzed the data set using the Statistical Package for the Social Sciences (SPSS) software. For the most part, frequency distributions and average ratings are presented. Where results were analyzed by respondent or WBIC technology characteristics, chi-square or ANOVA tests of significance were applied. A p-value of 0.05 or less indicates that there is less than a 5% probability that differences observed between groups are due to chance; or in other words, a greater than 95% probability that the differences observed in the selected categories of the respondents represent real differences among those groups. Where differences between subgroups are statistically significant, they have been marked.

Survey data were linked to water billing data (and other associated site information provided by the participating water agencies). Many surveys were sent to customers for whom water use data were not provided, but ultimately survey data were available from 625 smart controller sites that were also included in the impact analysis. A total of 2,294 sites were included in the impact analysis, so survey data were available for 28.5% of these properties. The combination of survey data, complete water use data, and climate data enabled several important analyses to be completed. These analyses investigated the impacts of changes to irrigation systems and landscape design on overall water savings.

Impact Evaluation Methodology

The fundamental goals of the impact evaluation were to (1) determine the water savings (if any) associated with the installation of smart controllers and (2) determine the factors that influence water savings. Nested within these two goals were numerous data analyses and research questions tasked to the evaluation team. Statistical analysis was conducted on three fundamental levels: local (by agency), regional (by climate zone), statewide (northern & southern programs, and combined). Results were also broken down by manufacturer, product, installation method, and customer class.

Statistical Sampling Methodology

One of the first tasks assigned to the Aquacraft evaluation team after the contract was awarded in 2005 was to develop a statistical sampling plan to determine how many smart controller sites from each participating agency should be included in the study. The evaluation team carefully considered a variety of options, but ultimately concluded that a saturation sample was the best option to ensure statistical reliability and power for the study as a whole. A saturation sample in this context means that every site that received a smart controller should be included in the impact evaluation if possible and if sufficient data were available. The full statistical sampling memo developed for this study is presented in Appendix D.

A saturation sample was selected for a number of reasons, but most importantly because it was desired to have as many data points for analysis as possible given the broad array of analyses to be conducted with the data set. A smaller sample size might have eased some data acquisition difficulties, but might not have provided sufficient sample size to evaluate a wide variety of smart controllers under varying climate conditions, installation methods, and distribution programs.

The fundamental unit of analysis for this smart controller evaluation study was the site. A site is a property where one or more smart controllers were installed. A single-family residential property with a single smart controller is a site as is a multi-family housing complex with 20 smart controllers installed.

A review of preliminary water use data provided by the Los Angeles Department of Water and Power (LADWP) in 2005 from 507 single-family smart controller installations suggested that a sample size as small as 80 sites might be sufficient to achieve the 95 percent confidence level desired. However, it was also clear that other sites in the smart controller programs were likely to have far more variable water use patterns. There was no way to guarantee that the rest of the data would have similar characteristics as those sites in Los Angeles and in fact it appeared that diversity was likely to be a characteristic trademark of the sites included in the smart controller programs.

The anticipated site diversity and large number of analytic factors (including analysis by agency, controller make and model, installation method, climate zone, etc.) convinced the evaluation team that obtaining as large a sample as possible was the best option. Smaller numbers of sites could have yielded statistically significant results, but a reduced sample size for this project would have been penny-wise and pound-foolish. Consequently a large sample size was sought. Ultimately, a total of 2,294 smart controller sites were included in the impact analysis.

Several fundamental pieces of data were required to include a smart site in the impact analysis:

1. *Historic water billing data* (at least 1 year of pre-installation baseline consumption and 1 year of post-installation consumption)
2. *Historic climate (evapotranspiration) data* from a nearby CIMIS weather station corresponding to the same time period for which billing data were provided.
3. *A measurement of the square footage irrigated at the site* (irrigated area)
4. *Basic information about the site, smart controller and installation* (address, zip code, make, model, utility distribution method)

All sites for which these fundamental data were available were included in the impact analysis.

Data Acquisition

Each region was responsible for assembling the fundamental data for each customer who received a smart controller and then providing this information to the evaluation team. The final deadline for submitting data for the impact analysis was in June 2008. The northern and southern California regional programs took two different approaches to collecting and providing these data.

Northern California Regional Database

The five participating northern California agencies decided to create a web-enabled central database for the purpose of storing data on the smart controller programs and to assist in producing required reports to DWR and the final project evaluation. An RFP was developed for the database project and Media Net Link, a local web design firm, was selected to develop the on-line database. The evaluation team provided technical support for the initial database design and the identification of data fields to be included.

The web-enabled database developed by MNL provided a method for uploading data and then offered limited access to those data via a series of queries. A bulk data download feature was developed to enable the evaluation team and participating utilities to extract data from the on-line database.

Each agency had the ability to upload all relevant data for the study including site and controller information and billing data. The evaluation team was able to download these data in an electronic format and import the data into Access and SPSS for analysis. Four of the northern California agencies successfully completed the upload to the regional database by the required deadline. EBMUD chose to provide their data directly in Excel format as they attempted to include as much late arriving post-retrofit data as possible.

Because of the difficulty involved in uploading data to the regional database and the limited value of the query tools provided it is uncertain the northern California agencies will continue to use this database in the future or will collect data for ongoing monitoring in a different way.

Southern California Data Assembly

MWD staff took the lead in assembling the required data from the southern California sites. This data assembly process was non-trivial: the southern California program involved nearly all of MWD's 26 member agencies and over 4,000 smart controllers. Requests were submitted to each participating agency and repeated follow-up was required before data were provided. Ultimately, data from 10 participating southern California utilities were able to provide the required data to MWD. This included a large portion of the smart controllers installed in southern California under the DWR grant. In addition, data on approximately 100 smart controller installations in Santa Barbara and Goleta were obtained and included in the analysis, although these sites were not formally part of the DWR study.

Once the member utilities provided their data to MWD, Alice Webb-Cole and her staff had the task of organizing the data and formatting in into multiple Excel spreadsheets. MWD provided data sets to the evaluation team as they were completed. Occasionally the evaluation team found errors or had questions about the data. The MWD staff was always responsive and all identified issues were taken care of quickly.

Data Cleaning and Database Preparation

Once the required customer and controller information and historic billing data were provided to the evaluation team, next on the list was the challenging task of assembling the varying utility data sets into a single, coherent database that could be used to conduct the impact analysis.

The database preparation process involved aligning and linking data provided by nearly 20 water providers, climate data from nearly 70 weather stations, and customer information data. The goal was to develop a data set that could be imported into SPSS so that statistical analysis could be completed. Part of the cleaning process involved determining for which sites the fundamental pieces of data (described above) were available and for which sites data were missing. Occasionally agencies were asked to provide additional data or to clarify issues identified within the data sets provided.

The fundamental analysis in this study was conducted at the site level. A site was any property where one or more than one smart controller was installed. In many cases, a site was a single-family residential property with a single water meter and a single smart controller. In a few cases, a site was a large campus comprised of numerous buildings with numerous water meters and extensive grounds where more than 50 smart controllers were installed. Part of the data cleaning process was to aggregate data for large sites and to ensure that all necessary data for each site was obtained.

The database cleaning process was one of the most painstaking and complex efforts in this study. With the multiple objectives of ensuring data quality, completeness, and accuracy as well as maximizing the number of smart controller sites that could be included in the study, the research team made a significant effort in task. Ultimately, 2,294 smart controller sites were available for inclusion in the impact analysis. Given the number of agencies and data sources involved with this project, obtaining a sample of this size and breadth is in itself a remarkable achievement.

Seasonal and Non-Seasonal Use from Billing Data

Indoor (non-seasonal) and outdoor (seasonal) use were disaggregated (unless a dedicated irrigation meter was indicated) using a minimum month or average winter consumption technique to estimate annual indoor use. Use of minimum month water consumption as a measure of indoor use works reasonably well in areas with negligible winter irrigation, but is less accurate in areas where irrigation is a year round activity. In some select cases it was preferable to use a fixed estimate of indoor use developed from Aquacraft water use studies in California (DeOreo, et. al. 2008), (Mayer et. al. 1999).

The participating water agencies in northern and southern California provided historic water use data from billing recorders for as many of the smart controller sites as possible. In order for a site to be included in the impact analysis, a minimum of 12 months of water consumption data from the time period *prior* to installation of the smart controller (pre-smart controller data) and one full year of water consumption data from the time period *after* installation of the smart controller (post-smart controller data) were required. In some cases, multiple years of pre- and post-installation data were provided thus permitting more expanded analysis discussed later in this report.

The pre- and post-installation billing data time periods for each site were often different. For example, a site where the smart controller was installed in June 2005 likely had pre-installation data from the 2004 calendar year and post installation data from July 2005 forward. At a different site where the smart controller was installed in September 2006 likely had pre-installation data from 2005 and 2006 and post-installation data from 2007. The key point is that only full years of data were included in the analysis and at least one full year of pre- and post-installation was required to include a smart controller site in the impact analysis. Differences in weather and climate conditions experienced in the different California regions during the different timer periods which billing data were provided were carefully accounted for using CIMIS weather data as described in this section of the report.

Some large smart controller sites were served by multiple water meters and in these cases the data from all meters serving the site were aggregated. Some sites were served by a dedicated irrigation meter which allowed for irrigation demand to be easily isolated. However, most of the sites in the study were served by a mixed use water meter typical for single-family residences. In these cases outdoor use was disaggregated using the minimum month estimation technique described above. All water use data were converted into units of thousands of gallons (kgal) for the purposes of analysis and reporting.

In the ideal situation, pre-installation water use and post-installation water use would correspond to 365 days of billing data before and after controller installation. However, meter readings were seldom (if ever) synchronous with the installation data of the smart controller. In this study, billing data and climate (CIMIS ET) data were aggregated into calendar months. The calendar month in which the smart controller installation occurred was excluded from the pre- and the post-installation periods. It was assumed that customers installed controllers promptly as in many cases they were required to trade in their old controller to receive the new one. Each smart controller site included in the impact analysis required at least 25 months of billing and climate data to be included in the study.

Given the wide variety of incoming billing data formats, it's important to note some general characteristics that were held across all available billing data:

- Volume units for incoming billing data were typically 100 cubic feet (hcf) or 1000 gallons (kgal), and less often gallons per day or acre-feet. All billing data units were converted into kgal prior to inclusion in the study database[6].
- Non-positive monthly or bi-monthly volumes (sometimes explainable as dollar-converted billing credits) are common in large utility billing data sets, and negative consumption numbers were occasionally found the data provided for this study. In all cases negative consumption values were discarded.

[6] Gallons per day is sometimes a preferred unit for analysis. However, in this case, not all billing data could be reliably converted to gallons per day since meter read dates were not consistently provided.

- For each account (unless a dedicated irrigation meter was indicated), the seasonal and non-seasonal consumption components were disaggregated from the annual total, based on annual billing data baseline[7].
- The calendar month in which the smart controller installation occurred was excluded from the pre- and the post-installation periods.
- Pre-installation: Billing date was between 0 and 392 days before the first day of the smart controller installation month. The criterion of 392 was the largest number of days less than 13 months; this arithmetic resulted in better inclusion of varied read dates[8].
- Post-installation billing data: Billing date was between 1 and 392 days after the last day of the smart controller installation month.
- The timeframe for climate data corresponded to the identical timeframe for billing data to the maximum extent possible since climate data were paired with a month and year. 392 days always corresponded to exactly 12 data points; the equivalent arithmetic to a 365 or 366-day interval.
- Every effort was made to match all available billing data to a logical span of climate values. In some cases, the nearest CIMIS station did not cover the same time span of billing data. In these cases, if utilities provided more than 25 months of billing data, the researchers took advantage of alternate *calendar* years of pre-installation billing and climate data. The smart controller installation date itself was always excluded from the pre- or post- data period.
- The majority of smart controller installations occurred at single-family residential utility accounts. In rare cases, multiple controllers, installation dates and areas were associated with a combination of more than one utility account on a single site. Since the analysis methodology in this study weighed this type of site equally with single-controller installations, the latest smart controller installation date assigned the beginning of post-installation data time frame.

Once the appropriate pre- and post-installation year of data were established, the application rate (inches) was calculated by dividing the outdoor water use by the landscape area and applying a standard unit conversion factor. The application rate is a measure of the depth of irrigation water applied across the entire landscape over a year and can be compared to the theoretical irrigation requirement, which is empirically determined from CIMIS data.

While billing and climate data are vital for this analysis, some individual sites were justifiably disqualified based on survey response data. For example:

- Though all other data appeared complete, the survey indicated that the customer remodeled their landscaping, or otherwise changed their irrigation patterns in a manner inconsistent with standard operation of a smart controller (i.e. they shut their system off over the summer), during the analysis time span. These sites were excluded.

[7] The baseline of billing data are the minimum bill over a given times pan multiplied by the number of bills in that time span, or if billing units are gallons per day, 365 * minimum bill, if billing units are gallons per month, 12 * minimum bill, etc.

[8] This allows, for example, an installation on Feb 15th 2005 to compare billing data from as early as Feb 1, 2004 and as late as Feb 28, 2006.

- A few survey respondents indicated that the smart controller was removed after installation, never configured correctly, or never installed to begin with. These sites were removed from the impact analysis dataset.

Evapotranspiration and Precipitation

The California Irrigation Management Information System (CIMIS) is a program in the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 120 automated weather stations in the state of California. CIMIS was developed in 1982 by the California Department of Water Resource and the University of California at Davis to assist California's irrigators manage their water resources efficiently. CIMIS weather stations are located in 18 different ET zones throughout California.

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 your crops, lawn, garden, and trees need for healthy growth and productivity"* (CIMIS 2008).

CIMIS designates ET from a standardized grass surface as ETo which is also referred to as gross ETo or reference ETo. This measurement does not include precipitation, which (as discussed below) is an important consideration when evaluating the water saving performance of smart controllers.

CIMIS maintains fixed stations providing reference evapotranspiration measurements (units are inches) paired with daily precipitation (also in inches) measured to a resolution of 0.1 mm. Daily ETo from CIMIS uses a slightly modified Penman-Monteith equation to estimate evapotranspiration rates (CIMIS 2008).[9]

CIMIS flags values for each variable for quality[10]: though a particular observation may be numeric, a quality control flag may indicate that value is in fact analytically meaningless. In the case of severe problem days, this analysis independently substitutes a monthly average value for either precipitation or ETo, or both (CIMIS 2008).[11]

To account for micro-climate differences to the extent possible, daily gross ETo data and daily precipitation measurements from the CIMIS network were carefully aligned with historic billing data for each site and then the controller installation data were used as the dividing marker between the pre- and post-installation periods. Care was taken to ensure that climate data *from the same weather station* was used for both the pre- and the post-installation analysis at every site. This sometimes meant selecting a weather station farther away from a site location, as the more proximal station had discontinuous or incomplete data for either the pre- or post-installation period. This complex process of matching and aligning pre- and post-installation water use and ET data allowed for weather corrections to be made on a site by site basis so that appropriate changes in water use could be measured.

[9] http://www.cimis.water.ca.gov/cimis/infoEtoCimisEquation.jsp
[10] http://www.cimis.water.ca.gov/cimis/dataQcCurrent.jsp
[11] Month = that calendar month, as opposed to a 30-day moving average.

Precipitation is an important factor to consider when evaluating the impact of smart control technology. Ideally, a smart controller should reduce or prevent unnecessary irrigation after sufficient rainfall has occurred. However, not all measurable precipitation can be considered effective at reducing the water requirement of landscape plants and turf. Small amounts of rain often do not penetrate the soil and large amounts of rain can exceed the capacity of the soil to retain the moisture. A daily model was used to net out effective precipitation for each study site using the techniques described in the methodology section of this report. A maximum of 25% of daily precipitation was considered effective. Alternative approaches to ET and precipitation were considered as well and analysis using different approaches are provided later in the "Sensitivity Analysis" section of this report.

Daily effective precipitation was estimated using established rules specific to a root depth of 12 inches as described in Table 5 (DeOreo, et. al. 2007), (Jensen, et. al. 1990).

Table 5: Effective precipitation methodology and assumptions.

If Daily Precipitation from CIMIS Was…	Action Taken	Reasoning
less than 0.15"	(ignored)	Too little precipitation to penetrate soil to the root zone.
between 0.15" and 1.15"	Effective precipitation = Precipitation – 0.15"	Useful amount of precipitation stored in the soil in a day.
greater than 1.15"	Effective precipitation = 1.0"	Precipitation in excess of 1 inch per day was considered to exceed the soil capacity and was hence not effective.

The soil moisture model considered is an approximation of change in water storage in the soil, with emphasis on limiting saturation by capping the amount of rainfall contributing toward change in soil moisture. The model assumes zero irrigation and reflects the maximum amount of rainfall available to plant roots given meteorologically measured daily rainfall and evapotranspiration.

The Net ET term (used to calculate Theoretical Irrigation Requirement) inherits a monthly balance from this model. The landscape coefficient K_c is used only against Net ET calculation – though the soil moisture model includes an evapotranspiration term, it does not include a coefficient to scale evapotranspiration. This soil moisture model operates under assumptions that are reasonable for K_c near 1.0, which is valid because turf K_c = 0.80 is subsequently applied to all sites for year-round turf growth.

A daily and monthly cap of 25% of total rainfall was enforced on effective precipitation. This depresses annual effective precipitation at the majority of CIMIS stations involved. Furthermore, an annual total of monthly values will rarely reach 25% for all months – 23% annual effective precipitation is more common.

For each day and month, the calculated effective precipitation was compared against the total. Effective precipitation was not allowed to exceed 25% of the total. Using this method, an average of 23.9% of the total annual precipitation during the pre period and 21.7% of the total annual precipitation during the post period was found to be effective across all weather stations in the study. Sensitivity analysis, presented in the impact analysis section of this report, was conducted where both gross ETo (effective precipitation = 0) and where a higher amount of effective precipitation were considered. This analysis shows the impact of the effective precipitation calculation on water savings in this study, but also provides a strong indication that the overall result that water savings were achieved would not be impacted if a different value for effective precipitation were used.

Theoretical Irrigation Requirement

Using the ETo and precipitation data (obtained primarily from CIMIS), the landscape area data provided by the participating agencies, and a standard crop coefficient of 0.8 recommended in the California Model Landscape Ordinance (and many other sources), the researchers calculated the theoretical irrigation requirement for each site during the pre- and post-installation year.

The Theoretical Irrigation Requirement (TIR) served as the fundamental measurement of the water requirement for each smart controller site in the study. The TIR was used to make corrections for changes in climate condition during the pre- and post-installation periods (as described in the next section) and to determine how closely the actual irrigation application matched the needs of each landscape in the study.

The fundamental equation used to calculate the theoretical irrigation requirement (TIR) in inches for each site was:

Equation 1: Theoretical Irrigation Requirement (TIR)

$$\text{Theoretical Irrigation Requirement } TIR \text{ (inches)} = (ET_O \times k_c) - \text{Effective Precipitation}$$

Where:

ETo = Gross annual evapotranspiration (inches) from CIMIS

Effective Precipitation = annual effective precipitation (inches) calculated as specified above

K_c = ET adjustment factor or crop/landscape coefficient = 0.8 (from Updated Model Water Efficient Landscape Ordinance[12]; also called K_L)

[12] Updated California Model Water Efficient Landscape Ordinance, Reference: Section 65597, Gov. Code.

The Water Use Classification of Landscape Species (WUCOLS), also titled "*A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California*", provides a cohesive statewide treatment of factors involved in irrigation requirement calculations and in particular the justification for the use 0.8 for K_c. The researchers understood that under ideal circumstances, a unique value of K_c should be calculated for each study site to account for the different plantings and hydrozones. The practical reality was that insufficient data were available to make such a calculation. Instead, each site was assumed to fulfill an average density, moderate microclimate cool-season grass landscape type from the WUCOLS specification, as shown in Table 6. This analysis shows a clear justification for using a K_c value of 0.8 for an average turf grass site and a moderate microclimate. Other documents consulted for this study such as the Updated California Model Water Efficient Landscape Ordinance use the same 0.8 value for K_c.

Table 6: Calculation of landscape coefficients under California guidelines

Coefficient	Explanation
Species coefficient, k_s	k_s = 0.8 for all sites, equivalent to cool season grass
Density coefficient, k_d	k_d = 1.0 for all sites, equivalent to average density
Microclimate coefficient, k_{mc}	k_{mc} = 1.0 for all sites, equivalent to moderate microclimate
Landscape coefficient $k_L = k_s * k_d * k_{mc}$	k_L = 0.8 for all sites
Landscape evapotranspiration (inches)	$ET_L = k_L$ * (Net ETo) = 0.8 * (Net ETo)

Assumptions Made in Calculating TIR

With incomplete data about the history of the irrigation system and landscaping at every smart controller site in the study, the statistical treatment used by the research team holds (does not test) the following assumptions:

- $\Delta k_c \equiv 0$ Any changes in ET_L are assumed to be climactic, rather than changes to any of k_s, k_d, or k_{mc}. Put another way, the landscaping is established, with no major changes throughout the period of the study. Undoubtedly, over a two year period some landscaping changes could have occurred in at least a few sites. Measuring the central tendency of a large sample should balance the effect of some sites establishing new turf against the effect of others trying to conserve water by reducing the irrigation of established turf.

- $IE \equiv 100\%$ The irrigation system itself was not altered or upgraded throughout the study, and any change in the irrigation application rate is due to the smart controller and its programming, rather than unmeasured changes in irrigation system efficiency. Although this was stated earlier as criteria for disqualifying certain sites, it's important to note that this assumption implies that WUCOLS approaches several methods for measuring irrigation efficiency *on site*. An interesting further area of study would compare the potential water savings and cost-effectiveness of a WBIC upgrade against those resulting from an irrigation system upgrade alone.

Neither of these assumptions alter the TIR calculation or the WUCOLS formulae shown in Table 6.

Adjusting for Changes in Weather During Pre- and Post-Installation Periods

Smart controllers are complex devices designed to adjust irrigation applications to match prevailing weather conditions. When working with irrigation consumption data from different time periods it is essential to take weather conditions into consideration so that changes in usage patterns are accurately attributed. In this study the fundamental method for adjusting for changes is climate and weather conditions in the pre- and post-installation periods (frequently referred to as the weather correction) was to calculate the percent of the Theoretical Irrigation Requirement (TIR) applied for each period and to compare the results.

The Theoretical Irrigation Requirement (TIR) represents an estimate of the landscape water needs at each study site. The Theoretical Irrigation Requirement is an imperfect estimate, but since more detailed site level data were not available, it is the best available way to approximate the irrigation requirement.

Application Ratio

The application rate at each site (measured in inches) was divided by the corresponding Theoretical Irrigation Requirement value (also measured in inches) to determine the percent of Theoretical Irrigation Requirement (TIR) applied at each site during the pre- and post-smart controller periods. This term is called the Application Ratio (AR). If 100% of the TIR is applied, AR = 1.0 = 100%. This indicates that the theoretical irrigation requirement at the site is identical to the actual irrigation application. If 150% of the TIR is applied, AR = 1.5 = 150%. This indicates that excess water was applied. If 75% of the TIR is applied, AR = 0.75 = 75%. This indicates less irrigation water than was theoretically required was applied to the site. The TIR divided by the application rate produces the percent of TIR applied = Application Ratio = AR. The formal calculation of this term is shown below.

Equation 2: Application Ratio (AR)

$$\text{Application Ratio (AR)} = \frac{\text{Application Rate (inches)}}{TIR\text{ (inches)}} = \frac{\dfrac{(\sum_{\text{n months}} usage) - n \cdot \min(usage)^*}{\text{landscape area}}}{(K_c \cdot \text{ETo}) - \text{effective precipitation}}$$

*Unless a dedicated irrigation meter was indicated.

Where:

ETo = Gross annual evapotranspiration (inches) from CIMIS

Effective Precipitation = annual effective precipitation (inches) calculated as specified above

K_c = ET adjustment factor or crop\landscape coefficient = 0.8 (from Updated Model Water Efficient Landscape Ordinance 2004[13])

[13] Updated California Model Water Efficient Landscape Ordinance, Reference: Section 65597, Gov. Code.

The AR was calculated for both the pre-smart controller year and for the post-smart controller year. The subtracted difference between the Pre-AR and the Post-AR is the weather-normalized Application Ratio change score or ΔAR applied. A negative value of ΔAR indicates a decrease in water use and a positive value of ΔAR indicates an increase in water use. This equation for the fractional unitless ΔAR factor is shown below.

Equation 3: Change in Application Ratio (ΔAR)

$$\Delta AR = Post\text{ - }AR - Pre\text{ - }AR$$

Where:

Pre-AR = the Application Ratio during the year before the smart controller was installed; and

Post-AR = the Application Ratio during the year after the smart controller was installed.

The percent change in water use for each site (percent change in use) is calculated as ΔAR divided by the Pre-AR. The equation for this percentage is shown below.

Equation 4: Percent Change in Water Use

$$\%\ \text{Change in Water Use} = \frac{\Delta AR}{Pre\text{ - }AR}$$

Where:

ΔAR = weather-normalized Application Ratio change score

Pre-AR = the Application Ratio during the year before the smart controller was installed.

The percent change in water use represents the percentage by which irrigation water use at a site has changed from the pre-smart controller year to the post-smart controller year taking into full consideration changes in the weather conditions and precipitation available at the site during those years. The % change in water use was multiplied by the pre-seasonal water use (kgal) to determine the weather-normalized volumetric change in water use at each smart controller site as shown in Equation 5.

The percent change in water use as calculated in this study is weather-normalized because the theoretical irrigation requirement in each year for each site used to calculate the Pre-TIR and Post-TIR and then the Pre-AR and Post-AR, effectively adjusting the change in Application Ratio change score for each unique climate condition. All of the work the research team spent aligning billing data and CIMIS data were for the purpose of making this essential weather correction calculation.

Equation 5: Weather-normalized Change in Water Use

$$\text{Change in volume} = \%\ \text{Change in Water Use} \times \text{Pre - Outdoor Use (kgal)}$$

The weather-normalized change in water use was the fundamental measurement used to establish water savings in this research study. Calculated as shown in Equation 5, the weather-normalized change in water use is an effective way to examine the impact of smart controllers on water use across study sites and allowed the researchers to measure the impact of smart controllers in a variety of contexts. A key assumption in this methodology is that the % change in water use (Equation 4) and the pre-installation outdoor water use (from billing data) are independent. The researchers carefully examined the co-variance of these two values and found it is small in comparison with the variance of the pre-outdoor use which supports the assumption of independence. Another thing to keep in mind with this methodology is that reductions in water use from one level of under-irrigation to a greater level of under-irrigation will be counted as a reduction in use, but this might not be correctly interpreted as a "savings".

Potential Sources of Uncertainty

Because of uncertainty in the irrigated area data and ET values and because the irrigation efficiency of each system was not known (and hence assumed to be 100% for all sites) there is an unknown amount of error in the key parameter estimates of Pre-AR, Post-AR and ΔAR. The landscape area could be too large or too small. The theoretical irrigation requirement could be too high or too low. Even the water use data could contain inaccuracies (although this is probably the least likely source of errors as long as the referential integrity of the database is carefully maintained as it was in this study). No control group was utilized in this study. However, since all sites were treated identically during the pre- and the post-smart controller periods, and because the sample size (n=2,294) is relatively large, the overall impact of the analysis of changes in water use derived from this methodology appear quite reasonable. Furthermore, the sensitivity analysis (presented and the end of the impact analysis section) confirms that if precipitation is disregarded and or if a higher percentage of precipitation is considered effective, the fundamental finding of this study is unchanged. That unchanged fundamental finding is that statistically significant reductions in water use were measured from the pre- to post-smart controller periods.

Descriptive and Validatory Statistics Methodology

The presentation of descriptive and validatory statistics about the California Smart Controller Programs provides a picture of what controller products were installed, what class of customers installed the products, where they were installed, how they were installed, the irrigated area of participating sites, the theoretical irrigation application requirement at these sites, and the actual irrigation application before and after the installation. Please note that the determination of the water savings achieved by these devices is part of the impact evaluation presented in the next section of this report.

Descriptive statistical analysis including mean, median, and standard deviation of a number of variables (landscape size, water use, application rate, TIR, AR, change in water use) was completed on three fundamental levels: local (by agency), regional (by county, congressional district, and ET zone), and statewide (northern & southern Program, and combined). Some results were also be broken down by manufacturer, product, installation method, and customer class.

The Statistical Package for Social Sciences (SPSS) software package was used to product descriptive statistics such as frequency distributions, means, medians, and standard deviations. The software package was used to help create summary tables of survey results such as those found in the chapter on customer survey response. Where appropriate validatory statistics, such as the 95% confidence intervals, were constructed around the means. A 95% confidence interval bounds the values in which, 95 times out of 100, the computed mean for the sample will match the true mean for the population.

ANOVA and Multiple Regression Methodology

ANOVA, bivariate, and multiple regression analyses were used to determine the factors that did and did not influence changes in water use. Multiple regression analysis was also used to compare the performance of different smart controller technologies on a level playing field because factors that were shown to influence water use could be controlled for as much as possible. All analyses that involved a comparison of one or more factors or groups were completed through the multiple regression effort.

ANOVA and Bivariate analyses. In order to examine the association of smart controller installation and site characteristics with changes in water use, ANOVA and bivariate analyses were performed. Using ANOVA (analysis of variance), the relationship between weather-normalized changes in water use and categorical variables such as the installation method, climate zone, control technology, etc. was examined. This test examines whether differences in the levels of the variable (weather-normalized changes in water use in this example) are different in the specified subgroups. Factors with p-values less than 0.05 were considered statistically significant. This means that for whatever change in the means was detected, the probability of that this change was due to simply random variation is less than 5%. Statistically significant factors found to impact changes in water use, and other factors of interest - were then used to construct multiple regression models as described below.

Multiple regression analyses. There were differences in the characteristics of smart controller sites in northern and southern California. There were also differences in characteristics between residential and non-residential smart controller sites. In order to ensure that any observed differences in weather-normalized water savings between different controller technologies (and a variety of other factors) were not due to differences in the distribution of other characteristics associated with water savings, multivariate analyses were performed. A multivariate analysis known as multiple linear regression allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and water savings estimates after adjusting for factors known to influence savings such as the application rate prior to installation of the smart controller.

The first step was to examine the bivariate relationships between water use and factors that might be associated. Where a significant relationship was observed, the factor was deemed appropriate for inclusion in a multiple linear regression model. A multiple linear regression model allows the simultaneous examination of the association of multiple factors with a single outcome measure of interest, often referred to as the dependent variable. In this instance, the estimated annual percent water savings per site was the dependent variable. The factors examined for an association with the dependent variable are referred to as independent or predictor variables. This simultaneous examination allowed researchers to look at a particular association of interest, for example the association of smart controller technology, simultaneously adjusted for all the other variables in the model.

Factors identified as significant through the ANOVA and bivariate analyses were entered into a series of regression models. A number of different regression models were examined using combinations of variables to choose the most predictive models presented in the impact analysis chapter. The researchers investigated the impact of transformation of the data set (lognormal and exponential based on the observed frequency distribution) to try and improve model fit and statistical significance, but it was determined that this exercise in fact offered no improvement over the linear models.

The statistics produced for regression equations include a test of the hypothesis that there is no relationship between the dependent variable and the predictor variables, the null hypothesis. The results of this test were reported as an F-statistic with an associated p-value. Conventionally, only models with a p-value of 0.05 or less are considered significant, meaning that there was less than a 5% chance that the difference predicted by the model was due to chance. Hence, at the 95% confidence level, the null hypothesis was rejected. In addition, an adjusted R-squared was calculated, which can be interpreted as the proportion of the variability in the dependent variable accounted for by the factors and the number of variables included in the regression model.

Regression coefficients were calculated for each predictor variable in the model. These coefficients can be interpreted as a slope of the average change in the dependant variable to a small change in the predictor variable. The regression coefficient represents the amount the dependent variable would change, all other variables held constant due to a small change in the independent variable. A test of statistical significance was calculated for each regression coefficient, with a corresponding p-value. A Bonferonni Correction was also applied.

The fit of the model and the appropriateness of the variables for inclusion in the model can be tested by examining a scatter plot of the predicted values (usually on the x-axis) and the residual values, usually on the y-axis. A predicted value for the dependent variable can be calculated for each case, given values for the independent variables in the model for each case. The residual values are the difference between the actual value of the dependent variable for a case and the predicted value. In a perfect model the residual value would be zero and all points would lie on the x-axis. If there is not an abnormal distribution of the dependent variable or of the other variables included in the regression model, the scatter plot will resemble a cloud or a "goose egg," with no discernible relationship or pattern between the predicted and residual values.

Adjusted means of the dependent variable can be calculated for subgroups of one of the independent variables, e.g., average annual water savings per smart controller site, adjusted for the other variables included in the model. This was done by applying the average values across the entire sample for each of the independent variables.

The results of this analysis are based on mathematical models and other statistical tools that seek to find the center point of a large group of data, or a line that represents the best fit between two variables. In practice, there will always be data points above and below the values predicted by even the best models. Statistical models often give the impression of great precision, however in reality these models seldom predict water savings for any specific site very well, but they will predict water savings for a large group much better.

When an analysis shows there is a 95% confidence level that there will be a specified difference if the average water savings between two groups this should be thought of not as a prediction that water savings of individual members of the group will vary by this amount, since due to the distribution of the data they might not, but as a prediction that there will be a 95% probability that the average water savings of a number of examples chosen from the two groups will vary by this amount. From the perspective of any planning or policy study that deals with large groups, the ability to understand such group dynamics is a key to good decision making.

Cost-Effectiveness Analysis

When people decide if the advantages of a particular action are likely to outweigh the drawbacks, they engage in a form of benefit-cost analysis. Traditional benefit-cost analysis attempts to weigh the total expected costs against the total expected benefits of an action in order to choose the best or most profitable option. Cost-effectiveness analysis is a form of economic analysis that compares the relative expenditure (costs) and outcomes (effects) of two or more courses of action. Cost-effectiveness analysis is often used where a full benefit-cost analysis is inappropriate or not possible given the available data (Griffin 2006).

In this study, which spanned four years, included multiple smart controller technologies, and involved nearly 30 water utilities; it was simply not feasible to conduct a traditional benefit-cost analysis. Neither the full costs nor the full benefits of smart controller programs was adequately measured by any party. What was possible was to use the water savings measured through this evaluation study to develop a series of cost-effectiveness analyses with the goal of determining the level of investment (or expenditure) that could be justified for the purpose of providing incentive and purchasing a smart controller. The mixture of study sites in this project was never intended to be a representative sample of potential smart controller customers – rather, the sample is a longitudinal mixture of sites, smart controller technologies, and program distribution methods.

The cost-effectiveness analysis was developed to examine both the utility and customer perspectives on the purchase and installation of smart controllers. No attempts were made to present the costs of purchasing, installing, and maintaining a controller. Although some retail controller price information (from 2007) is presented in Appendix A, the actual price paid by utilities and customers was only provided to the research team for a limited set of study sites. Utility costs for implementing the program are extremely difficult to account for. Since this was a pilot effort with several changes of course, the agency costs are really not representative of what a could be expected for a utility with a fresh start seeking to implement a program today, equipped with the information and guidance provided in this report.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. For the customer perspective, cost-effectiveness analysis was used to determine the level of investment it would be reasonable for a customer to make in a smart controller given the anticipated water and cost savings achievable through installation of the device. Other benefits of the smart controller such as convenience and improved landscape health are difficult to quantify in dollar terms, but are also discussed.

The cost-effectiveness analysis implemented in this study interjected financial factors to examine what level of investment might be appropriate and financially advantageous given the estimated water savings from targeted and general (non-targeted) smart controller programs. Those factors and the methods in this section have been generalized so that results can be broadly applied, but for individual agencies, smart controller options, customers, and site characteristics, a specialized analysis will be superior and preferred.

Given an expected lifetime of 10 years, the cost-effectiveness analysis measures the justified expense of an upgrade (or new installation) over that 10-year period. For purposes of comparison, the Net Present Value (NPV) of the cost of water over that period was calculated with an annual discount rate of 3%. For customers considering a smart controller purchase, the present worth of 10 years of water savings was calculated for a range of retail price values. For utilities, 10 years of water savings was calculated for a range of avoided cost for water values.

Table 7 presents a matrix of possible outcomes from cost effectiveness analysis. Sites that do not reduce water use will obviously not be cost-effective. In some cases, a smart controller may not be cost-effective even if water use is reduced, but other benefits of the smart controller may stimulate the purchase.

Table 7: Potential cost-effectiveness analysis outcomes

	Application Rate Decrease	**No Change In Water Use**	**Application Rate increase**
Cost effective over 10 year expected product life.	Clear benefits from smart controller.	NA	NA
Not cost effective over 10 year expected product life.	Water bill decreases, but savings take more than ten years to recoup expenditure. Benefits besides water/cost savings possible.	Benefits besides water/cost savings possible.	Benefits besides water/cost savings possible.

The cost-effectiveness analysis was constructed using the average and median per customer water savings estimated for sites with four different landscape areas (4,000 sf, 12,000, 25,000, sf, and 150,000 sf). These areas encompass the range of residential and non-residential landscapes found in northern and southern California and elsewhere. While not specifically designated as residential and non-residential analysis, the smaller landscape sizes are more typical of residential properties and the larger landscape sizes are more typical of commercial and dedicated irrigation properties.

A range of values for the avoided cost of water (utility perspective) and the retail cost of water (customer perspective) were considered. Many different utility agencies participated in this study and since each agency may have their own calculated avoided cost for water, the cost-effectiveness analysis considered a broad range of values. The avoided cost of water for the California agencies in this study ranges from approximately $100/acre-foot up to $1,000/acre-foot. For many agencies in other parts of the country the avoided cost for water can be as high as $15,000 per acre-foot. Since it is anticipated that this study will be of interest outside of California, the range of avoided cost values was expanded up to this very high range. The retail cost per hcf of water (customer perspective analysis) ranged from $0.50/hcf up to $12/hcf in an effort to provide useful information for a broad range of customers and utility agencies in California and beyond. The discount rate for present worth analysis was assumed to be 3% in all cases. The expected useful life of a smart controller is estimated at 10 years, so that was the length of time used for the cost-effectiveness calculations.

Additional Considerations for Cost-Effectiveness Analysis

The cost-effectiveness analysis developed for this study is likely too general to cover all participating agency and smart controller model conditions. It is acknowledged that the cost effectiveness analysis presented in this report does not fully consider potentially important factors such as tiered water rates. The cost model assumes flat water rate which may correspond, however savings across a typical tiered rate structure could make a smart controller more cost-effective. Other simplifying assumption may make it desirable for utilities to conduct their own cost-effectiveness analysis before implement a smart controller incentive program.

Data Analysis and Final Report Preparation

Research team members Peter Mayer and Matt Hayden from Aquacraft, Inc., and Erin Caldwell from National Research Center assembled the data and conducted the analyses in this research study. Renee Davis of Aquacraft, Inc. researched smart controller technologies and prepared the detailed controller information found in Appendix A. Bill DeOreo of Aquacraft, Inc. was instrumental in developing the analytic framework for the study and in particular the methodology used to make weather corrections. He also provided guidance during the entire project and in particular during the data analysis phase. Dr. Tom Miller of National Research Center oversaw the entire survey process and assisted with statistical methods. Dr. Peter Bickel of the University of California, Berkeley was the team statistical consultant. He reviewed the statistical methods employed by the research team including the sampling methodology, seasonal use disaggregation, weather corrections, ANOVA and bivariate analysis, well as the multiple regression models developed. Peter Mayer managed the project and was largely responsible for production of the final report.

Most data analysis for this study was accomplished using the Statistical Package for Social Sciences (SPSS). Additional analytic tools included Microsoft Access and Excel.

The final report preparation process began in 2005 and 2006 with the preparation of the interim process evaluation report for DWR. Working from that document and the original scope of work, an outline of the final report was developed. Data analysis was accomplished during the late Summer and Fall of 2008. Preliminary results were presented at the WaterSmart Innovations Conference in October 2008 in Las Vegas, Nevada. That process yielded some excellent suggestions for modifying and improving the analysis. These ideas were incorporated into the subsequent analytic process and final report preparation.

PROCESS EVALUATION OF CALIFORNIA SMART CONTROLLER PROGRAMS

Southern California Programs

The southern California smart controller grant program was developed and implemented by the Metropolitan Water District (MWD) and its member agencies. MWD issued agreements and allocated grant funding among its member agencies in February 2004. MWD organized a committee of its interested agencies to formulate implementation plans and provide input into the development of database and reporting requirements. This committee also tested the database and worked with MWD to adapt requirements and reporting forms as the program evolved.

To support its member agencies, MWD issued a Request for Information (RFI) to smart controller manufacturers to compile a list of available devices. Responses were received and an initial list of devices was provided to the agencies. Information on available controllers was posted on MWD's bewaterwise.com website. MWD also distributed brochures titled "Choosing a smart sprinkler controller for your home," which served as a simple buying guide for homeowners.

MWD's member agencies invested significant time and resources to implement and market their programs, which included selecting smart controllers for their respective programs. Agencies also familiarized themselves with various smart controllers on the market for inclusion in their local programs.

There was not much activity early in the program. MWD held a workshop to discuss implementation issues with its agencies. The agencies expressed several challenges they were facing in implementing programs, including:

- Lack of resources and expertise with this new technology
- Lack of understanding by homeowners on smart controller features, capabilities, and where to purchase them
- High costs compared to standard controllers

MWD took this feedback and formed an internal brainstorming group that met weekly to rethink the approach to program implementation. The concept developed as a result of these sessions was to test a large distribution event of smart controllers modeled after the ultra-low-flush program that has been successful over the past 10 – 15 years. MWD issued a Request for Proposals for smart controllers and purchased a small number of controllers to test the concept. MWD also developed forms and promotional materials for the distribution event such as the example shown in Figure 1.

Figure 1: MWD brochure announcing controller distribution event

MWD asked customers to pre-register for the event and assigned time slots for customers to exchange old units for smart controllers. Customers were required to disconnect their old controller and bring it to the event in exchange for a free new smart controller. MWD's consultant provided training on installation and programming of the new smart controller. For the first exchange event, MWD partnered with Armstrong Nurseries and the Los Angeles Department of Water and Power. MWD and LADWP staff coordinated the event and scheduled customers every half-hour to arrive with their old controller and go through a 20-minute training session on installation and programming.

There were not many customer registrations from the distribution of flyers, so MWD decided to issue a press release. A newspaper picked up the story and ran an article about the event in its Saturday edition. MWD had established a phone line for reservations, but did not know the article was going to print on Saturday and therefore and did not have the phone line staffed over the weekend. There was enormous customer response and the voice mailbox was full early Saturday morning, which caused customer frustration. MWD and LADWP received numerous complaints. The following Monday, MWD staff returned phone calls and continued clearing out the voicemails as they came in. By the end of Monday, the event schedule was fully subscribed.

This first distribution was very successful. MWD distributed 120 smart controllers. One of the unknown factors going into this first event was whether people would be willing to disconnect electrical wiring to their old controllers. Surprisingly, at least 98 percent of the participants brought in their old controllers, which were a varied group of devices, as shown in Figure 2.

Figure 2: Old irrigation timers collected by MWD at an exchange event

Based on customer response to the initial distribution event, MWD decided to test a number of methods to distribute smart controllers. MWD issued a Request for Proposals to purchase a larger number of controllers. Three manufacturers were selected, which were WeatherSet, Weathermatic and Aqua Conserve.

With a supply of controllers on hand, MWD began testing different methods. For some events, MWD staff and agency staff conducted the event. For others, MWD hired a consultant to conduct the distribution events. Many agencies distributed units from their offices or parking lots. Some agencies also provided lists of certified installers provided by the manufacturer to participants providing access to trained installers.

Exchange Programs

MWD worked with Descanso Garden to have a large distribution event that involved four MWD member agencies – Foothill MWD, City of Glendale, City of Pasadena, and City of Burbank. Participants received a DVD on programming and installation instead of a training class. This allowed for a larger number of controllers to be distributed in one day. At this one event, 432 controllers were distributed.

Another method tested to distribute a large number of controllers in one day was a drive-up exchange and distribution. Participants were pre-registered and went through drive-up "stations," where they signed their paperwork, then moved to the next station and dropped off their old controller, then the next station where they received their new controller and a DVD on installation and programming. Anyone with questions was directed to a holding area in order to not disrupt the flow of the process. At this event, 470 controllers were distributed.

MWD has a long-standing training program for homeowners called the California-Friendly Landscape Program (formerly named the Protector del Agua Program). In these classes, homeowners learn about landscape design, plant selection, sprinkler systems, and fertilization. This seemed like a logical place to offer controllers to homeowners. A new segment of the class was developed on installing and programming a smart controller. The California-Friendly Landscape classes allowed for smart controller distribution along with more extensive training. There were 26 California-Friendly Landscape Program classes where smart controllers were distributed. Participants were required to return their old controller before receiving the new smart controller similar to the other distribution programs.

MWD explored implementing comparable distributions to commercial customers. The theory was that since small commercial settings could use residential size controllers, distribution programs could apply to specific commercial customers. MWD explored this option with fast food establishments and churches, but found that it was difficult to gain access to these customers to discuss installing smart controllers. This effort was subsequently discontinued.

MWD tried offering controllers through a local community college class. Students were required to pay a small amount toward the cost of the controller. There was difficulty with this method due to a lack of control over student registration and inability to prescreen participants. Variability in student participation from different water agency service areas complicated data collection. Due to the complexity of this method, it was discontinued after the initial event.

Using the remaining smart controllers on-hand, MWD distributed smart controllers to participants that registered on-line. They were sent a confirmation email after verifying eligibility and provided an appointment to bring their old controller in exchange for a new smart controller. The distribution was held at MWD's headquarters in Los Angeles. Participants came from throughout MWD's service area. One hundred smart controllers were distributed through the on-line method. This method was by far the most cost-effective and simplest in terms of staff time for implementation.

While MWD conducted the distribution events, member agency programs also began in earnest. In early 2006, several agencies were successful in implementing direct-installation programs. MWD began to see local agency programs quickly getting units installed. In May 2006, MWD reallocated remaining grant funds to support agencies that were successfully implementing local programs. Photos from MWD exchange events are shown in Figure 3.

Figure 3: Photos from MWD smart controller exchange events

Rebate Programs

Rebate programs offer a financial incentive to customers to install a smart controller. Rebates in southern California range from $50 up to the full cost of a controller. A variation of rebates is a voucher program, where the customer applies for a voucher before the purchase of the smart controller. The rebates reported include some voucher programs. Installation is typically not included as part of a rebate or voucher program, but a number of agencies offered training programs to assist customers with proper installation. In addition, lists of trained and knowledgeable installers were provided. Agencies differed in how the rebate was provided to program participants and in the level of field verification required to ensure installation. Rebate programs were typically open to customers with automatic sprinkler systems.

There are some basic challenges associated with smart controller rebate programs: 1) Attracting participants; 2) Product availability; and 3) Free-riders. A number of southern California agencies that implemented a rebate program had difficulty publicizing the program and attracting participants. Smart controllers are a new technology and most customers are simply not aware of what they are and what they can do. It is often difficult for an agency to effectively market a rebate program in this situation. Once this technology gains in popularity and reaches deeper into the public consciousness, it should be much easier for an agency to attract participants to a rebate program. Free-riders are customers who purchase a device (in this case a smart controller) and get a rebate, but would have made the purchase even without the rebate. Free-riders can be a problem with any rebate program. When promoting a new and largely unknown technology such as smart controllers the problem of free-riders is likely to be much smaller than with a toilet or clothes washer rebate program.

Foothill MWD, San Diego County Water Authority, Long Beach Water Department, and Eastern MWD all implemented smart controller rebate programs. San Diego County hired a marketing firm to produce promotional materials for their rebate program. They were successful in recruiting participants, but found their financial incentives were not particularly motivating since a neighboring county offered substantially higher incentives at the same time. Long Beach didn't advertise their rebate program at the beginning and hence had almost no interest, but the program took off once a dedicated staff person was assigned to recruit high water-using customers and to perform installations. Long Beach also ran a targeted direct installation program. Eastern didn't experience any marketing or recruitment challenges, but their requirement for irrigation system repairs and upgrades slowed down the program process.

Direct Installation Programs

Direct installation programs identify a set of customers to solicit (e.g. high water users). These customers are then solicited to participate in the direct installation program where the agency either hires a contractor to perform the installations or does the installation work with its own staff. Typically the controller and installation is offered for free. The benefits of direct-installation programs are that the smart controllers are installed and programmed properly. However, these programs tend to be more expensive, as the utility must bear the cost of the hardware and the labor.

Summary of Programs

Consistent with MWD's initial program design (market-based approach), the southern California smart controller programs have evolved since they began in 2004 to adapt to the realities experienced by the implementing agencies. Most of the evolution was in the residential, self-install method. Several agencies (LADWP and Eastern) started by implementing targeted direct installation programs and then changed direction at some point to implement rebate and exchange programs. Long Beach started with a rebate program and moved to direct installation. Each of the methods employed in southern California has worked, but agencies have adapted their programs to either decrease costs or increase the distribution rate of smart controllers. This suggests that on-going evaluation, flexibility, and a willingness to adapt to changing conditions can be helpful when implementing smart controller programs.

The following chart shows the total number of controllers installed through the different program types. The largest number was the free exchange programs, where 2,475 controllers were distributed.

Looking at the programs by residential versus commercial, since all of the exchange programs were for residential, the breakdown shown below displays the difference in distribution methods used for the two different types of participants. For commercial participants, the largest numbers of controllers were distributed through direct-installation programs.

By the end of the grant, 20 of MWD's 26 member agencies participated in the program. Four of MWD's member agencies were excluded because they had a similar State grant for smart controllers. Table 8 shows a breakdown by member agency and program method used. Figure 4 and provide a summary of the distribution methods utilized in southern California.

Table 8: MWD smart controller distribution by member, method, and customer category

Agency	Residential			Commercial		Total
	Exchange	Rebate	Direct Install	Rebate	Direct Install	
Beverly Hills	1				41	42
Burbank	91					91
Calleguas	78			22		100
Central Basin	78			39	17	134
Eastern	3			100	44	147
Foothill	347	21				368
Glendale	168					168
Inland	286	93				379
Las Virgenes	22		1		45	68
Long Beach	47	32	198		67	344
LADWP	143		430		47	620
Pasadena	74		11	35		120
SDCWA	676	17		150		843
San Fernando	7					7
Santa Monica	61	3	63	2	1	130
Three Valleys	165					165
Torrance	20					20
USGV	167					167
West Basin	2	29			13	44
Western	39		207	52	379	677
Total	2,475	195	910	400	654	4,634

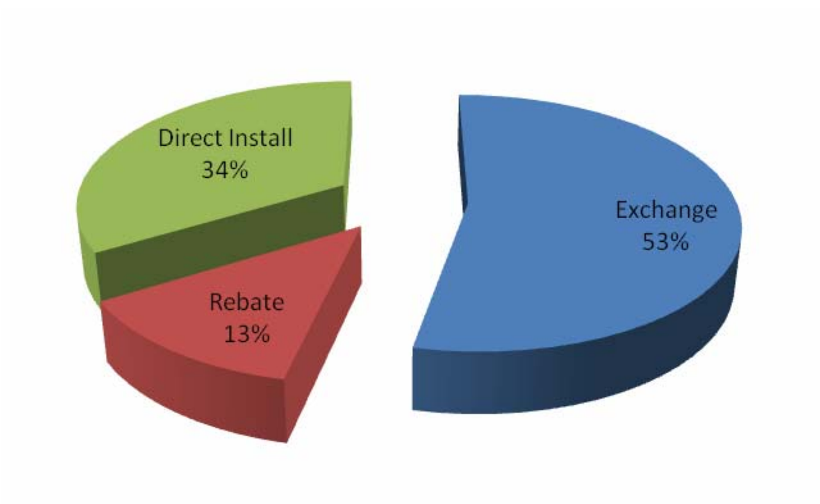

Figure 4: Summary of Southern California distribution methods

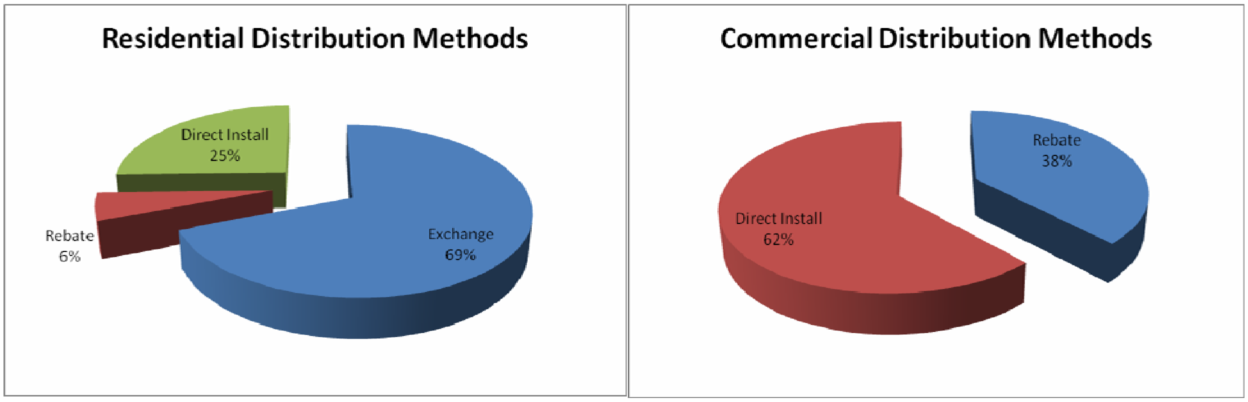

Figure 5: Residential and commercial distribution methods in southern California

Public Awareness of Smart Control Technology in Southern California Increases

MWD measured customer awareness of weather-based irrigation control technology in 2005 when the program began and again in 2007 as the distribution and education effort matured. In 2005, only 15% of respondents indicated that they were aware of the existence of weather-based control technology. In 2007, 38% of respondents were familiar with the technology. This substantial improvement was largely due to the MWD and member-agency program efforts. Such improvements bode well for the future of this technology in the region.

Northern California Programs

The northern California Smart Controller programs were made up of distribution programs at five participating agencies (listed earlier in this report) under the leadership of EBMUD. Much of the early effort was focused on conducting a market research study[14] to develop a strategy and plan, designing smart controller distribution programs, and creating a web-enabled database tool for collecting and centralizing data from the distribution programs. This effort in conducting background research and developing a web enabled database tool has established the groundwork for the program implementation, project evaluation, determination of water savings, and long-term monitoring of water use on participating sites.

Before developing individual northern California programs, the six agencies first developed an interagency Memorandum of Understanding (MOU) to establish the responsibilities of each agency with respect to administrating the grant funds awarded by DWR and satisfying the conditions of the grant agreement. The MOU:

1. Established a Project Coordination Team made up of one representative from each agency.
2. Established a procurement process to hire a third-party regional project administrator and to hire a vendor to develop a regional database.

[14] The market research effort was an EBMUD project conducted by PMSI.

3. Established that a third-party vendor would be hired to evaluate the statewide program. The California Urban Water Conservation Council (CUWCC) agreed to facilitate the procurement process and the statewide evaluation for both the northern and southern California programs.

Figure 6 shows the relationship of the agencies and agreements that were put in place to implement the northern California WBIC program. Establishing the administrative structure and developing multiple agreements required substantial time and resources on the part of EBMUD and its northern California partners. An extension of eighteen months was requested from DWR and granted to allow a full irrigation season to collect data for this report. There was regional coordination on the database. Each agency designed and implemented its own program.

Coordinated Regional Database

The five participating northern California agencies created a web-enabled central database for the purpose of storing data on the smart controller programs and to assist in producing required reports to DWR and the final project evaluation. In September 2004 an RFP was issued for the database development and Media Net Link (MNL), a San Ramon firm specializing in business web services was selected to develop program specifications and a database tool. After an extensive specification and development process, MNL's tool became operational in 2007 and was used to provide data for this report by four of the five northern California agencies. The central database did provide a tool for uniform data collection, but it did not prove to be as user friendly or capable as originally envisioned.

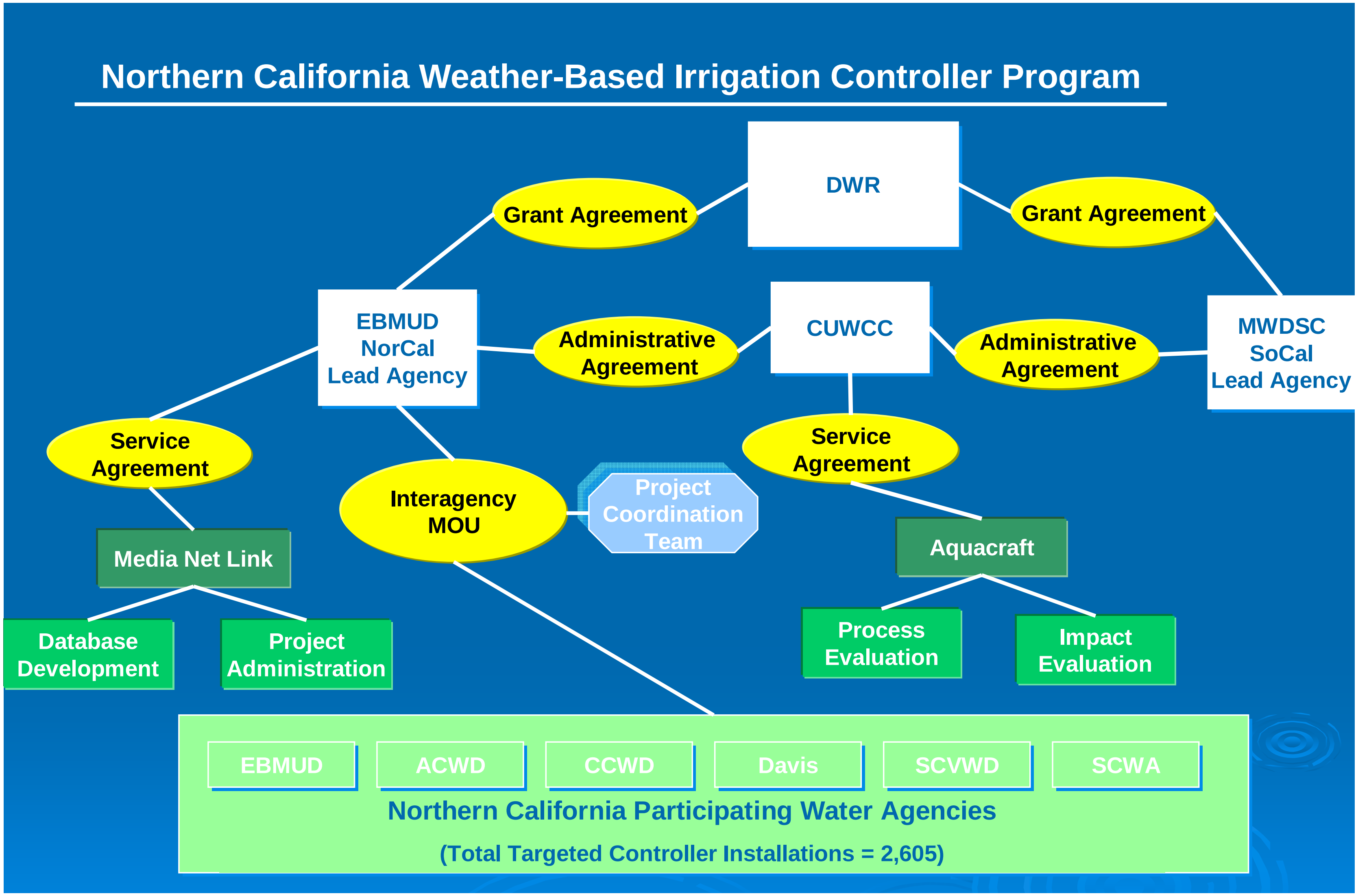

Figure 6: Relationship chart for northern California programs

Controllers Installed in Northern California

Some northern California agencies began their incentive programs in 2004, but more formal programs began in 2005 and 2006. Distribution methods focused on targeted rebates and vouchers. Table 9 presents a summary of the controllers installed through October 2008 as part of the northern California program.

Table 9: Northern California smart controller installations by agency

Agency	1 to 12 Stations		13 to 24 Stations		25 Stations and up		Number of Controllers Installed	Original Number of Controllers Allocated
	Direct Install	Self Install	Direct Install	Self Install	Direct Install	Self Install		
EBMUD		442		297		63	802	1305
Alameda	6	47	20	37	1	3	114	124
Contra Costa		56		60		25	141	149
Santa Clara	66	12	40	200	3	137	458	657
Sonoma	88	40	19	26	4	21	198	291
Total	**160**	**597**	**79**	**620**	**8**	**249**	**1713**	**2605**

Goal of Market Transformation

Many of the incentive programs implemented northern California were intended to “transform” consumer behavior by encouraging the adoption of new technologies. Agencies like EBMUD believed this effort in market transformation distinguished their program from more traditional demand management efforts, but they also pointed out that demand management and market transformation are distinct yet complimentary approaches.

Demand management programs typically focus on cost-effective conservation through the delivery of water saving devices or services at a low cost with a target market comprised of end users. Market transformation programs focus on strategies that promote long-term market changes that further return on investment without the continuing need for incentives after a threshold of market change has been achieved. The target audience for a market transformation program involving smart controllers might include manufacturers, distributors, retailers and service providers as well as the retail consumer.

The PMSI market research report prepared for EBMUD concluded that consumer incentives (such as rebates and vouchers) were likely to be more successful if market and product performance information were provided to potential program participants. With this knowledge, EBMUD in particular sought to use their agency incentives to educate and influence both consumer and distribution ends of the supply chain.

EBMUD Marketing Strategy and Plan

To maximize potential water savings and cost-effectiveness, EBMUD identified a target audience of residential and non-residential customers using an average of 750 gallons per day outdoors during the irrigation season. Other northern California agencies adopted a different approach as described in Table 11.

EBMUD contracted with Planned Marketing Solutions International (PMSI) to develop a marketing strategy and plan for their smart controller distribution program. PMSI has experience in marketing smart controllers through their work with the Irrigation Association and SWAT. Although funded by EBMUD as part of their program development work, the information was shared with the northern California partners as well as interested agencies in the south. The work was not billable to the DWR grant but was considered part of the EBMUD cost share for program development and implementation.

The PMSI report, primarily based on two residential focus groups and interviews with facility and property managers conducted in October 2005, identified target audiences for smart controllers, marketing objectives, potential program challenges and obstacles, strengths and opportunities, marketing strategies, and recommended marketing tactics.

Two key marketing objectives were identified:

1. Motivate 940 qualified EBMUD residential customers and 365 qualified commercial customers to replace their existing conventional controllers with smart controller technology.
2. Meet this installation goal by no later than April 15, 2007 - with the majority of controllers installed as soon as possible to maximize the time period over which they can be evaluated for water savings potential.

A number of the report's recommendations proved useful. Key obstacles identified by PMSI include educating the target audience about the technology and its value and overcoming resistance to "customer inertia." Findings indicated this "inertia" is more likely to be an issue for residential customers according to the report. Commercial targets were anticipated to be more immediately receptive to the smart controller technology.

Strengths and opportunities within the smart controller program identified by PMSI ranged from the expected performance of smart controller technology to the cost savings (up to 50% of the controller cost) to be offered to participants. The report also noted that irrigation contractors and distributors should be supportive of the program as it offers new revenue opportunities for them and most Bay area distributors already had smart controllers in inventory.

Marketing strategies for residential customers described by PMSI include:

- Professional installation (except for insistent do-it-yourself types).

- Engaging landscape and irrigation contractors and experts and key influencers in the decision process.
- Launching landscape and irrigation contractor initiatives prior to the end-user program.
- Targeting qualified end users.
- Providing useful information to potential participants.
- Recruiting partners to serve as real world case studies.
- Leveraging industry organizations to promote the program.
- Additional marketing strategies for commercial customers described by PMSI include:
    - Interactive tactics to engage the customer in dialog.
    - Promoting certified Water Smart Irrigation Controller (WSIC) installation among landscape professionals.

PMSI's primary marketing message for residential customers was, "Installing a WSIC (or having a WSIC installed) in place of my traditional irrigation timer will save me money—now (through EBMUD's voucher program) and in the future (from reduced water use), while maintaining the health and beauty of my landscaping."

The recommended residential marketing tactics included:

- Develop end-user voucher program infrastructure.
- Generate targeted awareness of WSIC technology and the EBMUD voucher program.
- Support and build upon awareness efforts with more in-depth WSIC educational resources.

Similarly, the primary marketing message for commercial customers was, "Installing WSICs in place of traditional irrigation timers in the properties I manage is a smart decision. WSICs maximize irrigation efficiency, reduce water use and give me better control of my landscape irrigation while maintaining the health and beauty of the landscaping and helping the environment."

The recommended commercial marketing tactics included:

- Develop end-user voucher program infrastructure.
- Generate targeted awareness of WSIC technology and the EBMUD voucher program.
- Support targeted commercial end-users in making a case for WSIC technology within their organizations.

EBMUD was hopeful that their approach to conducting market research, developing a marketing strategy, and requiring product performance testing would in the long term lead to increased consumer awareness and satisfaction, as well as contribute to larger and longer term water savings.

Revised EBMUD Program

Beginning in January 2008 EBMUD deployed a revised and simplified smart controller distribution program with the goal of getting more controllers installed. Most significantly, the financial incentive was changed from a voucher to a rebate. The application process was simplified and the "pre-application" eliminated to make it easier for participants to enroll. Under the revised program, rebate monies were not made available to participants until an inspection was conducted that confirmed the installation and programming of the smart controller.

The revised EBMUD program featured a new consolidated information brochure, and article in the EBMUD bill insert publication "Customer Pipeline", point of purchase displays, an improved informational web page, and advertisements in local print media.

Rebate amounts, shown in Table 10, were based on historic irrigation demand at the site. Customers who historically used more water for irrigation were eligible for a large rebate since they presumably had need for a large and more expensive smart controller. Special rules applied for customers who installed more than one controller. The revised program still included the key feature of a utility inspection of each smart controller installation to ensure proper programming.

Table 10: EBMUD Smart Controller Rebate Amounts (2008)

Calculated Historic Irrigation Demand (gpd)	EBMUD Rebate Amount ($)
250 to 749	$100
750 to 2,999	$250
3,000 to 5,999	$350
6,000 and above	$500

Examples of marketing materials used by EBMUD are shown below in Figure 7 and Figure 8. EBMUD utilized some of the marketing materials developed by the Smart Water Application Technology (SWAT) program and found that they were particularly effective and explaining the concept of weather-based irrigation control and in stimulating customers to respond to incentive program offers.

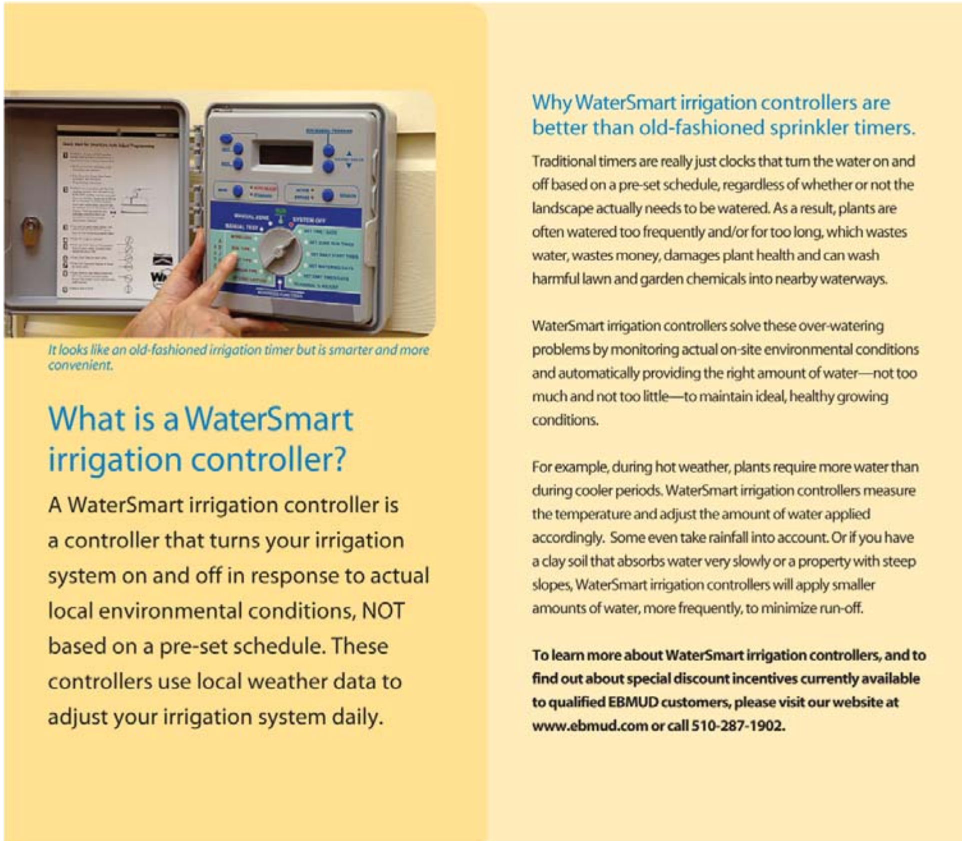

Figure 7: EMBUD Marketing Brochure Example 1

Figure 8: EMBUD Marketing Brochure Example 2

Summary of Implemented Northern California WBIC Programs

Northern California agencies implemented primarily rebate programs that evolved as they gained experience with the technology and program implementation. A summary of the northern California programs is provided in Table 11. Detailed descriptions and information about each program is provided in Appendix G. In general, the northern California programs were simplified over time from both an administrative and participant perspective. This was an effort to increase participation which rarely reached anticipated levels.

Table 11: Summary of Northern California Smart Controller Incentive Programs

Agency	Incentive	Description
EBMUD	Voucher/Rebate	Program started as a self-install voucher program targeting residential and commercial customers with high water irrigation use. Later changed to a rebate to simplify program administration and remove barriers for landscape contractors promoting the program.
Santa Clara Valley	Direct Install/Rebate	SCVWD provided pre-installation landscape surveys for each participant. Participants had the option of professional installation or self-installation. The installation program was modified to a rebate program in order to include additional controller manufacturers, minimize program administration and to meet landscape contractor's needs.
Contra Costa	Rebate – based on # of stations	CCWD ran two rebate programs. One program was a single-family residential program offering $25 per active station rebate. A second program focused on CII/multi-family users. This program provided a $40 per active station rebate. The programs targeted high water users.
Sonoma County	Rebate	Initially separate programs were created for residential and commercial customers. Customers were required to participate in a pre-qualifying audit before purchasing the smart controllers. The program was revised to reduce program requirements and combine the residential and commercial programs into a single program with one application form.
Alameda County	Rebate	ACWD program was originally launched as a direct contractor install rebate program but was changed to a self-install rebate program to simplify the program and encourage participation. Any replacement controller or add-on device that adjusted the irrigation schedule based on ET was eligible, subject to ACWD approval.

Controllers Installed Through DWR Grant Programs

Table 12 shows the total number of controllers installed through the southern and northern California smart controller programs. The southern program has distributed 83.9% of their anticipated total and distributed more large non-residential controllers than originally anticipated. Since non-residential controllers are more expensive, the southern California agencies were able use all of the DWR grant funding allotted for their program.

Northern California agencies had installed 65.8% of their target by October 2008. In addition to the controller distribution effort the northern agencies have worked over the grant period developing a detailed marketing plan to assist in the development of their installation programs and a regional web-based database to assist with program reporting over the five-year life of the project. The northern agencies sought an extension from DWR to complete the targeted number of controller installations but this was not approved and program installations are officially complete.

Table 12: Smart controller installations by region (as of 10/2008)

Region	Total # of Controllers Installed	Original Installation Projection	% of Original Estimate Installed
Southern California	4,629	5,514	83.9%
Northern California	1,713	2,605	65.8%
Total	6,342	8,119	78.1%

Figure 9 shows the installation data of smart controllers in northern and southern California graphically. The x-axis is the installation data and the first y-axis is the number of sites where controllers were installed on that date. The second y-axis is the cumulative percentage of controllers installed. This graph illustrates the southern California distribution events (many controllers given out at one time). It also shows the 2003-04 installations in Los Angeles. Since a full year of post-installation data were required to include a site in the impact analysis, the more recent install dates in northern California were not included. This figure provides graphical explanation for why only about 308 smart controller sites from that region could be included. Any controllers installed after June 2007 would not have been in the field long enough for sufficient post-installation data to be provided to impact analysis team. However, the grant funding agreements with DWR specify that post-installation data shall be collected for five years after installation, so there should be ample opportunity to evaluate the impact of all the smart controllers installed through these programs.

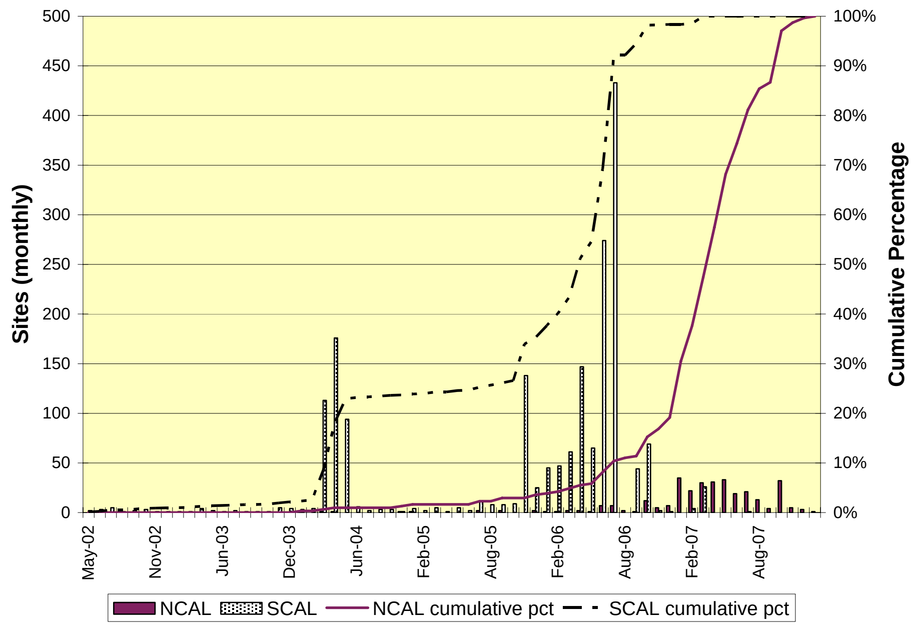

Figure 9: Smart controller installation date by region

CUSTOMER SATISFACTION SURVEY RESULTS FROM CALIFORNIA SMART CONTROLLER PROGRAMS

The results from the customer survey related to customer satisfaction are described in this section. Survey response rates are presented earlier in the report in Table 4. A complete set of results can be found in Appendix F. Some questions were asked of respondents about the type of landscaping on their property or the types of repairs made to the irrigation system at the time of installation or after installation. These questions were asked to determine whether these factors might be associated with observed changes in water use. None of these factors were found to be associated.

Respondent property and controller types

Nearly all of the surveys came from residential customers; 96% of respondents reported that the smart controller was installed in a single-family private residence (see Table 13). The survey respondents were more heavily weighted towards residential customers while the customers receiving a smart controller included many more non-residential customers. Among the customers for who water billing data were available (not just those who completed a survey), 85% were residential customers.

Table 13: Type of property where smart controller installed

Is the property where the smart controller was installed a . . .	Percent of Respondents	Number of Respondents
single-family private residence	95.6%	N=1222
multi-family housing complex	1.6%	N=20
park, playground or median	1.3%	N=17
commercial, industrial or institutional property	1.5%	N=19
Total	100.0%	N=1278

Respondents were asked whether their controller had an external sensor. Most (82%), replied that it did, with 10% saying that it did not, and another 8% answering they were unsure. Those who did have an external sensor were asked what type they had. The most common types among those with sensors were rain sensors (78%), temperature sensors (22%) and solar sensors (13%, see Table 14). About 8% of respondents were unsure what type of sensor was on their controller.

Table 14: Type of sensor, according to customer

What type of sensor(s) is it?	Percent of Respondents	Number of Respondents
Rain sensor	78.0%	N=622
Temperature sensor	22.3%	N=178
Solar sensor	13.0%	N=104
Soil moisture sensor	3.1%	N=25
Don't know	8.4%	N=67
Other	2.6%	N=21
Total*	100.0%	N=797

*Actual totals will equal more than 100% as respondents could give more than one answer

Those completing the questionnaire were asked when they thought they would recover the costs of purchasing and installing the smart controller. About three-quarters said there were no costs, as the controller and installation were free. Among the other one-quarter of respondents, about half thought it would take between two to four years, while about 25% thought it would only take one year, and the remaining 25% thought it would take 5 years or more.

Table 15: Expectations of cost recovery

By when, if at all, do you expect to recover the costs of purchasing and installing the smart controller?	Percent of Respondents	Number of Respondents
more than 5 years	6.2%	N=79
about 4 years	2.9%	N=37
about 3 years	4.4%	N=57
about 2 years	4.9%	N=63
about 1 year	5.7%	N=73
no costs -- smart controller and installation were free	75.9%	N=972
Total	100.0%	N=1281

For a majority of respondents (55%), the reason they selected the type of weather-based irrigation controller they installed was that it was the only type offered through the smart controller program in which they participated. Otherwise, price was the most compelling reason, mentioned by 20% of respondents, followed by receiving a recommendation or the controller's features.

Table 16: Reasons for selecting type of controller

What influenced you to select your particular irrigation controller model?	Percent of Respondents	Number of Respondents
Only one offered on rebate, voucher, or exchange program	54.7%	N=727
Price	20.1%	N=267
Recommendation	16.3%	N=216
Features	15.7%	N=209
Helped me set correct schedule	7.7%	N=102
No fee for signal	6.7%	N=89
Advertising	5.6%	N=75
Other	10.4%	N=138
Total*	100.0%	N=1328

*Actual totals will equal more than 100% as respondents could give more than one answer

Most respondents (87%, data not shown) reported they had not chosen a controller model for which a signaling fee was required. Some respondents (generally those who had a choice of controller) were asked whether the signaling fee impacted their decision of the choice of controller. About half (48%, see Table 17) indicated the signal fee did not influence their decision. Some respondents (12%) felt the potential benefits of the controller with a fee outweighed the associated costs. Others (25%) chose a model without the fee because they felt the fee would be too expensive in the long term.

Table 17: Influence of signaling fee on choice of controller

Did a signaling fee influence your choice of controller?	Percent of Respondents	Number of Respondents
Signal fee did not impact my decision	48.4%	N=179
I chose a controller with signal fee because the potential benefits outweigh the extra cost	11.9%	N=44
I chose one without a signal fee because the fee makes the controller too expensive over the long term	25.4%	N=94
The water agency is paying for the signaling fee	10.5%	N=39
Other reason(s)	8.9%	N=33
Total*	100.0%	N=370

*Actual totals will equal more than 100% as respondents could give more than one answer

Those respondents who had controllers with an associated signaling fee were asked whether they thought they would continue to pay the fee after the program ended. About half (48%, see Table 18) indicated that they would not continue to pay the fee. Failure to continue the signaling fee would transform signal-based smart controllers into a conventional controller. Although the results from Table 18 are only based on 46 respondents, the high percentage of customers indicating they will not continue to pay the signaling fee after the program ends is of concern and this should be the subject of follow-up research during the on-going program monitoring effort.

Table 18: Likelihood of continuing to pay signaling fee

Will you continue to pay for it after the program ends?	Percent of Respondents	Number of Respondents
Yes	19.6%	N=9
No	47.8%	N=22
not sure	32.6%	N=15
Total	100.0%	N=46

Participation in the smart controller program

When asked how they had heard of the smart controller program in which they had participated, most respondents replied they had learned of it through a utility bill insert (38%, see Table 19). Other common methods included newspaper article (19%), word of mouth (16%), a landscape education class (15%) and through a solicitation letter (13%).

Table 19: Methods by which respondents' heard of smart controller programs

How did you hear about the smart controller program?	Percent of Respondents	Number of Respondents
Utility bill insert	38.4%	N=501
Newspaper article	18.5%	N=241
Friend, neighbor or coworker	16.0%	N=209
Landscape education class (e.g. "Protector del Agua")	14.5%	N=189
Solicitation letter	12.7%	N=166
Newspaper advertisement	6.4%	N=83
Irrigation contractor/professional	4.7%	N=62
A public service announcement on the radio or television	1.7%	N=22
Other	1.4%	N=18
Lawn maintenance service	0.5%	N=7
Total*	100.0%	N=1306

*Actual totals will equal more than 100% as respondents could give more than one answer

The most frequently mentioned reasons given for installing a smart controller, named by more than half of respondents, included that it was free, to increase water efficiency, and to avoid having to change the scheduling program with weather changes (see Table 20). The perceived benefits of the smart controller included water-efficiency, cost-efficiency and the savings in time and effort (see Table 21).

Table 20: Reasons for installing smart controllers

Why did you (or the organization for which you work) decide to install a smart controller?	Percent of Respondents	Number of Respondents
It was free	65.1%	N=871
Water efficiency for myself or my organization	57.3%	N=766
Automatic scheduling to avoid changing the program when weather changes	51.5%	N=689
Environmental benefits	48.1%	N=643
Saves money	46.0%	N=615
There was a controller exchange program	43.5%	N=648
To avoid watering during rainstorms	45.1%	N=603
Liked the new technology	36.2%	N=484
Improved landscape health/benefit	31.2%	N=417
Saves time and effort	30.6%	N=409
Incentive program offered by the utility	26.1%	N=349
Needed a new controller	12.4%	N=166
Other	3.4%	N=45
Total*	100.0%	N=1337

*Actual totals will equal more than 100% as respondents could give more than one answer

Table 21: Perceived benefits of smart controllers

Which, if any, of the following do you perceive as a benefit of having a smart controller?	Percent of Respondents	Number of Respondents
Water-efficient	80.7%	N=1012
Saves time and effort	52.7%	N=661
Saves money	49.0%	N=614
Cost-efficient	37.4%	N=469
Improves the health of the landscape	34.9%	N=438
Makes programming the settings easier	33.5%	N=420
Other	7.1%	N=89
Total*	100.0%	N=1254

*Actual totals will equal more than 100% as respondents could give more than one answer

Customer satisfaction with smart controller

One of the primary purposes of the survey was to learn about customers' experiences with the weather-based irrigation controller technology. Nearly 8 in 10 customers reported they were "somewhat" or "very" satisfied with their smart controllers, with nearly half (46%) indicating they were "very satisfied" (see :).

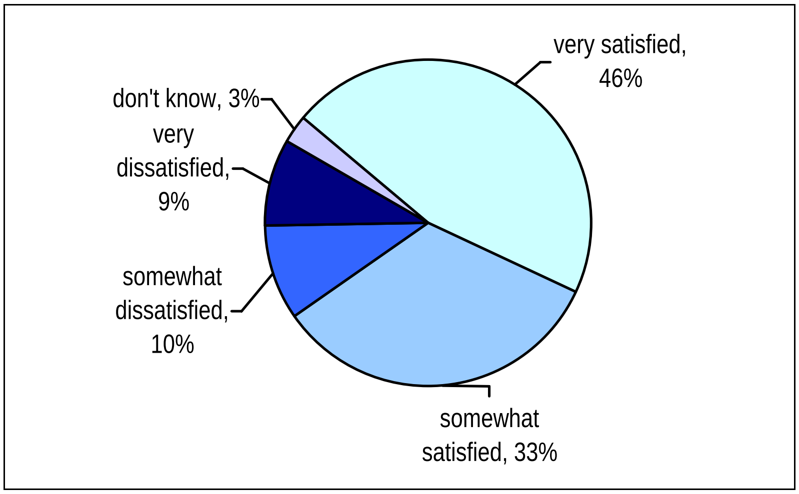

Figure 10: Satisfaction with smart controller

To determine customers' perceptions about the impact of the technology on their landscape watered by the irrigation system for which the smart controllers were installed, respondents were asked to rate the health of the impacted landscape before and after installation of the controllers. A small positive impact was seen; 71% of respondents rated the health of their landscape before installation of the controllers as "excellent" or "good" compared to 83% who rated the health of their landscape as "excellent" or "good" after installation of the controllers (see Figure 11).

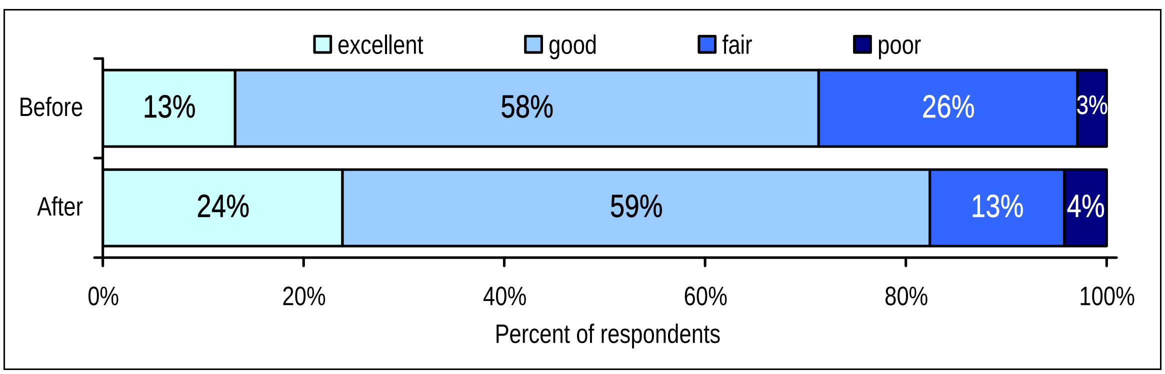

Figure 11: Ratings of health of landscape before and after installation of the smart controllers

A series of four statements relating to their experiences with smart controllers were presented to those completing the questionnaire. Respondents were asked to what extent they agreed or disagreed with each statement. In general, respondents reported positive experiences. Three-quarters agreed that the controllers performed without any glitches (see Figure 12). Two-thirds of those who had experienced glitches said the glitches had been resolved. Nearly 8 in 10 thought the smart controller has helped them save water, while 83% believe smart controllers are labor-saving devices.

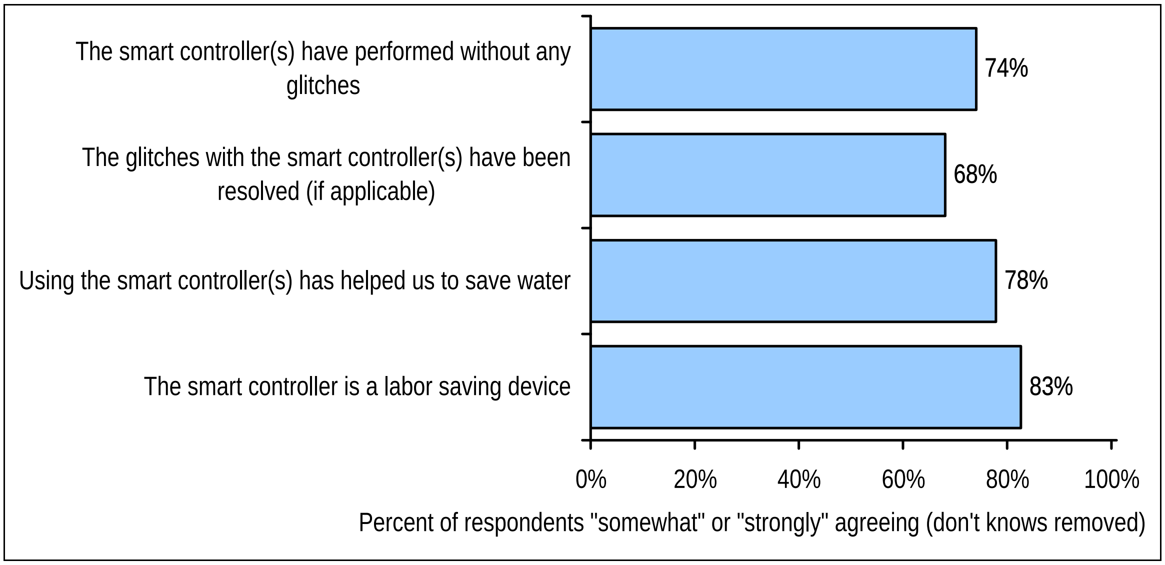

Figure 12: Ratings of experience with smart controllers

When asked to compare their new smart controller to their old one, many more respondents rated the smart controller as "better" than rated it as "worse" on each of the aspects rated (see Table 22). However, "understanding how to use it" was rated as "worse" by 28% of respondents (although 43% rated it as "better").

Table 22: Ratings of smart controller compared to previously-used controller

How would you rate each of the following characteristics of your new smart controller compared to your old controller?	much better	somewhat better	about the same	somewhat worse	much worse	not applicable	Total	
Reliability	29.1%	21.7%	36.8%	4.3%	5.2%	3.0%	100.0%	N=1287
Performance of the controller (how well it waters the landscape)	35.9%	25.7%	26.8%	4.5%	4.4%	2.7%	100.0%	N=1286
Water-efficiency of the controller (uses less water)	40.8%	29.0%	17.1%	4.4%	4.6%	4.0%	100.0%	N=1260
Understanding of how to use it	19.7%	23.7%	26.3%	17.3%	10.5%	2.5%	100.0%	N=1290
Ease of use overall	25.9%	26.5%	22.8%	13.9%	8.3%	2.6%	100.0%	N=1284
Ease of programming the watering schedule	23.7%	23.8%	21.7%	16.7%	11.4%	2.7%	100.0%	N=1288

Customer Satisfaction with the Installation and Maintenance Process

Respondents were asked who had installed and set-up their new smart controller. Most (62%, see Table 23) had installed the controllers themselves. A series of questions about the installation and set-up process were then posed. Some of the questions were asked only of those whose controllers had been installed by the manufacturer or by the water utility, while some were asked only of those who had handled installation themselves (even if they had hired someone or used their own staff). In general, respondents felt the installation process went fairly smoothly (see Figure 13). The lowest ratings were given to understanding the programming instructions and setting the irrigation schedule; 69% of respondents who installed the controller themselves agreed that it was "easy to understand the smart controller programming instructions" and only 44% felt "setting the irrigation schedule was easy." Overall, 85% of respondents reported they at least somewhat agreed that they were pleased with the installation and set-up process. Few differences were found in the ratings by the type of installation, although those whose controllers were installed by the manufacturer or utility were somewhat more likely to report having problems with the smart controller since installation (58%) than were those who installed the controllers themselves (35%). This may be because manufacturer or utility installations were more likely to have taken place on larger commercial properties.

Table 23: Type of installation

Who installed and set-up your new smart controller?	Percent of Respondents	Number of Respondents
Self	61.7%	N=780
Other family member	6.0%	N=76
Manager or owner's staff	1.7%	N=22
Manager or owner's hired contractor/electrician/handyman	8.2%	N=104
A manufacturer representative	2.1%	N=26
A professional installer from the water utility	11.4%	N=144
Other	8.1%	N=102
A landscape contractor	.9%	N=11
Total	100.0%	N=1265

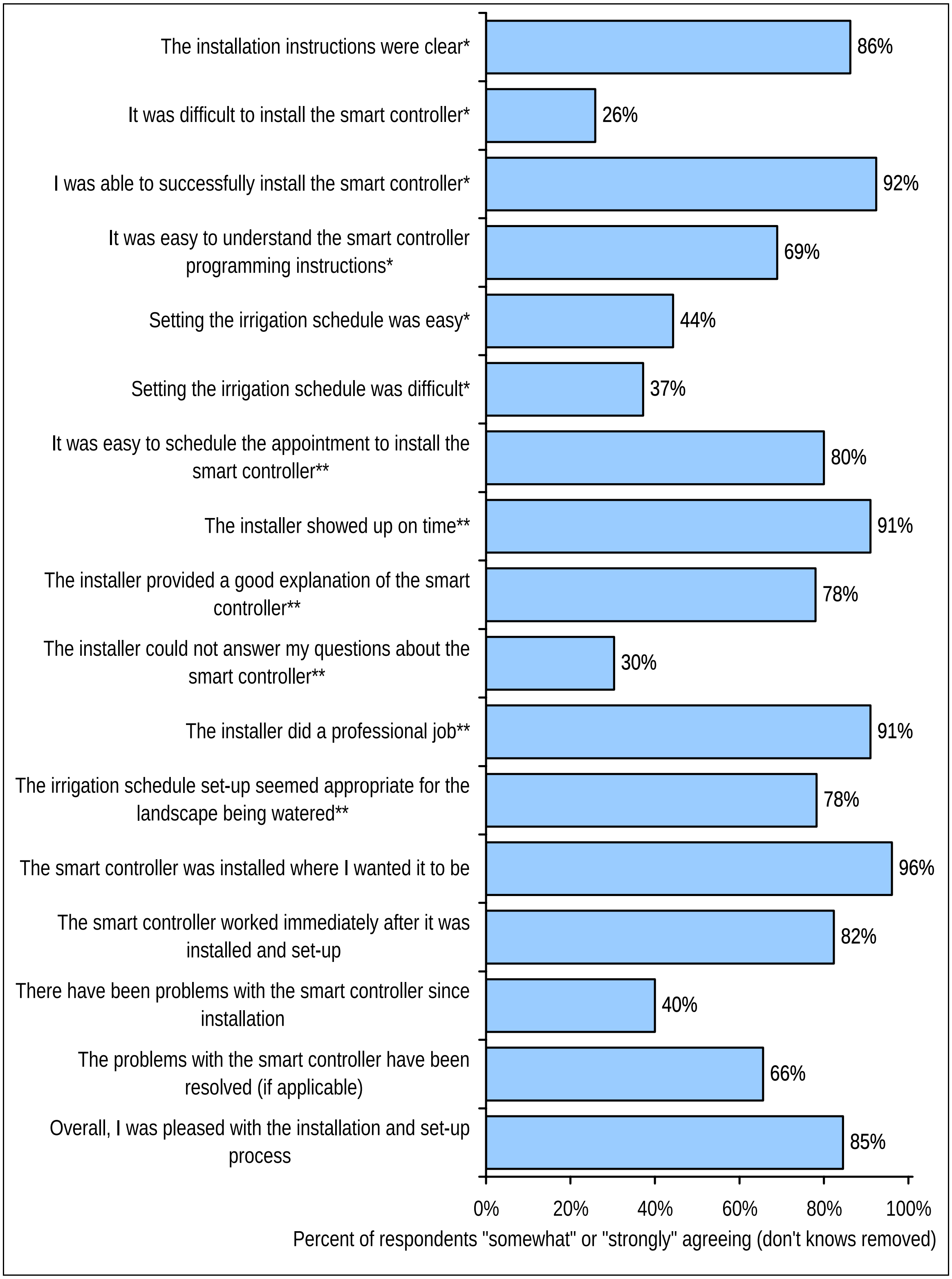

Figure 13: Ratings of the installation and set-up process

* Asked only of those who installed the controller themselves
** Asked only of those whose controllers were installed by the manufacturer or the water utility.

In general, it took respondents very little time to install and set-up their smart controllers; the average time needed was 2 hours and 44 minutes (see Table 24). Most respondents (71%) felt the amount of needed was about right (see Figure 14). About 2 in 10 respondents felt the amount of time needed was somewhat or far too long.

Table 24: Amount of time needed for installation and set-up of controllers

How long did the installation and set-up of the smart controller take?	Avg.	25th Percentile	Median (50th Percentile)	75th Percentile	Max.	N
How long did the installation and set-up of the smart controller take?	2:44	1:00	2:00	3:00	45:00	N=1032

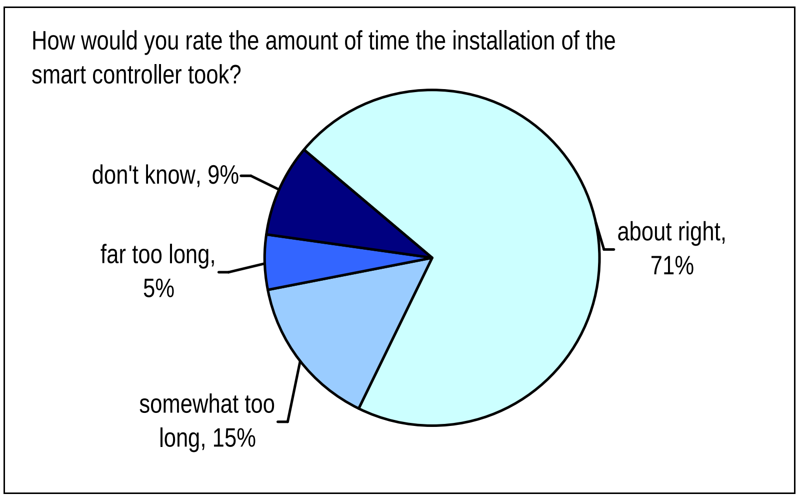

Figure 14: Rating of amount of time needed for installation

Respondents were asked whether they had needed to ask for assistance with the installation process or set-up of the irrigation schedule. Nearly 4 in 10 (39%) said they had asked for assistance. Of these, 60% said someone had come out to the site to assist them. In general, respondents who received assistance were quite satisfied with the assistance received; nearly 6 in 10 were “very” satisfied, and another 2 in 10 were “somewhat satisfied (see Figure 15). About 2 in 10 were at least somewhat dissatisfied, or did not feel they could give an opinion.

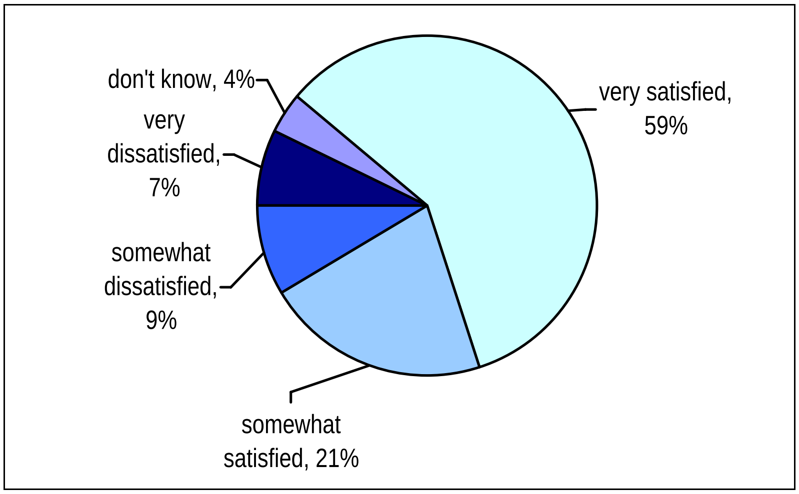

Figure 15: Satisfaction with installation or set-up assistance received

About a third of respondents who had installed the smart controllers themselves (or had someone do it on their behalf) said they called the smart controller manufacturer for technical support on installation or setting the irrigation schedule (29%, data not shown). Just over half of these respondents rated the support they received as excellent (52%, see Figure 16). About 1 in 10 respondents rated the support as only "fair" and another 1 in 10 as "poor."

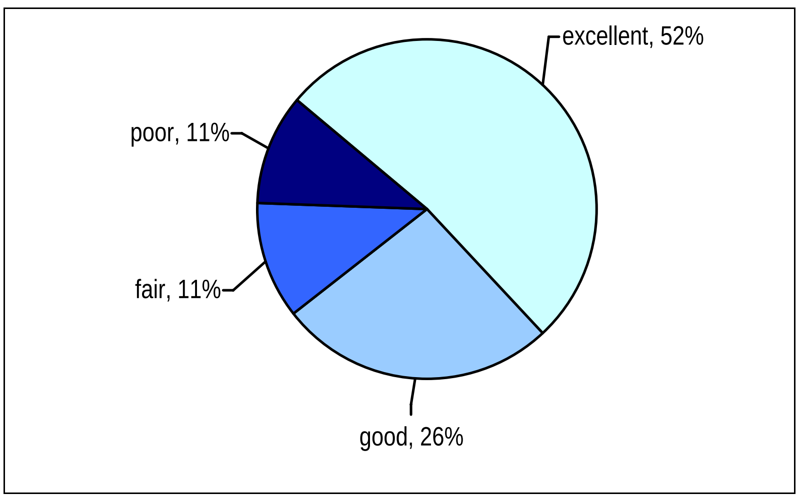

Figure 16: Rating of support received from smart controller manufacturer

When asked whether they had followed the manufacturer's instructions for setting the watering schedule for the smart controller, most respondents who had installed the controller themselves (or had someone do it on their behalf) reported they had done so (85%, data not shown). Those who had not followed the manufacturer's instructions were asked how they had programmed the controller. The most common changes were to the schedule or to the landscape information (see Table 25).

Table 25: Types of changes made in programming smart controller schedule

How did you program the smart controller schedule? (if did not follow manufacturer's instructions	Percent of Respondents	Number of Respondents
Changed the schedule	48.7%	N=76
Changed the site information	10.9%	N=17
Changed the weather input	5.1%	N=8
Changed the landscape information	23.7%	N=37
Other	25.6%	N=40
Total	100.0%	N=156

When self-installers were asked how confident they were that the irrigation schedule set for the smart controller was correct, about 4 in 10 were "very" confident, while another 4 in 10 were "somewhat" confident (see Figure 17). The remaining 2 in 10 were not very confident, or did not know.

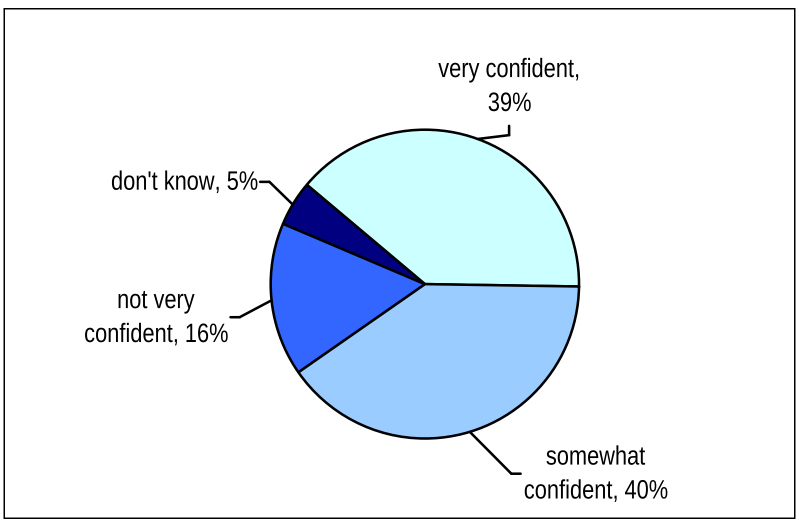

Figure 17: Respondents' confidence in irrigation schedule

About two-thirds of respondents who had had their controller installed by another party such as a landscape professional, the manufacturer, or water utility reported they had changed the programmed watering schedule since installation (69%, data not shown). The most common reason given for changing the program were that the controller underwatered (52%), although 31% changed the programming because the controller overwatered (see Table 26).

Table 26: Reasons for changing the watering schedule

Why did you change it?	Percent of Respondents Who Had Changed Programming	Number of Respondents Who Had Changed Programming
It underwatered	51.9%	N=56
It overwatered	30.6%	N=33
I didn't trust its performance	13.9%	N=15
Other	20.4%	N=22
Total*	100.0%	N=108

*Actual totals will equal more than 100% as respondents could give more than one answer

Those who had changed the programming were asked how easy or difficult it was to change the programming. Over half (51%, see Figure 18) felt it was at least "somewhat" easy. About a third thought it was at least somewhat difficult.

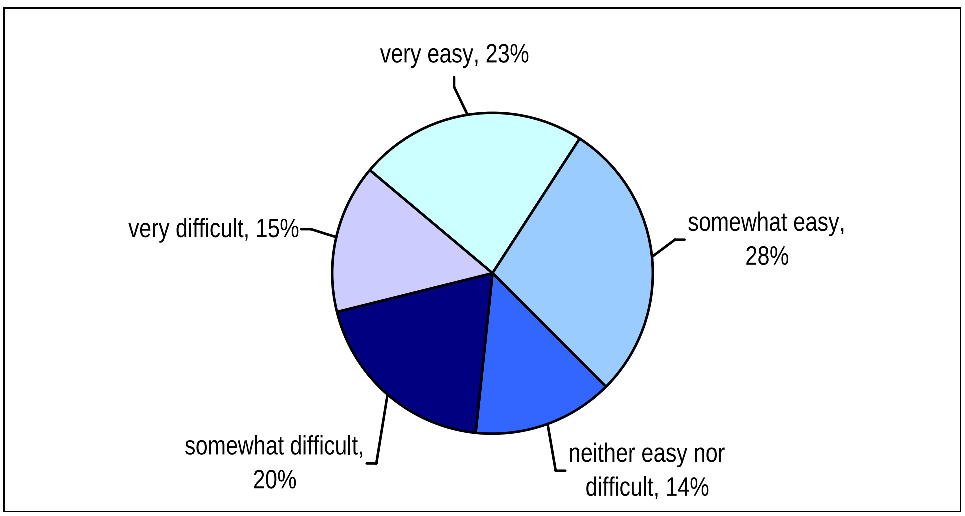

Figure 18: Ease of changing programming by respondents who had changed it

About 2 in 10 (22%, data not shown) of respondents had called the smart controller manufacturer for technical support in the previous year. About 1 in 10 (12%, data not shown) had called the water utility for technical support previous year. Ratings of the support received were generally positive, with about three-quarters of respondents rating each as "excellent" or "good" (see Figure 19 and Figure 20).

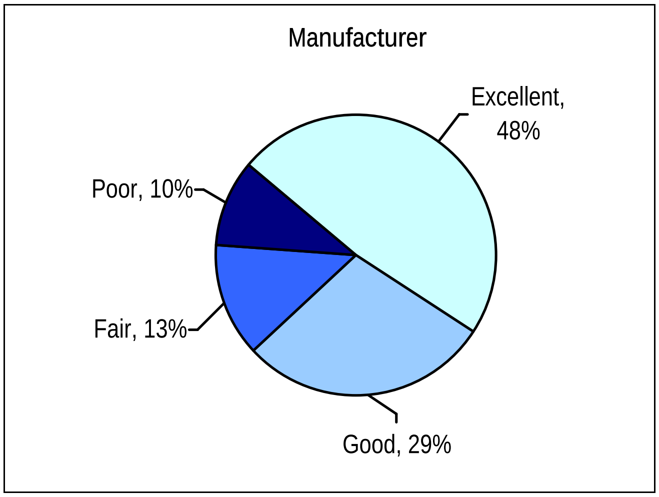

Figure 19: Ratings of support received from manufacturer

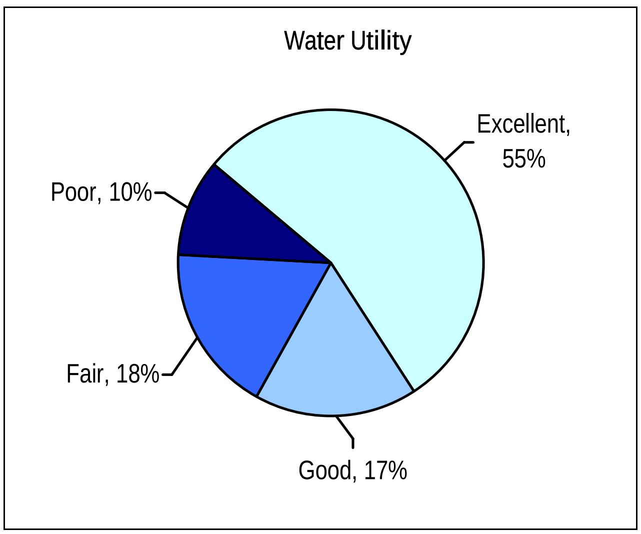

Figure 20: Ratings of support received from the utility

Customer Satisfaction with Smart Controller Programs

Customer satisfaction with the utilities' smart controller programs was assessed through the questionnaire. Respondents were asked how satisfied or dissatisfied they were with various aspects of the smart controller program offered by their local water utility. Satisfaction ratings were very high, with 81% or more of respondents at least "somewhat" satisfied with each aspect included on the questionnaire (see Figure 21).

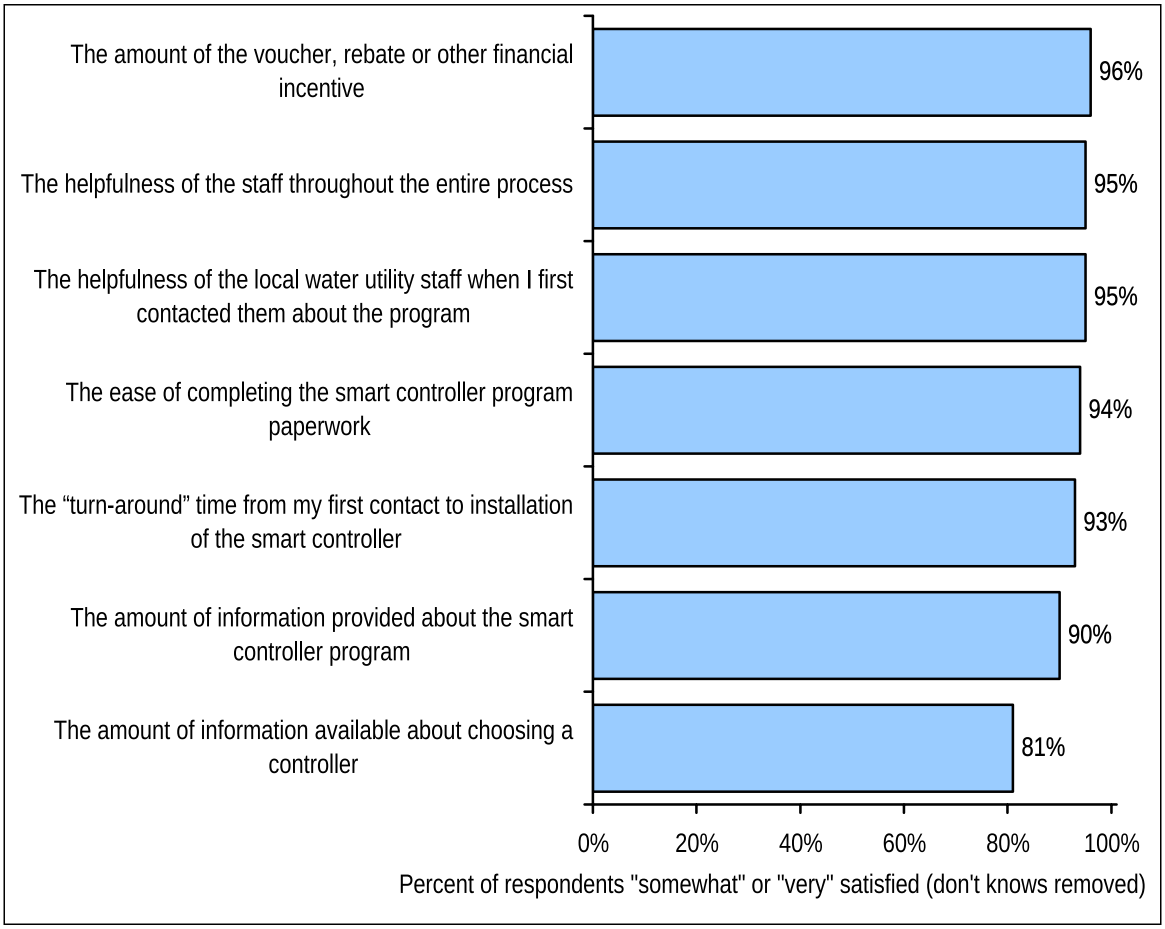

Figure 21: Ratings of smart controller programs

The smart controller program was successful in incenting people to try a weather-based irrigation controller who might not otherwise have done so; about two thirds (66%, see Table 27) of respondents said they would have been somewhat or very unlikely to purchase the controller without the incentive offered by their water utility. However, respondents were happy with the programs; more than 8 in 10 said they would be somewhat or very likely to recommend the smart controller program to a neighbor, friend or co-worker. About the same proportion would also recommend the smart controller itself.

Table 27: Likelihood of recommending smart controller

How likely or unlikely would you . . .	**very likely**	**somewhat likely**	**somewhat unlikely**	**very unlikely**	**don't know**	**Total**	
have been to purchase the controller without the rebate, voucher or other incentive program offered by your water utility?	6.9%	23.0%	26.8%	38.8%	4.5%	100.0%	N=1316
be to recommend the smart controller program to a neighbor, friend or co-worker?	53.9%	28.3%	6.2%	10.0%	1.7%	100.0%	N=1320
be to recommend a smart controller to a neighbor, friend or co-worker?	49.7%	30.1%	7.6%	10.9%	1.7%	100.0%	N=1293

It should be noted that some blank questionnaires were returned to NRC. On many of these surveys, the recipient had made some comment about why they were unable or unwilling to complete the questionnaire. These comments were classified into a few categories, and are summarized in Table 28 below. On 22 of the 57 blank returned surveys (40%), recipients commented that they had not yet installed the controller, but were likely to do so in the future. A few others had never installed the controller and were not planning to do so. Several mentioned that the instructions were confusing or they found it too difficult to install (10 recipients), while a few others felt it was too costly to install (3 recipients). Some had issues with the way the controller worked and so declined to install it. A few had installed the controller, but did not like the way it worked. Some people had installed the controller but had subsequently removed it because of how it worked (8 recipients).

Table 28: Comments received on surveys returned blank

Comment on Returned Blank Survey	Percent of Respondents	Number of Respondents
Because of life events, did not install	39%	N=22
Too difficult to install/instructions confusing	18%	N=10
Removed because did not like the way it worked	12%	N=7
Too costly to install	5%	N=3
Did not install because of issues with the way it worked	5%	N=3
Don't like the way it works	4%	N=2
Removed because was watering too little	2%	N=1
Bad experience with installation	2%	N=1
Other	14%	N=8
TOTAL	100%	N=57

Recommendations to WBIC manufacturers and water utilities

The final two questions contained on the survey asked respondents to write, in their own words, what improvements they would recommend to the manufacturer of their smart controllers and what improvements they would recommend to water utilities for the smart controller programs. A summary of the comments are provided in Table 29 and Table 30 below.

A wide variety of comments were made by those responding to these questions. The most common themes are identified in the tables below. Many respondents (12% of those making a comment, see Table 29) reported that they had no recommendations to make to the manufacturers; they were satisfied with the product. Those who did have suggestions were likely to suggest improvement of the manual or instructions (15.5%) or to make the device easier to use (13.6%). A few (9.5%) reported that their controller was not working or was broken.

A significant portion of those making a comment about recommendations for the water utilities said they were satisfied with the programs and had no recommended changes (14.0%, see Table 30). Some recommended improved customer or technical support (10.2%), while others suggested that additional advertising or promotion of the programs should be undertaken (9.1%). Others used this section to repeat comments or complaints about their smart controller.

Table 29: Respondent recommendations to WBIC manufacturers

What improvements, if any, would you recommend to the manufacturer of your smart controller?	Percent of Respondents	Number of Respondents
Improve manual/instructions	15.5%	N=83
Simplify the device/programming	13.6%	N=73
Satisfied/no changes	12.1%	N=65
Not working/broken	9.5%	N=51
Customer/tech support needs improvement	4.9%	N=26
Controller overwaters/underwaters	3.9%	N=21
Controller problems/controllers need improvement	3.0%	N=16
Don't Know	0.7%	N=4
Other	36.8%	N=197
TOTAL	100.0%	N=536

Table 30: Respondent recommendations to water utilities

What improvements, if any, would you recommend to the water utilities for the smart controller program?	Percent of Respondents	Number of Respondents
Satisfied/no changes	14.0%	N=74
Customer/tech support needs improvement	10.2%	N=54
Advertising/promoting	9.1%	N=48
Not working/broken	8.5%	N=45
Improve manual/instructions	8.3%	N=44
Simplify the device/programming	7.9%	N=42
Controller problems/controllers need improvement	3.4%	N=18
Controller overwaters/underwaters	2.5%	N=13
Don't Know	1.1%	N=6
Other	35.0%	N=185
TOTAL	100.0%	N=529

IMPACT EVALUATION OF CALIFORNIA SMART CONTROLLER PROGRAMS

Introduction

The impact evaluation of the California Smart Controller Programs was designed to answer important questions about installation and performance of this technology. The impact evaluation was divided into three sections:

1. Descriptive and validatory statistics
2. Multiple regression modeling
3. Cost-effectiveness analysis

The descriptive and validatory statistics section presents a picture of what controller products were analyzed, how and where they were installed, the landscape area at the study sites[15], the water use of the participants before and after installation, climate conditions before and after installation, irrigation application rates before and after, and the weather-normalized change in application rate after installation of the smart controllers. The weather-normalized change in application rate is the fundamental measurement of water savings utilized in this study.

Multiple regression analysis was used to determine the factors that did and did not influence changes in water use. Multiple regression analysis was also used to compare the performance of different smart controller technologies on a level playing field because factors that were shown to influence water use could be controlled for as much as possible. All analyses that involved a comparison of one or more factors or groups were completed through the multiple regression effort.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. From the customer perspective, cost-effectiveness analysis was used to determine the reasonable level of customer investment given the anticipated water and cost savings from smart controllers. Other benefits of the smart controller such as convenience and improved landscape health are difficult to quantify in dollar terms, but are also discussed.

Every effort was made to ensure that the results presented in this report are objective and accurate. All impact analyses were conducted in a scientific and impartial manner without any preconceived notions about what the findings would or should be. In order to maximize the objectivity of the analyses the make and model of each controller was encrypted so that that the researchers did not know which controller achieved any level of savings until the final preparation of the report. The research team has made efforts to identify both the weaknesses and strengths of different analyses and to bring these to the attention of the reader. The

[15] The landscape areas were supplied by the water districts based on their best information, and were not verified by the consultants as part of this study.

researchers have called out areas where the potential for errors in the data exist. Sensitivity analysis was conducted to examine variations in key factors like Evapotranspiration (differing methodologies treat precipitation and crop coefficients differently). These results are also presented in this section.

Water use data included in this study was from monthly or bi-monthly billing records. Consequently, this study focused on annual use, and did not examine of how the controllers distribute irrigation events through shorter time interval than a year (i.e. frequency and duration or irrigation run times for periods of days or weeks). With such coarse data it is possible that a controller might apply an amount of water close to the theoretical irrigation requirement over the course of a month or two, but within a given week the irrigation run times might not be distributed properly to avoid frequent shallow watering. While the distribution of irrigation events through time could not be examined in this study, it is potentially significant in the way smart controllers can affect overall plant health over time and should be the subject of further investigation.

The research team has worked to be thorough and careful, but it must be understood that errors are always a possibility. Any errors that are found after the publication of this report should be reported to the research team will be corrected promptly and if necessary, errata will be published.

Descriptive and Validatory Statistics from California Smart Controller Programs

The presentation of descriptive and validatory statistics about the California Smart Controller Programs provides a picture of what controller products were installed, what class of customers installed the products, where they were installed, how they were installed, the irrigated area of participating sites, the theoretical irrigation application requirement at these sites, and the actual irrigation application before and after the installation.

Determining the water savings achieved by these devices, a fundamental goal of this study, is part of the impact evaluation and is shown in this report section. Where specified, changes in water use have been adjusted to reflect changes in climate conditions during the pre- and post-installation years. For some analyses in this study, such as determining the factors that influenced changes in water use and comparing performance of different smart controller technologies, multiple regression analysis was performed. Those results are presented in a subsequent section of this report.

There were more smart controllers installed through the DWR grant programs than are included in the impact analysis presented here. Only smart controller sites where complete fundamental data were provided (such as a full year of pre- and post- installation water use, landscape area, pre- and post-installation ET rates, and basic controller information) were included in the impact analysis. The DWR grant agreement calls for on-going monitoring of smart controller sites for five years after installation so additional results from sites not included in this analysis and information on the longer-term performance of these technologies will be available in years to come.

Statistical analysis was completed on three fundamental levels: local (by agency), regional, and statewide (northern & southern Program, and combined). Some results are also presented by manufacturer, product, installation method, and customer class.

Smart Controller Products Included In Evaluation

Smart controllers produced by 14 different manufacturers were included in the impact analysis. A listing of these controller products, the number of sites where the technology was installed, and basic information about the smart control technology is provided in Table 31. More detailed information about the smart controller products installed though the California Smart Controller Programs is provided in an earlier section of this report and extensive information about each type of smart controller in the study is provided in Appendix A.

Installation Method

The California Weather-Based Irrigation programs used a wide variety of methods to distribute and install smart control technologies across different climate zones and customer categories. A summary of the number of installations included in the impact analysis by installation method, climate zone, and customer category are presented below in Table 32, Table 33, Table 34, and Table 35.

A summary by installation method is presented in Table 32. Among the sites included in the impact analysis, 59.9% were designated as self-installed and 40.1% were designated as Professional/Utility installed. Installation method is not a precise designation as it is not always known who actually installed or most importantly programmed the controller.

- **Self-Installed** - Sites designated as Self-Installed indicate the customer was solely responsible for installing and programming the controller. However, at self-installed sites, the customer could easily have hired someone to perform these tasks without the knowledge of the agency or the evaluation team.

- **Professionally Installed** - Sites designated as Professional/Utility installed indicate that the controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer. This category includes sites where a landscape professional completed all aspects of the installation and sites where the customer physically mounted the clock and a utility representative inspected the installation, reviewed the program, and potentially made changes to the controller set up. Not enough information was available to the evaluation team to distinguish further between these installation methods.

Table 31: Smart controller manufacturers included in the impact analysis

Manufacturer	Weather data source	Station or zone capacity	SWAT test performance report available	Number of controller sites in impact analysis
Accurate WeatherSet	On-site solar and rain sensors	8-48	No	342
Aqua Conserve	Historic ET curves with onsite temperature sensor	6-66	Yes	288
Calsense	Onsite ET sensor. Soil moisture sensor	8-48	Yes	17
ET Water Systems	Public and ETWS weather station data managed by centralized computer	1-48	Yes	94
Hunter Industries	On-site weather station with full set of sensors	1-48	Yes	44
HydroPoint Weather TRAK	Public and Private Weather stations managed by central computer and wireless delivery	6-48	Yes	537
Irritrol Systems	Public weather stations data managed by centralized computer server	6-24	Yes	37
Rain Master	Automatic, historic or manually entered ET or optional on-site weather station	6-36	Yes	22
Toro Company	Public weather station data managed by central computer server	6-24	Yes	68
Weathermatic	On-site temperature and rain sensors and solar radiation estimated based on location	8 to 48	Yes	838
Various: Acclima, HydroEarth, Lawn Logic, Nelson	Various	Various	Acclima – Yes Others - No	7*

*Controllers installed at fewer than 15 sites were included in the overall impact analysis, but not in analysis by brand because of the lack of sample size and hence statistical validity.

Table 32: Installation method summary of impact analysis sites

Installation Method	# of Sites	%
Self-Installed*	1,375	59.9%
Professional/Utility**	919	40.1%

*Customer was responsible for installing the controller. They could have hired someone else to do it, but this information is not known.
**Controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer.

Climate Zones Where Controllers Were Installed

The California Irrigation Management Information System (CIMIS) is a program in the Office of Water Use Efficiency (OWUE), California Department of Water Resources (DWR) that manages a network of over 130 automated weather stations in the state of California. CIMIS was developed in 1982 by the California Department of Water Resource and the University of California at Davis to assist California's irrigators manage their water resources efficiently. CIMIS weather stations are located in 18 different ET zones throughout California. For the purposes of this study, smart controller sites were located in a climate zone based upon the nearest CIMIS station. Stations located in CIMIS zones 1, 2, or 3 were designated as coastal. Stations located in CIMIS zones 4, 5, or 6 were designated as intermediate. Stations located in CIMIS zones 7 or higher were designated as inland. A map of California showing the different CIMIS ET zones is provided in Appendix C.

A summary of smart controller sites included in the impact analysis by climate zone is presented in Table 33. Among the sites included in the impact analysis, 28.6% were located in the coastal ET zone, 62.9% were located in the intermediate climate zone, and 8.5% were located in the Inland climate zone.

Table 33: Climate zone summary of impact analysis sites

Climate Zone	# of Sites	%
Coastal	655	28.6%
Intermediate	1,444	62.9%
Inland	195	8.5%

Water Customer Categories

Table 34 shows the number and percentage of smart controller sites included in the impact analysis by customer category. Three distinct customer categories could be adequately identified for all impact analysis sites: (1) Single-family residential; (2) Multi-family, Commercial, and Other Non-residential; and (3) Irrigation only. A large majority (86.6%) of the impact analysis smart controller sites were single-family residential. Only 12.9% of the sites fell into the non-single-family catch-all category that included multi-family residential properties, commercial sites, and other non-residential accounts. Dedicated irrigation accounts accounted for 0.5% of the total.

Table 34: Customer category summary of impact analysis sites

Type of Site	All Sites	Northern Sites	Southern Sites
Single-Family Residential	1,987	295	1,692
Multi-Family, Commercial, and Other Non-Residential	296	105	191
Irrigation only	11	11	
Total	2,294	411	1,883

Table 35 summarizes the results of the previous analysis into a single table. Residential sites in the intermediate climate zone with self-installed smart controllers accounted for 41% of the total and professionally installed controllers in this category accounted for 12.1% of the total. About half of the commercial controllers were professionally installed in the intermediate climate zone.

Table 35: Smart controller installations by customer category, climate zone, and installation method

<table>
<tr><th>Customer Category</th><th>Climate Zone</th><th>Install Method</th><th># of Sites</th><th>%</th></tr>
<tr><td rowspan="5">Commercial, Multi-Family, Other Non-Residential</td><td rowspan="2">Coastal</td><td>Professional</td><td>33</td><td>1.4%</td></tr>
<tr><td>Self</td><td>33</td><td>1.4%</td></tr>
<tr><td>Inland</td><td>Professional</td><td>8</td><td>0.3%</td></tr>
<tr><td rowspan="2">Intermediate</td><td>Professional</td><td>146</td><td>6.4%</td></tr>
<tr><td>Self</td><td>76</td><td>3.3%</td></tr>
<tr><td rowspan="2">Irrigation</td><td>Coastal</td><td>Self</td><td>2</td><td>0.1%</td></tr>
<tr><td>Intermediate</td><td>Professional</td><td>9</td><td>0.4%</td></tr>
<tr><td rowspan="6">Residential</td><td rowspan="2">Coastal</td><td>Professional</td><td>295</td><td>12.9%</td></tr>
<tr><td>Self</td><td>291</td><td>12.7%</td></tr>
<tr><td rowspan="2">Inland</td><td>Professional</td><td>150</td><td>6.5%</td></tr>
<tr><td>Self</td><td>37</td><td>1.6%</td></tr>
<tr><td rowspan="2">Intermediate</td><td>Professional</td><td>278</td><td>12.1%</td></tr>
<tr><td>Self</td><td>935</td><td>40.8%</td></tr>
</table>

Water Agency

Data on the smart controllers included in the impact analysis for each of the participating water agencies are provided in Table 36. The number of sites included in the impact analysis, the installation method, and the type of property where the installation occurred are tabulated. Sites in northern California were more likely to be classified as professionally installed. Northern utilities strived to inspect each installation and make adjustments to the controller programming as appropriate. The large majority of smart controllers (approximately 82%) were placed in sites in southern California where distribution programs were more effective at getting a larger number of controllers into the field in time to be included in this evaluation.

The Los Angeles Department of Water and Power (LADWP), San Diego County Water Authority, Foothill Municipal Water District, and East Bay Municipal Utility District (EBMUD) had the most smart controller sites. Combined these four agencies accounted for more than 60% of all the installations in the study.

Controller Brand and Region

A listing of the various brands of smart controller included in the study and the regions where they were installed is presented in Table 37. Weathermatic, HydroPoint (including Toro and Irritrol), Accurate WeatherSet, and Aqua Conserve were the most commonly installed technologies across the study, accounting for about 92% of all installations. These technologies accounted for approximately 64% of the installations in northern California and 98% of the installations in southern California. Smart control technology manufactured by ET Water and Hunter accounted for about 33% of the installations in northern California. Technologies installed on fewer than 15 sites in the study were included in the overall analysis, but not included in water use comparisons by brand because of the lack of statistical reliability obtainable from such a small sample size.

Table 36: Installation and Site Classification for Participating Water Agencies

		Site Classification					
		Commercial		Irrigation		Residential	
		Installation Method					
Site Location	# of Sites	Pro.	Self	Pro.	Self	Pro.	Self
ACWD	5	1				1	3
Burbank	76						76
CCWD	32	5				27	
Eastern	87	48	39				
EBMUD	333	38	41	9	2	113	130
Foothill	245						245
Glendale	109						109
Goleta	26	8				18	
Inland Empire	186						186
LADWP	477	16				366	95
Pasadena	17		17				
Santa Barbara	73	15				58	
Santa Monica	71	2				44	24
SCV	34	15	2			14	3
SCWA	7	3				3	1
SDCWA	401		10				391
Western	115	36				79	
Total	2294	187	109	9	2	723	1263

Table 37: Number of Controller Sites by Region and Brand*

Controller Brand	Number of Controller Sites		
	All Sites	Northern Sites	Southern Sites
Acclima	1	1	
Accurate WeatherSet	342	3	339
Aqua Conserve	288	52	236
Calsense	17	1	16
ET Water	94	93	1
Hunter	44	44	
HydroEarth	2		2
HydroPoint	537	52	485
Irritrol	37	34	3
LawnLogic	1	1	
Nelson	3	1	2
Rain Master	22	5	17
Toro	68	42	26
Weathermatic	838	82	756

*Only sites included in the impact analysis

Table 38 shows the number of controller sites at each participating water agency by brand. Some agencies such as the Contra Costa Water District included a wide variety of different smart controller technologies in their program. Contra Costa had 10 different brands of controllers installed. Inland Empire by comparison had only two different brands of smart controller installed on sites within its service area and Pasadena only utilized one technology.

Table 38: Smart Controller Brands Installed at Each Participating Water Agency*

Manufacturer → Agency↓	Acclima	Accurate WeatherSet	Aqua Conserve	Calsense	ET Water	Hunter	HydroEarth	HydroPoint	Irritrol	LawnLogic	Nelson	Rain Master	Toro	Weathermatic
Alameda County WD	1					1		2		1				
Burbank			31											45
Contra Costa WD		3	2		1	4		3	4		1	1	1	12
Eastern			84				2						1	
EBMUD			46	1	89	39		14	29			4	41	70
Foothill								1						244
Glendale														109
Goleta								26						
Inland Empire		185												1
LADWP		95		16				366						
Pasadena												17		
Santa Barbara								73						
Santa Monica			42		1			2						26
Santa Clara Valley			4					30						
Sonoma County WA					3			3	1					
San Diego County WA		59	1					5	3		2			331
Western			78					12					25	

*Only sites included in the impact analysis

Landscape Area

Landscape area is a critical factor for determining the efficiency of water use at a site using historic billing data. Dividing the annual volume of water used for irrigation (from billing data) by the landscape area measurement provides a measurement of the annually applied water in inches. This value can then be compared against the evapotranspiration rate to determine irrigation efficiency.

The participating agencies were asked to provide a measurement of landscape area for each site where a smart controller was installed. The request for landscape area data were made at the beginning of the evaluation project and it was understood that this information was essential information for any site that was to be included in the impact analysis. Any site for which landscape area could not be obtained was not included in the impact analysis. Landscape area data were provided for 2,294 sites where sufficient pre- and post-smart controller water consumption data were also available.

Ideally, the measurement of landscape area should include all parts of a property that are landscaped or landscapable and are or could be irrigated. This measurement is alternatively known as the irrigated area or the irrigable area. Typically such landscape area measurements are made (1) using computer mapping and imagery software such as a geographic information system (GIS) as shown in Figure 22; (2) by physically measuring the landscape area at a site using a measuring wheel, tape measure, and other tools; or (3) by obtaining lot size measurement from tax assessor records and deducting an estimated amount of impervious area to obtain landscape area.

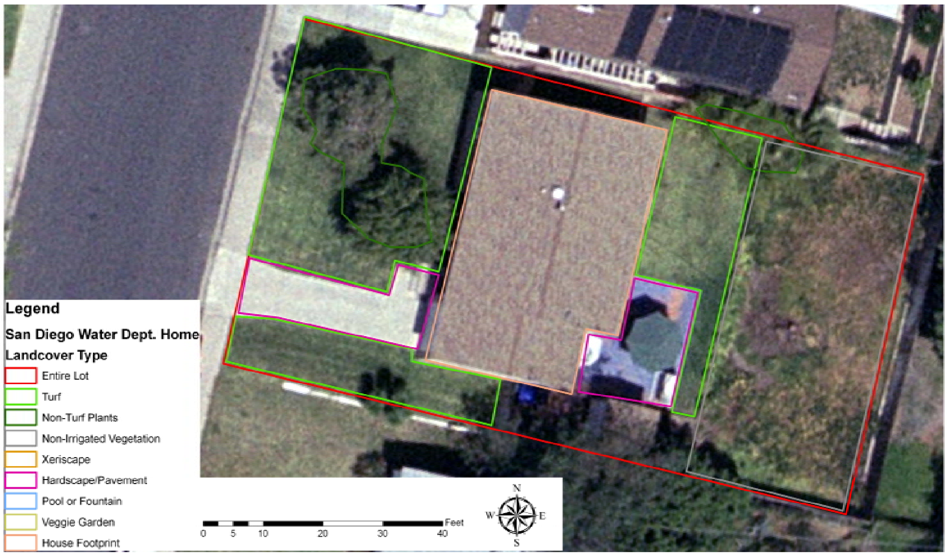

Figure 22: Example of using digital imagery and geographical information system tools to calculate landscape area

The example shown in Figure 22 presents a detail analysis of the various landscape materials found at a site. While such a detailed level of analysis is desirable, the time and effort required of the participating agencies made this level of analysis beyond what was possible for this study. While some site measurements for this study were made using digital imagery and GIS, others were obtained through physical measurements, and many were obtained from tax assessor records.

A frequency distribution showing the landscape area measurements at 2,294 smart controllers study sites is presented in Figure 23. Descriptive statistics on the landscape area in each region and each participating agency are presented in Table 39. The average landscape area in the study was 28,386 square feet (sf), which is more than half an acre. The average landscape size was large because of more than 80 sites included in the study with landscape areas exceeding 100,000 square feet. The largest site had a landscape area of 4.7 million square feet – more than 100 acres. The median landscape size in the study group was 6,534 square feet which is much more typical of the landscape area for single-family residential properties in California and elsewhere across the country. Most of the smart controllers installed in this study were placed at single-family homes and the median value is more representative of a typical installation site than the average when there are large outliers.

Many of the larger sites were located in the northern California agencies where a higher percentage of non-residential and large multi-family customers were specifically targeted to receive smart controllers. The average landscape area among the northern sites was 73,133 sf and the median was 23,786 sf compared with an average of 18,619 sf and a median of 4,313 sf in the southern California sites.

As noted above, methods for measuring the landscape area varied and in many cases information about the measurement method utilized was not provided to the analysis team. Since accurate information on landscape area is critical to determination of the TIR and the application rate and hence the degree of under or over irrigation, the analysis team moved forward with the data provided, with the understanding the amount of error in this variable could not be determined. One factor that provides some reassurance in the results, however, is that any errors in the measurement of landscape area are in all probability random ones rather than systematic. This means that while the scatter of the data may be increased, the means and central tendencies of the estimates are less affected. Systematic errors could cause erroneous overall conclusions, which could invalidate study findings. Future researchers may wish to refine landscape area measurements and obtain more detailed information about the plant materials at each study site, which could improve overall accuracy of the results.

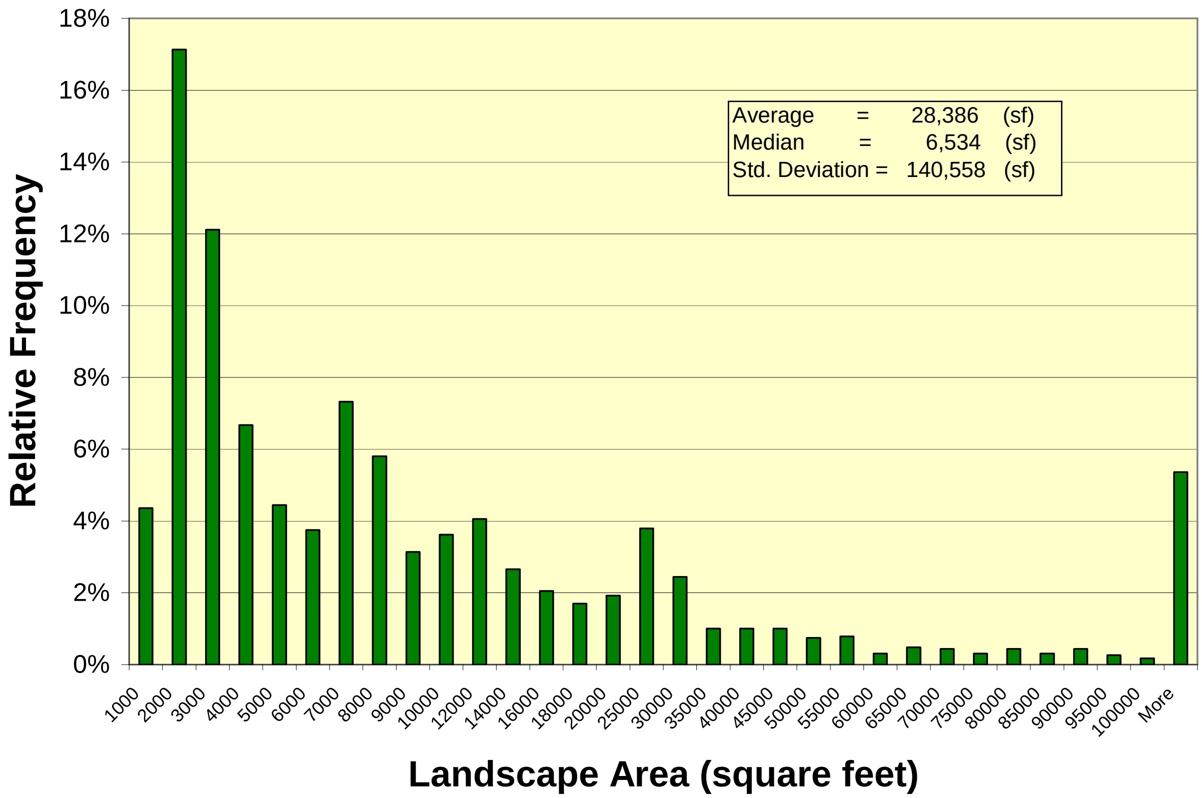

Figure 23: Landscape Area Frequency Distribution

Table 39: Landscape Area (square feet) Descriptive Statistics

Site Location	Landscape Area (square feet)						
	N	Total	Mean	Median	Std. Dev.	Min.	Max.
All Sites	2294	65,116,796	28385.7	6534.0	140558.3	240	4741279
Northern Sites	411	30,057,499	73132.6	23786.0	248165.1	629	4741279
Southern Sites	1883	35,059,389	18618.9	4313.2	100607.0	240	2843692
Coastal ET Zone	655	16,705,579	25504.7	6638.4	68499.9	390	875150
Intermediate ET Zone	1444	42,052,890	29122.5	5208.5	161112.8	240	4741279
Inland ET Zone	195	6,358,365	32607.0	6847.8	156757.5	690	1561245
Professional Installation	920	37,356,324	40604.7	9781.8	142586.0	500	2843692
Self Installation	1374	27,760,571	20204.2	3000.0	138635.2	240	4741279
Commercial	296	35,287,137	119213.3	25820.6	363712.9	629	4741279
Irrigation	11	609,322	55392.9	21770.0	100829.1	10165	356630
Residential	1987	29,220,425	14705.8	4890.0	41094.4	240	472185
Alameda County WD	5	63,895	12779.0	3841.0	19261.4	1682	46771
Burbank	76	188,541	2480.8	2250.0	1460.1	375	6635
Contra Costa WD	32	883,968	27624.0	10827.0	49101.3	3277	215759
Eastern	87	2,093,394	24062.0	13778.0	53927.1	648	460500
EBMUD	333	23,006,038	69087.2	26627.0	93993.3	4000	498475
Foothill	245	834,985	3408.1	2400.0	3210.1	240	25352
Glendale	109	320,373	2939.2	2100.0	2310.3	588	12900
Goleta	26	1,122,763	43183.2	18714.8	58245.7	1084	241579
Inland Empire	186	612,163	3291.2	2665.2	2726.6	637	26136
LADWP	477	10,004,646	20974.1	7004.4	111222.6	690	1561245
Pasadena	17	1,399,710	82335.9	44000.0	122697.1	10000	523000
Santa Barbara	73	2,966,545	40637.6	22112.0	48059.6	4554	248670
Santa Monica	71	178,295	2511.2	2400.0	1092.4	500	6600
Santa Clara Valley	34	5,121,485	150631.9	8998.7	811216.2	629	4741279
Sonoma County WA	7	982,107	140301.0	3307.0	182016.1	1230	441302
San Diego County WA	401	2,138,734	5333.5	2400.0	8852.5	300	104544
Western	115	13,199,217	114775.8	26136.1	310035.4	971	2843691

Potential Sources of Uncertainty

The level of accuracy of the landscape area data provided to the analysis team was not known and could not be independently verified. In many cases the method used to determine the landscape area was not specified by the local agency when data from the study was provided. Errors in the landscape size could impact calculation of applied water and comparisons of applied water at the site to theoretical requirements. However, the landscape size does not change from pre- to post-installation, so any errors will impact application rate measurements equally. Inaccuracy in the measurement of landscape area should not significantly impact the calculation of water savings at any given site. Regardless, it is important to acknowledge potential sources of error in the analyses and results presented in this report, and the measurement of landscape size is certainly one of these potential sources. Any follow-on work using data set from this study would benefit from verification and if necessary re-measurement task for landscape areas.

Water Use and Applied Water

The participating water agencies in northern and southern California provided historic water use data from billing recorders for as many of the smart controller sites as possible. In order for a site to be included in the impact analysis a minimum of one full year (12 months) of water consumption data from the time period *prior* to installation of the smart controller (pre-smart controller data) and one full year of water consumption data from the time period *after* installation of the smart controller (post-smart controller data) were required. In some cases, multiple years of pre- and post-installation data were provided thus permitting more expanded analysis discussed later in this report.

The pre- and post-installation billing data time periods for each site were often different. For example, a site where the smart controller was installed in June 2005 likely had pre-installation data from the 2004 calendar year and post installation data from July 2005 forward. At a different site where the smart controller was installed in September 2006 likely had pre-installation data from 2005 and 2006 and post-installation data from 2007. The key point is that only full years of data were included in the analysis and at least one full year of pre- and post-installation was required to include a smart controller site in the impact analysis. Differences in weather and climate conditions experienced in the different California regions during the different timer periods which billing data were provided were carefully accounted for using CIMIS weather data as described in the methodology section of this report.

Some large smart controller sites were served by multiple water meters and in these cases the data from all meters serving the site were aggregated. Some sites were served by a dedicated irrigation meter, which allowed irrigation demand to be easily isolated. However, a mixed-use water meter, which is typical for single-family residences, served most of the sites in this study. In these cases, outdoor use was disaggregated using the minimum month estimation technique described in the methodology section of this report. All water use data were converted into units of thousands of gallons (kgal) for the purposes of analysis and reporting.

Pre- and Post-Smart Controller Water Use

Sufficient pre- and post-installation data were provided for 2,294 smart controller sites in California. The average annual outdoor water use during the pre- and post-smart controller installation periods is presented in Table 40 (pre) and Table 41 (post). These tables present summary results for all sites, northern and southern sites, sites by climate zone, and for each individual water agency.

The average (mean) annual outdoor water use for all sites during the pre-installation period was 777.0 kgal and the median was 132.7 kgal. The average is clearly influenced by outliers such as large sites with high irrigation use. During the post-smart controller installation period the average (mean) annual outdoor water use for all sites was 757.0 kgal and the median was 127.9 kgal. Without considering the effects of weather, outdoor water use decreased by an average of 20 kgal (2.6%) after installation of the smart controllers. While suggestive these data alone cannot be used to adequately measure the impact of smart controllers. Only weather-normalized data that takes into consideration the landscape area should be used to interpret the impact of these devices.

Table 40: Pre-Smart Controller Annual Outdoor Water Use (kgal) Descriptive Statistics

Site Location	Pre-Smart Controller Annual Outdoor Water Use (kgal)					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	777.0	132.7	6927.4	3.0	271652.7
Northern Sites	411	1795.4	312.7	13482.5	24.0	271652.7
Southern Sites	1883	554.7	105.0	4311.8	3.0	151680.2
Coastal ET Zone	655	560.4	130.3	1739.5	3.0	28352.9
Intermediate ET Zone	1444	900.8	139.5	8600.3	3.0	271652.7
Inland ET Zone	195	588.3	117.0	2556.3	12.0	25630.2
Professional Install.	920	1058.2	233.5	6100.5	12.7	151680.2
Self Installation	1374	588.8	89.9	7426.0	3.0	271652.7
Commercial	296	4059.7	651.9	18889.6	20.2	271652.7
Irrigation	11	995.8	182.2	2573.8	63.7	8741.5
Residential	1987	286.8	111.0	724.6	3.0	8432.6
Alameda County WD	5	450.9	250.6	593.6	34.4	1500.0
Burbank	76	102.9	89.0	57.3	7.5	314.9
Contra Costa WD	32	733.5	229.5	1387.6	74.8	6583.1
Eastern	87	590.7	338.2	953.9	20.2	6865.0
EBMUD	333	1196.6	321.0	1960.9	45.6	14172.2
Foothill	245	75.8	57.0	70.5	3.7	529.0
Glendale	109	29.5	25.0	29.0	3.0	252.9
Goleta	26	980.2	473.5	1342.9	77.0	5976.5
Inland Empire	186	148.1	119.5	109.4	9.0	867.0
LADWP	477	457.4	112.0	2253.3	12.0	28352.9
Pasadena	17	4145.3	2478.9	5057.1	563.2	20134.7
Santa Barbara	73	612.1	454.0	486.9	59.0	3168.5
Santa Monica	71	145.7	143.0	91.8	6.7	395.0
Santa Clara Valley	34	8586.3	499.1	46486.4	31.0	271652.7
Sonoma County WA	7	3116.4	130.9	4729.6	24.0	12856.0
San Diego County WA	401	169.0	77.0	358.0	3.0	4868.0
Western	115	4339.5	910.3	16191.5	51.6	151680.2

Table 41: Post-Smart Controller Annual Outdoor Water Use (kgal) Descriptive Statistics

Site Location	Post-Smart Controller Annual Outdoor Water Use (kgal)					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	757.0	127.9	6549.6	0.0	240421.4
Northern Sites	411	1693.2	303.8	11961.3	0.0	240421.4
Southern Sites	1883	552.6	101.6	4567.6	1.5	160110.1
Coastal ET Zone	655	525.1	136.7	1590.2	2.2	26400.7
Intermediate ET Zone	1444	883.2	122.2	8124.7	0.0	240421.4
Inland ET Zone	195	601.4	135.2	2679.0	8.2	25470.1
Professional Install.	920	1057.2	228.5	6448.0	4.5	160110.1
Self Installation	1374	556.0	86.8	6611.4	0.0	240421.4
Commercial	296	4009.5	628.2	17822.6	15.7	240421.4
Irrigation	11	1126.1	288.1	2816.4	78.3	9604.4
Residential	1987	270.4	108.5	700.6	0.0	10044.5
Alameda County WD	5	331.8	151.1	532.4	25.4	1276.8
Burbank	76	97.9	87.7	59.2	17.2	346.3
Contra Costa WD	32	741.5	230.8	1468.0	18.7	6488.9
Eastern	87	531.6	284.3	1107.0	15.7	8747.2
EBMUD	333	1155.5	314.2	1951.4	0.0	15377.0
Foothill	245	77.5	54.6	74.8	3.0	511.5
Glendale	109	28.0	24.9	27.8	2.9	209.1
Goleta	26	884.0	473.5	1122.9	55.4	4980.2
Inland Empire	186	106.0	81.2	91.6	2.2	481.6
LADWP	477	454.5	118.9	2231.3	8.2	26400.7
Pasadena	17	4545.0	2600.8	5934.8	609.6	24953.3
Santa Barbara	73	506.6	374.0	379.6	41.0	2008.4
Santa Monica	71	151.7	145.7	104.1	3.7	432.2
Santa Clara Valley	34	7751.7	394.6	41117.0	44.9	240421.4
Sonoma County WA	7	3167.6	120.4	4820.5	56.8	13119.9
San Diego County WA	401	173.2	86.8	359.2	1.5	4166.4
Western	115	4442.5	677.7	17244.8	42.6	160110.1

Pre- and Post-Smart Controller Application Rates

As explained in the methodology section of the report, the application rate (inches) was calculated by dividing the outdoor water use by the landscape area and applying a unit conversion factor. The application rate is a measure of the depth of irrigation water applied across the entire landscape over a year and can be compared to the theoretical irrigation requirement which is empirically determined from CIMIS data.

A comparison of the pre- and post-smart controller irrigation application rate frequency distributions is shown in Figure 24. Descriptive statistics showing the pre-smart controller application rates are presented in Table 42. Post-smart controller application rates are presented in Table 43. These values have not been adjusted for changes in weather and climate conditions during the pre- and post-installation periods.

The average application rate across all study sites during the pre-smart controller period was 52.5 inches and the median was 37.7 inches. The average application rate during the post-smart controller period was 50.4 inches and the median was 34.6 inches. Perhaps surprisingly, the average application rate among sites in the inland ET zone was only 30.0 inches during the post-period, which was lower than the average application rates in the coastal and intermediate ET zones. During the pre-smart controller period, the average application rate in the northern California sites (which were initially targeted because of their apparently high historic water use) was 34.9 inches compared with an average of 56.3 inches in the southern sites. During the post-smart controller period the average application rate in the northern sites was 35.0 inches and 53.7 inches in the southern sites. Without weather correction, the application rate in the northern sites was essentially unchanged while in southern California it decreased slightly (2.6 inches or 4.6%).

The frequency distributions of pre- and post- application rates are shown in Figure 24. Over-irrigation remains a problem for many sites, even after the installation of a smart controller. In both the pre- and post-smart controller periods, more than 10 percent of the sites applied 100 inches of water or more and nearly 5 percent of the sites applied more than 150 inches of water, far exceeding the theoretical irrigation requirement in any of the climate zones in the study.

During the pre-installation period the mean ETo for the study group was 47.63 inches, and during the post-install period it rose slightly to 49.6 inches. Thus, on average, the post-install period had a slightly higher irrigation requirement than did the pre-install period. The change in ETo from pre to post periods indicates the importance of the weather correction step in the analysis, and is helpful to keep in mind when interpreting the results.

Excess irrigation was observed in this study sample during both the pre- and post-installation periods, but the small number of sites (less than 5%) than applied more than 150 inches of water during the pre-installation period were not necessarily the same sites that applied more than 150 inches in the post period. After the installation of the smart controller there was a shift in the constituency of excess irrigators. The level of excess irrigation found in this study is typical of what has been found in other research studies examining the impacts of automatic irrigation (DeOreo, et. al. 2008), (Sovocool et. al. 2006), (Mayer et. al., 1999). Levels of excess irrigation shown in Figure 24 may be unintentional and can be the result of a wide variety of factors such as leaks caused by broken head or valves, controller programming errors, and un-related outdoor demands such as re-filling of swimming pools, washing pavements, children playing outdoors with a hose, or simply leaving a hose running by mistake.

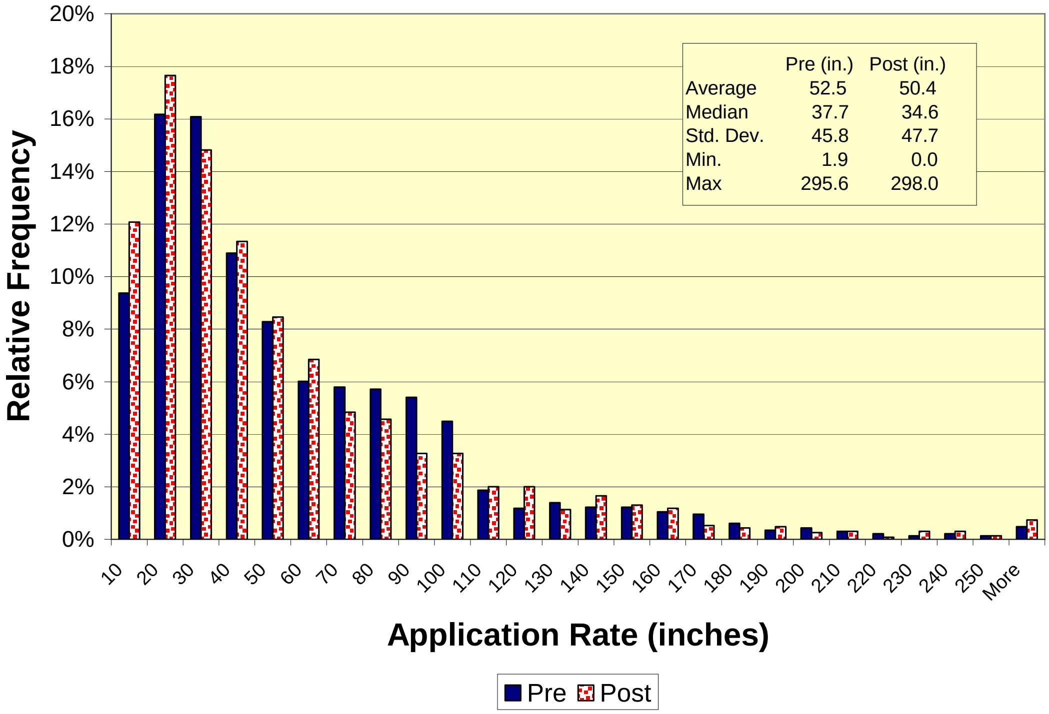

Figure 24: Pre- and Post-Smart Controller Annual Application Rate Frequency Distributions

In this study, sites that during the pre-installation period applied either no water outdoors (0 inches) or applied greater than 300 inches of were removed from the sample before any analysis was conducted. This filter excluded about 100 sites final sample of 2294.[16] The 300 inch cutoff point was selected by the research team based on a review of the frequency distribution of pre-installation application rates and a review of other research studies on automatic irrigation in arid regions. The researchers concluded that application rates above 300 inches were uncommon (though not unheard of) and hence were likely a product of faulty water use or area data or abnormal water use patterns. While application rates between 100 and 300 inches are excessive in almost any climate, previous research has shown that they are not uncommon and the research team determined that in absence of additional compelling information about a site there was no scientifically justifiable reason to exclude these sites from the study simply because their pre-installation application rate was higher than expected (DeOreo, et. al. 2008), (Sovocool et. al. 2006), (Mayer et. al., 1999).

[16] It is important to note that sites were only screened out based on their pre-installation application rates. Once included in the analysis, a site could not be removed because of a high (or low) post-installation application rate. Altering the sample based on post-installation information would violate fundamental principles of scientific investigation for conducting an "intervention" style of research study.

Table 42: Pre-Smart Controller Annual Application Rate (inches) Descriptive Statistics

Site Location	Pre-Smart Controller Annual Application Rate (inches)					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	52.5	37.7	45.8	1.9	295.6
Northern Sites	411	34.9	25.3	30.9	1.9	236.2
Southern Sites	1883	56.3	41.5	47.6	3.0	295.6
Coastal ET Zone	655	52.8	37.5	47.0	3.0	280.9
Intermediate ET Zone	1444	54.5	40.2	46.3	1.9	295.6
Inland ET Zone	195	36.6	27.4	33.6	3.2	245.4
Professional Installation	920	42.8	30.6	36.4	2.5	262.1
Self Installation	1374	58.9	43.1	50.2	1.9	295.6
Commercial	296	53.4	41.8	39.9	3.9	262.1
Irrigation	11	17.8	13.3	12.1	2.8	39.3
Residential	1987	52.5	36.7	46.7	1.9	295.6
Alameda County WD	5	85.2	51.5	69.8	32.8	196.1
Burbank	76	82.9	67.4	50.3	3.9	219.2
Contra Costa WD	32	46.7	39.1	27.7	8.4	155.0
Eastern	87	48.4	41.5	29.1	5.8	136.9
EBMUD	333	27.2	22.1	23.7	1.9	236.2
Foothill	245	49.7	36.1	45.1	3.2	214.0
Glendale	109	20.7	17.8	15.3	3.2	81.9
Goleta	26	44.3	35.8	26.5	12.0	114.1
Inland Empire	186	88.7	78.7	58.2	4.0	295.6
LADWP	477	39.8	28.0	35.6	3.0	250.9
Pasadena	17	95.6	90.2	41.0	13.6	161.1
Santa Barbara	73	39.3	32.0	25.7	4.0	92.7
Santa Monica	71	99.1	91.4	59.7	7.2	260.4
Santa Clara Valley	34	84.9	82.2	18.3	60.3	171.9
Sonoma County WA	7	67.8	50.1	57.5	14.0	151.3
San Diego County WA	401	64.2	54.5	49.2	3.4	280.9
Western	115	62.4	59.3	42.1	4.4	262.1

Table 43: Post-Smart Controller Annual Application Rate (inches) Descriptive Statistics

Site Locations	Post-Smart Controller Annual Application Rate (inches) N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	50.4	34.6	47.7	0.0	298.0
Northern Sites	411	35.0	24.1	36.6	0.0	297.8
Southern Sites	1883	53.7	38.2	49.2	3.0	298.0
Coastal ET Zone	655	52.9	37.7	50.6	3.0	298.0
Intermediate ET Zone	1444	51.0	33.9	48.2	0.0	297.8
Inland ET Zone	195	37.1	30.0	28.2	3.8	171.0
Professional Installation	920	42.3	31.1	39.3	1.9	297.8
Self Installation	1374	55.7	37.8	51.9	0.0	298.0
Commercial	296	51.8	40.5	42.2	4.0	266.2
Irrigation	11	20.9	18.0	10.7	5.2	43.2
Residential	1987	50.3	33.7	48.6	0.0	298.0
Alameda County WD	5	37.5	28.7	16.2	24.3	63.1
Burbank	76	78.9	66.9	51.2	9.3	230.5
Contra Costa WD	32	41.1	34.1	27.0	6.0	152.8
Eastern	87	42.1	36.8	26.7	4.1	132.7
EBMUD	333	26.5	21.4	26.5	0.0	297.8
Foothill	245	51.5	35.0	50.0	3.1	287.7
Glendale	109	20.5	15.6	17.7	3.1	102.6
Goleta	26	41.2	34.4	24.7	7.6	95.7
Inland Empire	186	65.9	44.9	60.3	3.2	296.5
LADWP	477	37.4	30.4	29.9	3.0	184.7
Pasadena	17	103.5	97.9	49.7	13.9	237.8
Santa Barbara	73	32.9	27.9	22.8	4.2	96.5
Santa Monica	71	100.7	94.1	65.0	3.2	255.3
Santa Clara Valley	34	105.9	96.4	48.9	30.8	240.3
Sonoma County WA	7	63.8	59.8	41.1	15.6	140.6
San Diego County WA	401	68.9	54.7	57.4	3.3	298.0
Western	115	56.9	48.6	39.9	5.1	207.4

Theoretical Irrigation Requirement (TIR)

As described in the methodology section of this report, climate data were obtained from proximal CIMIS weather stations across northern and southern California. Daily gross ETo data and daily precipitation measurements were carefully aligned with historic billing data for each site and then the controller installation date was used as the dividing marker between the pre- and post-installation periods. Care was taken to ensure that climate data *from the same weather station* was used for both the pre- and the post-installation analysis at every site. This sometimes meant selecting a weather station farther away from a site location, as the more proximal station had discontinuous or incomplete data for either the pre- or post-installation period. This complex process of matching and aligning pre- and post-installation water use and ET data allowed for weather corrections to be made on a site-by-site basis so that appropriate changes in water use could be measured.

Precipitation is an important factor to consider when evaluating the impact of smart control technology. Ideally a smart controller should reduce or prevent unnecessary irrigation after sufficient rainfall has occurred. However, not all measurable precipitation can be considered effective at reducing the water requirement of landscape plants and turf. Small amounts of rain often do not penetrate the soil and large amounts of rain can exceed the capacity of the soil to retain the moisture. A daily model was used to net out effective precipitation for each study site using the techniques described in the methodology section of this report. For any given day, effective precipitation was not allowed to exceed 25% of total daily precipitation. Alternative approaches to ET and precipitation were considered as well and analysis using different approaches are provided later in the Sensitivity Analysis section of this report. Effective precipitation is discussed further at the end of this report section.

The fundamental equation used to calculate the theoretical irrigation requirement (TIR) in inches for each site was:

$$\text{Theoretical Irrigation Requirement } TIR \text{ (inches)} = (ET_O \times K_c) \text{ - Effective Rainfall}$$

Where:

ETo = Gross annual evapotranspiration (inches) from CIMIS

Effective Precipitation = annual precipitation (inches) calculated as specified above; (daily effective precipitation ≤ 25% total daily precipitation).

K_c = ET adjustment factor or crop/landscape coefficient = 0.8 (from Updated Model Water Efficient Landscape Ordinance 2004[17, 18])

In this calculation of TIR the irrigation efficiency factor, which is normally on the denominator of the right hand side of the equation was effectively set to 1.0. If an efficiency of less than 1 had been used this would have increased the TIR, which would have decreased the amount of over-irrigation both before and after the installations. Since the study team had few if any about the individual irrigation systems on which to base an estimate of their efficiencies the decision was made to set the efficiencies to a unit value of 1. The researchers recognized that this reduced the TIR's, but since the primary analysis was on the impact on application ratios, which are less affected by changes to the TIR this was considered the best option.

[17] Updated California Model Water Efficient Landscape Ordinance, Reference: Section 65597, Gov. Code.

[18] California is currently considering adopting a *Kc* value of 0.7 in the latest version of the Model Water Efficient Landscape Ordinance. Although 0.8 was used in this study, the impact of using a value of 0.7 is discussed in the Sensitivity Analysis section of this report.

A comparison of the TIR values measured for the pre- and post-smart controller installation periods is presented in Figure 25. It was generally slightly hotter and drier during the post-installation period, hence the amount of water required to adequately irrigate the study site landscapes was determined to be higher. The frequency distributions shown in Figure 25 show a definite shift towards higher values during the post-installation year. TIR was 1.9% higher on average during the post-installation year.

The annual Theoretical Irrigation Requirement for all participating agencies during the pre-installation year is presented in Table 44. Annual TIR during the post-installation year is presented in Table 45. These tables also show the measured evapotranspiration rates for the northern and southern sites combined and for the three identified CIMIS climate zones. TIR was higher (indicating a hotter and drier climate) on average during the post-installation period in most of the study sites, with some notable exceptions (Alameda, Goleta, LADWP, and Santa Barbara). In both periods the district with the highest average TIR was the Western Water District, and the lowest TIR's were found in Alameda County, EBMUD and LADWP.

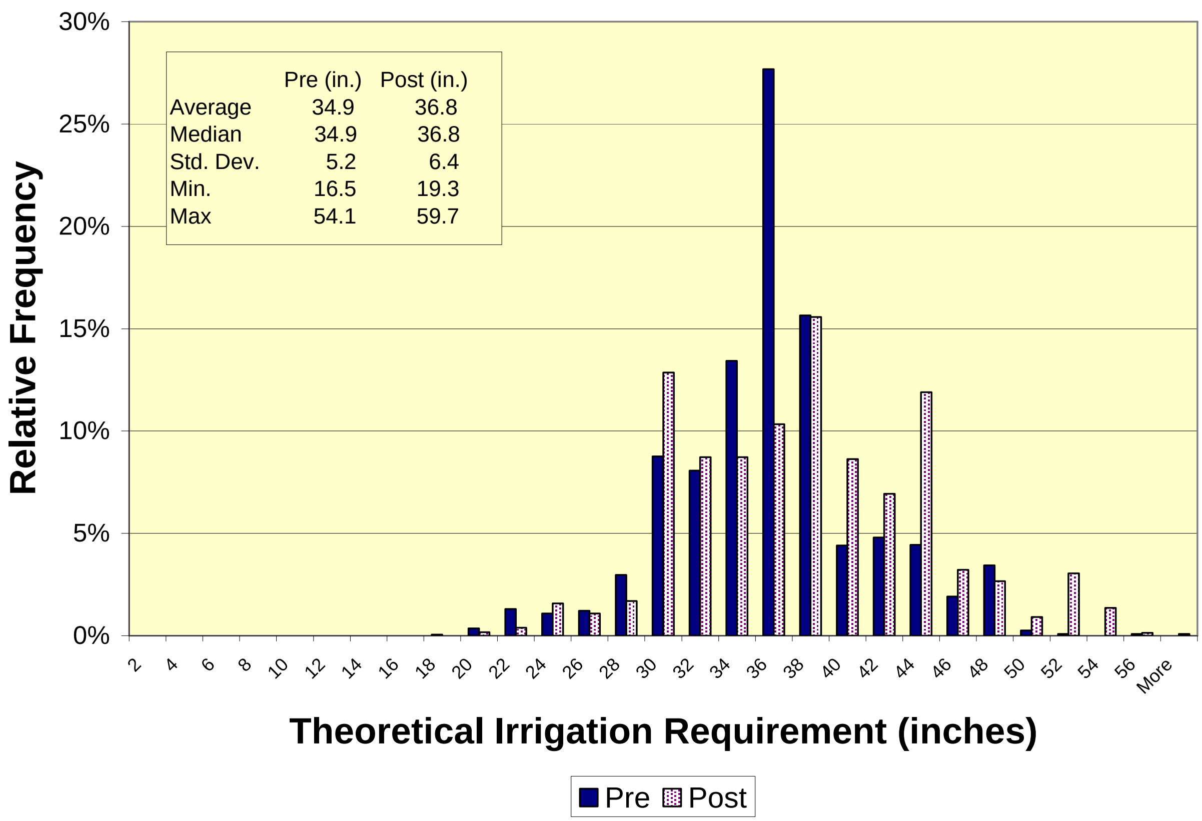

Figure 25: Pre- and Post-Smart Controller Annual TIR Frequency Distributions

Table 44: Pre-Smart Controller Annual TIR (inches) Descriptive Statistics

Site Locations	Pre-Smart Controller Annual TIR (inches)					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	34.9	34.9	5.2	16.5	54.1
Northern Sites	411	31.2	33.8	5.6	16.5	46.0
Southern Sites	1883	35.8	35.2	4.7	24.7	54.1
Coastal ET Zone	655	34.3	34.7	2.7	21.3	46.0
Intermediate ET Zone	1444	35.3	35.2	6.1	16.5	54.1
Inland ET Zone	195	34.3	35.7	3.2	26.1	39.8
Professional Installation	920	35.1	34.7	5.5	16.5	51.7
Self Installation	1374	34.9	35.2	5.0	20.1	54.1
Commercial	296	37.3	37.2	8.5	16.5	54.1
Irrigation	11	29.4	28.5	5.7	22.8	37.2
Residential	1987	34.6	34.9	4.4	19.3	48.8
Alameda County WD	5	33.6	32.9	2.5	30.6	37.5
Burbank	76	34.7	36.7	3.0	24.7	46.2
Contra Costa WD	32	36.5	37.2	2.8	30.6	46.0
Eastern	87	46.6	46.4	2.2	42.3	54.1
EBMUD	333	30.3	33.6	5.5	16.5	39.8
Foothill	245	32.5	34.9	3.7	26.0	44.6
Glendale	109	34.0	36.7	3.9	28.4	36.7
Goleta	26	34.8	32.7	4.3	28.3	45.6
Inland Empire	186	33.9	33.5	3.3	31.1	45.6
LADWP	477	34.1	34.0	2.4	26.1	39.0
Pasadena	17	33.3	32.2	3.4	28.0	39.4
Santa Barbara	73	34.3	34.3	3.2	27.8	40.3
Santa Monica	71	34.5	34.7	2.2	29.7	41.5
Santa Clara Valley	34	35.0	34.2	4.6	20.1	40.5
Sonoma County WA	7	28.1	27.6	1.7	26.2	31.2
San Diego County WA	401	37.9	35.5	4.3	27.7	48.8
Western	115	41.2	41.1	2.8	33.4	49.8

Table 45: Post-Smart Controller Annual TIR (inches) Descriptive Statistics

Site Locations	Post-Smart Controller Annual TIR (inches)					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	36.8	36.8	6.4	19.3	59.7
Northern Sites	411	32.4	33.3	5.4	19.3	45.0
Southern Sites	1883	37.8	37.4	6.3	25.4	59.7
Coastal ET Zone	655	33.8	34.9	3.9	22.9	49.1
Intermediate ET Zone	1444	38.9	39.7	6.8	19.3	59.7
Inland ET Zone	195	31.4	31.0	2.8	26.5	40.9
Professional Install.	920	33.7	31.0	6.8	19.3	55.8
Self Installation	1374	38.9	38.0	5.2	22.9	59.7
Commercial	296	40.1	40.0	9.8	19.3	59.7
Irrigation	11	30.5	32.8	6.1	21.0	37.6
Residential	1987	36.3	36.8	5.6	19.4	53.9
Alameda County WD	5	31.2	31.5	4.7	24.9	38.2
Burbank	76	40.5	42.4	2.6	33.8	50.2
Contra Costa WD	32	37.6	38.7	3.7	20.9	45.0
Eastern	87	51.4	50.2	2.6	40.1	59.7
EBMUD	333	31.4	33.1	5.1	19.3	39.6
Foothill	245	37.2	38.5	3.7	28.6	49.8
Glendale	109	39.6	42.4	4.0	29.9	42.4
Goleta	26	33.4	32.7	3.2	30.1	44.9
Inland Empire	186	41.8	40.1	3.5	34.6	53.9
LADWP	477	31.2	29.7	3.0	25.4	43.6
Pasadena	17	40.6	42.4	4.6	32.9	49.8
Santa Barbara	73	32.8	32.3	3.1	27.0	40.3
Santa Monica	71	34.9	34.9	1.7	30.6	41.1
Santa Clara Valley	34	37.3	40.0	4.9	22.9	43.1
Sonoma County WA	7	32.5	32.3	2.4	30.7	37.6
San Diego County WA	401	40.3	37.4	5.0	31.0	50.9
Western	115	42.1	41.4	2.6	39.1	52.4

Application Ratio - Percent of Theoretical Irrigation Requirement Applied

Smart controllers are complex devices designed to adjust irrigation applications to match prevailing weather conditions. When working with irrigation consumption data from different time periods it is essential to take weather conditions into consideration so that changes in usage patterns are accurately attributed. In this study the fundamental method for adjusting for changes is climate and weather conditions in the pre- and post-installation periods was to calculate the

Application Ratio (AR), i.e. the percent of TIR applied for each period, and to compare the results.

TIR represents an estimate of the theoretical irrigation requirement at each study site. To the extent that accurate site data are not available, the Theoretical Irrigation Requirement is an imperfect estimate, but it is the best way to approximate the irrigation requirement and gage the degree of over or under irrigation occurring. Ideally, additional factors such as shading, slope, soil type, and specific plant material could be used to develop more precise TIR estimates. Shading in particular has been shown to have a significant impact on irrigation requirements. The effects of inaccuracies in the data are largely mitigated by the fact the conditions at each site remained largely the same during the test periods with the exception of the controllers present. Thus errors in other landscape factors would have the same impact during each period, and would tend to cancel themselves out.

The application rate at each site (measured in inches) was divided by the corresponding TIR value (also measured in inches) to determine the Application Ratio (AR), the percent of TIR applied at each site during the pre- and post-smart controller periods. For example, if 100% of the TIR is applied, it is assumed that the theoretical irrigation requirement at the site is perfectly matched by the irrigation application. If 150% of the TIR is applied then it is assumed that excess water was applied. If 75% of the TIR is applied then it is assumed that less irrigation water than was theoretically required was applied to the site.

The pre and post install frequency distributions of Application Ratios at each of the 2,294 smart controller study sites is compared in Figure 26. During the pre-smart controller periods, an average of 151.3% of the theoretical irrigation requirement was applied to the study sites suggesting that about 50% more irrigation water than was required was applied to these sites. The pre-median value was 107.9%.

During the post-smart controller periods, an average of 136.8% of the theoretical irrigation requirement was applied at the 2,294 smart controller study sites. The post- median value was 96.2%. This is an important result that clearly shows that the smart controller technologies reduced water use at these sites overall and moved irrigation application rates lower and closer to the theoretical requirement.

Figure 26 shows the reduction in the Application Ratio from the pre- to the post-smart controller periods. The reductions in water use measured through this analysis were found to be statistically significant at the 95% confidence level.

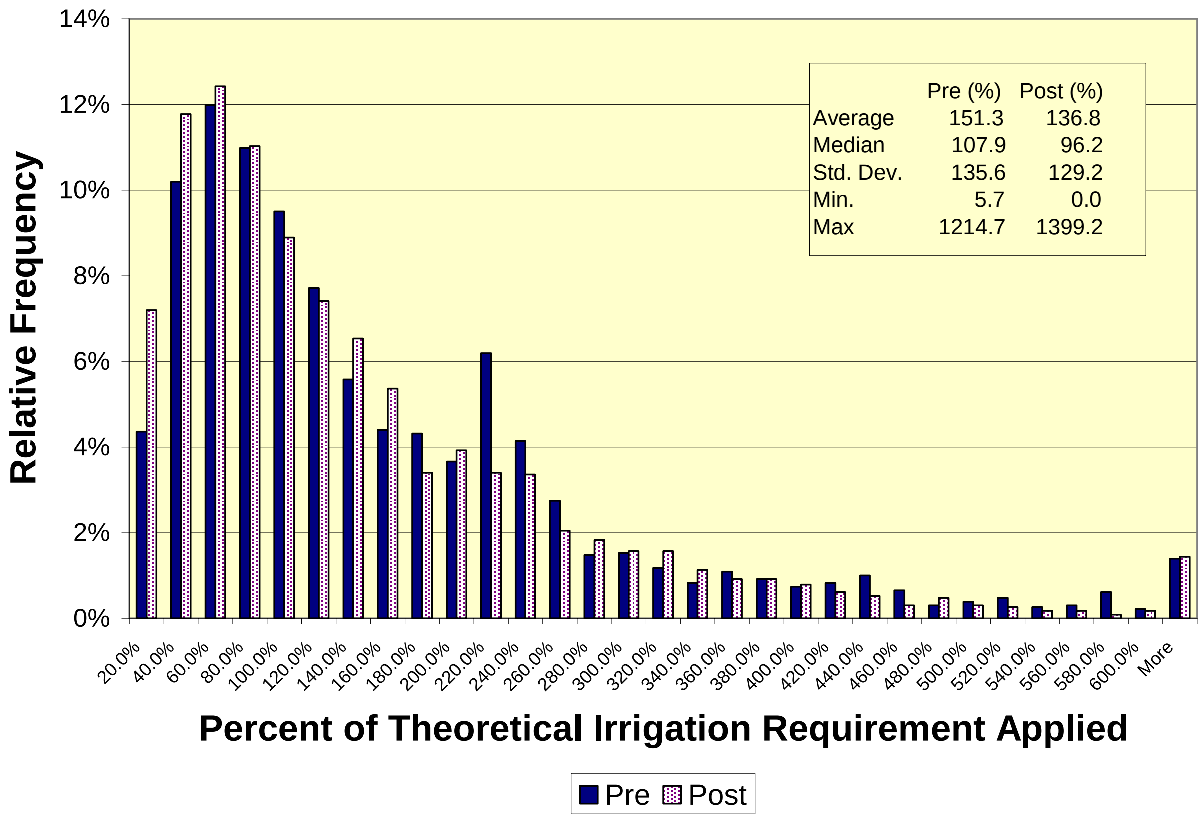

Figure 26: Pre- and Post-Smart Controller Application Ratio Frequency Distributions

The Application Ratio at each participating agency (and by region and climate zone) during the pre-smart controller period is presented in Table 46. Excess irrigation was prevalent in many study sites, but was greater in southern California. At 52.1% percent of the 2,294 smart controller sites in this study, irrigation water was applied in excess of the corresponding TIR requirement during the pre-smart controller period. After the smart controller was installed, water was applied in excess of TIR requirements at 47.8% of the sites. This represents an improvement of about 4.3%.

The researchers had little information about the condition of the landscapes at the sites in this study. However it is known that each site was equipped with an automatic irrigation system. At nearly 48% of the sites in the study, water was applied below the theoretical irrigation requirement. In cannot be assumed that the landscape at these sites was in poor condition. There are many legitimate reasons why irrigation at a particular location may be well below the calculated TIR. Shading may be the most significant factor. Solar radiation is the single most important factor in the ET equation and sites with significant amounts of shade may have greatly reduced irrigation demands. The plant materials included in the landscape may also be an important factor. The TIR in this study was calculated for a basic turf landscape. Landscapes containing native and water wise plants may require less water than an identical turf landscape.

The Application Ratio during the post-smart controller period is presented in Table 47. The fractional change from the pre- to the post-smart controller periods is presented in Table 48 as the weather-normalized change in irrigation application. Excess irrigation was reduced from the pre- to post-smart controller periods. Application rates were brought closer to the theoretical requirement (approximated by TIR) in nearly all of the participating agencies. This indicates that the smart controllers performed as designed and intended on average.

Table 46: Pre-Smart Controller Application Ratio Descriptive Statistics

Site Locations	Pre-Smart Controller Application Ratio Descriptive Statistics					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	151.3%	107.9%	135.6%	5.7%	1214.5%
Northern Sites	411	113.8%	84.1%	112.3%	5.7%	1214.5%
Southern Sites	1883	159.5%	115.9%	138.8%	8.2%	901.7%
Coastal ET Zone	655	154.4%	109.0%	139.1%	8.9%	901.7%
Intermediate ET Zone	1444	155.1%	112.0%	135.6%	5.7%	1214.5%
Inland ET Zone	195	112.6%	78.6%	116.7%	8.2%	833.9%
Professional Install.	920	123.2%	89.6%	109.9%	7.8%	1214.5%
Self Installation	1374	170.1%	122.0%	147.4%	5.7%	901.7%
Commercial	296	148.0%	117.7%	122.7%	10.0%	1214.5%
Irrigation	11	63.8%	40.8%	45.3%	7.8%	148.1%
Residential	1987	152.3%	107.3%	137.6%	5.7%	901.7%
Alameda County WD	5	258.7%	151.4%	228.5%	99.7%	641.2%
Burbank	76	240.0%	198.4%	145.3%	12.0%	620.7%
Contra Costa WD	32	128.6%	109.0%	77.1%	21.4%	446.7%
Eastern	87	104.2%	90.7%	63.2%	12.4%	307.5%
EBMUD	333	93.8%	73.3%	100.1%	5.7%	1214.5%
Foothill	245	152.6%	111.4%	136.9%	8.9%	742.7%
Glendale	109	61.8%	49.1%	48.1%	9.5%	288.2%
Goleta	26	129.1%	104.4%	79.8%	36.6%	364.2%
Inland Empire	186	261.8%	228.3%	173.4%	12.8%	839.0%
LADWP	477	119.7%	82.3%	113.8%	8.2%	833.9%
Pasadena	17	287.4%	254.4%	124.4%	42.3%	511.8%
Santa Barbara	73	116.8%	95.1%	78.7%	11.8%	288.1%
Santa Monica	71	289.3%	268.7%	177.6%	20.6%	767.5%
Santa Clara Valley	34	248.3%	233.7%	79.3%	197.2%	562.0%
Sonoma County WA	7	245.6%	169.8%	210.7%	51.4%	548.8%
San Diego County WA	401	170.6%	136.9%	136.1%	9.6%	901.7%
Western	115	150.9%	144.1%	99.1%	10.0%	608.4%

Table 47: Post-Smart Controller Application Ratio Descriptive Statistics

Site Locations	Post-Smart Controller Percent of Application Ratio Descriptive Statistics					
	N	Mean	Median	Std. Deviation	Min.	Max.
All Sites	2294	136.8%	96.2%	129.2%	0.0%	1399.2%
Northern Sites	411	109.2%	76.2%	121.0%	0.0%	1399.2%
Southern Sites	1883	142.8%	104.0%	130.2%	7.0%	945.1%
Coastal ET Zone	655	153.7%	113.6%	143.1%	9.5%	945.1%
Intermediate ET Zone	1444	131.7%	88.2%	126.8%	0.0%	1399.2%
Inland ET Zone	195	117.8%	96.6%	85.5%	10.5%	501.3%
Professional Install.	920	126.1%	94.4%	118.2%	6.9%	1399.2%
Self Installation	1374	143.9%	98.2%	135.7%	0.0%	945.1%
Commercial	296	132.6%	100.7%	109.2%	7.6%	712.6%
Irrigation	11	71.3%	73.7%	35.2%	14.4%	134.0%
Residential	1987	137.8%	95.5%	132.2%	0.0%	1399.2%
Alameda County WD	5	117.9%	110.6%	36.9%	77.1%	165.4%
Burbank	76	194.5%	169.8%	126.1%	24.4%	607.2%
Contra Costa WD	32	109.1%	89.6%	74.9%	17.9%	431.4%
Eastern	87	81.7%	73.2%	50.8%	7.6%	247.2%
EBMUD	333	88.7%	68.1%	105.0%	0.0%	1399.2%
Foothill	245	140.3%	94.5%	138.6%	7.3%	825.9%
Glendale	109	53.1%	38.3%	50.0%	7.3%	301.8%
Goleta	26	124.7%	105.7%	77.0%	24.2%	314.9%
Inland Empire	186	160.2%	107.1%	148.2%	7.0%	665.2%
LADWP	477	117.7%	98.9%	87.8%	10.2%	502.4%
Pasadena	17	260.7%	233.1%	137.4%	32.8%	629.1%
Santa Barbara	73	101.3%	87.2%	71.1%	13.3%	311.1%
Santa Monica	71	291.6%	271.2%	191.9%	9.5%	778.0%
Santa Clara Valley	34	290.5%	241.3%	151.7%	91.0%	727.3%
Sonoma County WA	7	195.1%	180.8%	126.7%	50.9%	434.9%
San Diego County WA	401	173.8%	136.2%	152.6%	9.1%	945.1%
Western	115	134.7%	118.4%	93.4%	12.8%	523.0%

Potential Sources of Uncertainty

A key premise of this study is that any errors in the data are generally random rather than systematic in nature. This means that while it is likely that there exist some errors in the key parameters such as irrigated areas, water use, ET etc. among study sites, these errors are scattered both above and below the true values are not systematically low or high. Random errors increase the variance and the confidence intervals, but they do not significantly impact mean values. Random errors make it harder to detect changes in the means with statistical confidence, but they do not change the fundamental conclusions of the study. Systematic errors on the other hand can throw the entire analysis off. For example, if *all* of the irrigated area data were too high then all of the application rates and TIR values would be wrong by a proportionate amount, and the fundamental conclusions about irrigation efficiencies would be affected.

There is an unknown amount of uncertainty in the estimates presented due to possible errors in: water use data, irrigated area data, ET values and irrigation systems' efficiency (which was unknown but assumed to be 100% efficient). The landscape area could be too large or too small. The TIR could be too high or too low. Specific information about the sites was not known such as shading, soil type, slope, plant materials, etc. Even the water use data could contain inaccuracies.

Since errors on individual sites affected the analysis the same way during the pre- and the post-smart controller periods, and because the sample size (n=2,294) is quite large, the overall impact of the errors on analysis of changes in water use did not preclude making statistically reliable conclusions on changes in water use. Furthermore, the sensitivity analysis (presented later in this section) confirms that even if systematic errors were made in an item such as precipitation, or if precipitation was totally disregarded it would not invalidate the conclusions of the study.

Weather-Normalized Change in Application Ratio

The weather-normalized fractional change in Application Ratio, ΔAR, is an important change in use measurement that was used to establish the factors that influenced water savings and used as a part of the per site water savings calculation in this research study. Calculated as the fractional change (from the pre-smart controller period) in the Application Ratio at each site, the weather-normalized change in application ratio was a primary means for examining the impact of smart controllers on water use across study sites with weather effects held constant. The average percent change in irrigation volume was then calculated by dividing ΔAR by the pre-AR as shown earlier in the methodology section in Equation 4.[19]

The ΔAR statistics for each agency and climate zone are presented in Table 48 and a frequency distribution showing the weather-normalized percent change in irrigation application is presented in Figure 27.

[19] It is important to understand that this is a percentage change calculated using seasonal (outdoor) use rather than total use.

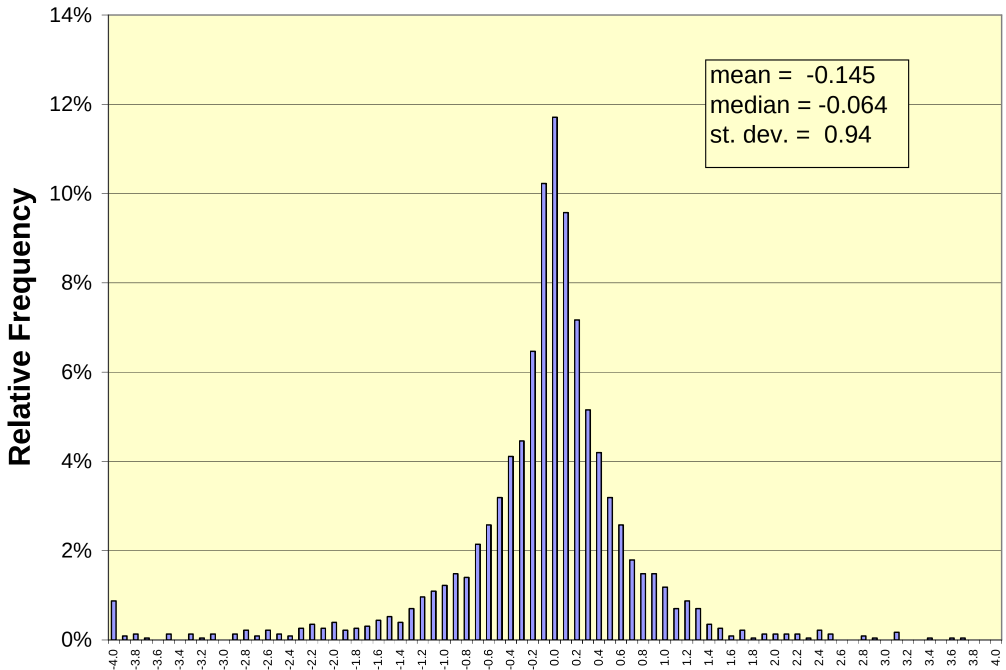

Figure 27: Fractional change in Application Ratio (ΔAR) Frequency Distribution

The frequency distribution of change in application ratio, shown in Figure 27, shows the shape and spread of the data that were used to determine the broad impact of smart controllers in this study and was also used as the independent variable in the modeling section described later in this report. It is important to note that this frequency distribution, while not a perfect bell curve, can be quite reasonably described as “normal” or “Gaussian” in character. The t-tests and some of the other statistical analyses conducted using these data have a built in assumption of normality.

A total of 1,300 (56.7%) of the 2,294 study sites had a statistically significant reduction in weather-normalized application ratio. While 959 (41.8%) sites had a statistically significant increase in application ratio. For 35 (1.5%) of sites, there was not a statistically significant change in application ratio. These results are shown in Table 49.

While the overall findings show reductions in application ratio through the installation of smart controllers, it is also significant that 41.8% of study sites experienced an increase in weather-normalized application ratio after the installation of a smart controller. Differences between sites that increased and decreased weather-normalized irrigation applications were examined and results are presented In
Table **50** .

Table 48: Weather-Normalized Change in Application Ratio Descriptive Statistics

Site Locations	Weather-Normalized Fractional Change in Application Ratio Descriptive and Validatory Statistics				
	N	Mean	Std. Deviation	95% Confidence Boundary	Statistically Significant Reduction?
All Sites	2294	-0.145	0.94	+ or - 0.038	Yes
Northern Sites	411	-0.046	0.86	+ or -0.083	No
Southern Sites	1883	-0.167	0.95	+ or - 0.043	Yes
Coastal ET Zone	655	-0.007	0.70	+ or - 0.053	No
Intermediate ET Zone	1444	-0.234	1.03	+ or - 0.053	Yes
Inland ET Zone	195	0.052	0.86	+ or - 0.120	No
Professional Installation	920	0.029	0.74	+ or - 0.048	No
Self Installation	1374	-0.262	1.03	+ or - 0.054	Yes
Commercial	296	-0.154	0.75	+ or -0.085	Yes
Irrigation	11	0.075	0.26	+ or - 0.154	No
Residential	1987	-0.145	0.96	+ or - 0.042	Yes
Alameda County WD	5	-1.408	2.24	+ or - 1.963	No
Burbank	76	-0.455	1.16	+ or - 0.261	Yes
Contra Costa WD	32	-0.195	0.57	+ or - 0.199	No
Eastern	87	-0.225	0.43	+ or - 0.091	Yes
EBMUD[20]	333	-0.051	0.64	+ or - 0.068	No
Foothill	245	-0.123	0.79	+ or -0.099	Yes
Glendale	109	-0.087	0.22	+ or - 0.041	Yes
Goleta	26	-0.044	0.39	+ or - 0.150	No
Inland Empire	186	-1.016	1.67	+ or - 0.240	Yes
LADWP	477	-0.020	0.76	+ or - 0.068	No
Pasadena	17	-0.267	0.86	+ or - 0.409	No
Santa Barbara	73	-0.155	0.47	+ or - 0.107	Yes
Santa Monica	71	0.023	0.96	+ or - 0.223	No
Santa Clara Valley	34	0.422	1.82	+ or - 0.610	No
Sonoma County WA	7	-0.505	1.36	+ or - 1.006	No
San Diego County WA	401	0.032	0.89	+ or - 0.087	No
Western	115	-0.162	0.64	+ or - 0.116	Yes

The Application Ratio prior to installing the smart controller (pre-AR) was one of the most importance differences between sites in this study. Sites that increased application after installation of a smart controller had a mean pre-AR of 131% and a median of 95%. The median indicates that more than half of these sites were applying less than the theoretical irrigation requirement prior to the installation of the smart controller. Since smart controllers are designed to adapt irrigation to match the theoretical requirement, it would be expected that installing a smart controller at a site with a history of applying less than the theoretical irrigation requirement

[20] In 2007, EBMUD requested a voluntary 10% cutback in usage from customers in response to drought conditions. Some of the post-installation water use data from EBMUD came from this time frame. It was not possible to determine if this effort impacted water savings in this study.

will result in increased water use. Sites that decreased application after installation of a smart controller had a mean pre-AR of 182% and a median of 137%. The median here indicates that most of these sites were irrigating in excess of the theoretical requirement prior to installation of the smart controller. These are exactly the type of sites that should be targeted to receive a smart controller if water use reductions are the desired goal.

Residential sites were more likely to increase application than non-residential sites. Landscape area was not a determining factor. The mean landscape area among sites that increased application was smaller, but the median landscape area was higher.

Table 49: Number of smart controller sites with a statistically significant change in application ratio

Statistically significant change in Application Ratio?	# of Sites	%
Increase	959	41.8%
No change (+ or – 0.006)	35	1.5%
Decrease	1300	56.7%

Table 50: Comparison of sites that increased and decreased irrigation application ratios with statistical significance after installation of a smart controller

Category	Sub-Category	Increased Application Ratio	Decreased Application Ratio
Customer Category	Non-Residential Sites	32.9%	67.1%
	Residential Sites	43.0%	57.0%
Landscape Area (sf)	Mean	22,084	28,505
	Median	6,286	5,698
Pre-Application Ratio (%)	Mean	131%	182%
	Median	95%	137%

Weather-Normalized Change in Outdoor Water Use

The weather-normalized change in outdoor water use presents the overall impact of the smart controllers installed in this study with respect to actual water conservation. The weather-normalized change in outdoor use volume was calculated by for each of the 2,294 smart controller study sites by multiplying the weather-normalized percent change in water use by the pre-installation seasonal volume (shown in Equation 4 and Equation 5 and described in the methodology) This provides a calculation of the changes in per site water use effected by the smart controllers, normalized for changes in the weather conditions during the pre- and post-installation periods at each site.

Overall, outdoor water use was reduced by an average of 47.3 kgal per site (-6.1% of average outdoor use) across the 2,294 sites examined in this study as part of the California Weather-Based Irrigation Controller Programs. This reduction was found to be statistically significant at the 95% confidence level. At smart controller sites in northern California the average change in outdoor use was a reduction of 122.2 kgal per site (-6.8% of average outdoor use). This change was not statistically significant at the 95% confidence level, but was significant at the 90% confidence level. At smart controller sites in southern California the average change in outdoor use was a reduction of 30.9 kgal per site (-5.6% of average outdoor use) and this was statistically significant at the 95% confidence level. These results and the findings for each agency and climate zone are presented in Table 51..

In this analysis, all sites are included regardless if water use increased or decreased after the installation of the smart controller. For some agencies, increases in water use offset decreases once the change volume was considered. Weather-normalized outdoor water use decreased on average at 16 of the 17 participating agencies, but not all of these reductions were statistically significant at the 95% confidence level. Statistically significant changes in outdoor water use were found in 8 of 17 participating agencies.

The results in Table 51 bring the magnitude of the size of the smart controller sites and volumes of water used into the analysis. Application ratio analysis, as presented earlier in this section, treats each site equally regardless of size and historic water use. But when weather-normalized changes in volume are calculated, large sites take on greater significance and some different and interesting conclusions about the overall impact of smart controllers can be considered.

Table 51: Weather-Normalized Change in Outdoor Water Use Descriptive Statistics

Site Locations	Weather-Normalized Change in Outdoor Use Descriptive and Validatory Statistics					
	N	Mean (kgal)	Std. Deviation	95% Conf. Boundary	Statistically Significant Reduction?	% Change
All Sites	2294	-47.3	669.5	27.4	Yes	-6.1%
Northern Sites	411	-122.2	1305.2	126.2	No	-6.8%
Southern Sites	1883	-30.9	416.5	18.8	Yes	-5.6%
Coastal ET Zone	655	-42.5	399.3	30.6	Yes	-7.6%
Intermediate ET Zone	1444	-52.2	756.7	39.0	Yes	-5.8%
Inland ET Zone	195	-26.2	707.4	99.3	No	-4.5%
Pro. Installation	920	-38.3	599.0	38.7	No	-3.6%
Self Installation	1374	-53.2	712.8	37.7	Yes	-9.0%
Commercial	296	-228.9	1783.8	203.2	Yes	-5.6%
Irrigation	11	108.3	231.1	136.6	No	10.9%
Residential	1987	-21.1	197.0	8.7	Yes	-7.3%
Alameda County WD	5	-83.6	81.2	71.2	Yes	-18.5%
Burbank	76	-19.0	49.1	11.0	Yes	-18.4%
Contra Costa WD	32	-15.1	268.3	93.0	No	-2.1%
Eastern	87	-110.6	284.5	59.8	Yes	-18.7%
EBMUD[21]	333	-70.0	499.0	53.6	Yes	-5.8%
Foothill	245	-7.8	34.6	4.3	Yes	-10.2%
Glendale	109	-5.3	12.9	2.4	Yes	-18.0%
Goleta	26	-32.6	230.2	88.5	No	-3.3%
Inland Empire	186	-61.6	93.7	13.5	Yes	-41.6%
LADWP	477	-25.4	600.9	53.9	No	-5.5%
Pasadena	17	-353.6	956.2	454.6	No	-8.5%
Santa Barbara	73	-90.2	259.2	59.4	Yes	-14.7%
Santa Monica	71	5.7	41.3	9.6	No	3.9%
Santa Clara Valley	34	-694.9	4254.5	1430.1	No	-8.1%
Sonoma County WA	7	-340.9	753.9	558.5	No	-10.9%
San Diego County WA	401	-7.4	117.7	11.5	No	-4.4%
Western	115	-44.2	1007.4	184.1	No	-1.0%

Weather-Normalized Change in Total Irrigation Volume

The total weather-normalized volumetric change in usage for each study site and region is presented in Table 52. This table includes only the results from the 2,294 smart controller sites included in the impact analysis. In this sample, with only one year of post-installation data, the smart controllers sites have reduced demand by 108,418.5 kilo-gallons (-144,942 hcf, 330 acre-feet) across California.

[21] In 2007, EBMUD requested a voluntary 10% cutback in usage from customers in response to drought conditions. Some of the post-installation water use data from EBMUD came from this time frame. It was not possible to determine if this effort impacted water savings in this study.

Additional water savings results summarized by participating water agency are presented in Appendix H.

Table 52: Summed weather-normalized change in water use (kgal)

Site Location	Weather-Normalized Total Change in Water Use		
	kgal	hcf	acre-feet
All Sites	-108,418.5	-144,941.9	-330.0
Northern Sites	-50,215.0	-67,131.2	-152.8
Southern Sites	-58,203.4	-77,810.7	-177.1
Coastal ET Zone	-27,864.8	-37,251.7	-84.8
Intermediate ET Zone	-75,440.9	-100,855.0	-229.6
Inland ET Zone	-5,112.9	-6,835.3	-15.6
Professional Installation	-35,233.0	-47,102.1	-107.2
Self Installation	-73,185.5	-97,839.8	-222.7
Commercial	-67,751.9	-90,575.8	-206.2
Irrigation	1,191.2	1,592.5	3.6
Residential	-41,857.8	-55,958.6	-127.4
Alameda County WD	-418.1	-558.9	-1.3
Burbank	-1,442.5	-1,928.5	-4.4
Contra Costa WD	-484.2	-647.3	-1.5
Eastern	-9,625.3	-12,867.9	-29.3
EBMUD	-23,299.0	-31,147.8	-70.9
Foothill	-1,899.5	-2,539.4	-5.8
Glendale	-579.2	-774.4	-1.8
Goleta	-846.6	-1,131.8	-2.6
Inland Empire	-11,463.3	-15,324.9	-34.9
LADWP	-12,100.1	-16176.3	-36.8
Pasadena	-6,010.6	-8,035.5	-18.3
Santa Barbara	-6,584.5	-8,802.6	-20.0
Santa Monica	401.8	537.1	1.2
Santa Clara Valley	-23,627.7	-31,587.2	-71.9
Sonoma County WA	-2,386.1	-3,190.0	-7.3
San Diego County WA	-2,974.9	-3,977.1	-9.1
Western	-5,078.5	-6,789.3	-15.5

A summary of the weather-normalized change in water use as a percentage, a volume, and gallons per square foot of landscape area as well as the landscape areas is presented in Table 53. Mean and median values are presented. Most of these data are presented in separate tables, earlier in this report, but this table provides a useful summary of some of the key findings by region, ET zone, installation method, customer category, and agency.

Table 53: Area and Weather-Normalized Change in Outdoor Water Use (kgal/year, gallons/sf, %)

				Weather-Normalized Change in Outdoor Water Use				
		Area (sf)		Per Site Change In Irrigation Volume (kgal/year)		Gallons/Square Foot		% Change in Outdoor Use
Site Location	N	Mean	Median	Mean	Median	Mean	Median	Mean
All Sites	2294	28385.7	6534.0	-47.3	-6.5	-1.7	-1.0	-6.1%
Northern Sites	411	73132.6	23786.0	-122.2	-15.6	-1.7	-0.7	-6.8%
Southern Sites	1883	18618.9	4313.2	-30.9	-5.7	-1.7	-1.3	-5.6%
Coastal ET Zone	655	25504.7	6638.4	-42.5	-0.2	-1.7	0.0	-7.6%
Inland ET Zone	195	32607	6847.8	-52.2	-10.7	-1.8	-2.0	-5.8%
Intermediate ET Zone	1444	29122.5	5208.5	-26.2	15.6	-0.8	2.3	-4.5%
Professional Installation	920	40604.7	9781.8	-38.3	-4.5	-0.9	-0.5	-3.6%
Self Installation	1374	20204.2	3000.0	-53.3	-7.4	-2.6	-2.5	-9.0%
Commercial	296	119213.3	25820.6	-228.9	-49.2	-1.9	-1.9	-5.6%
Irrigation	11	55392.9	21770.0	108.3	39.7	2.0	1.8	10.9%
Residential	1987	14705.8	4890.0	-21.1	-4.8	-1.4	-1.0	-7.3%
Alameda County WD	5	12779.0	3841.0	-83.6	-59.8	-6.5	-15.6	-18.5%
Burbank	76	2480.8	2250.0	-19.0	-10.7	-7.7	-4.7	-18.4%
Contra Costa WD	32	27624.0	10827.0	-15.1	-32.3	-0.5	-3.0	-2.1%
Eastern	87	24062.0	13778.0	-110.6	-47.8	-4.6	-3.5	-18.7%
EBMUD	333	69087.2	26627.0	-70.0	-19.8	-1.0	-0.7	-5.8%
Foothill	245	3408.1	2400.0	-7.8	-3.3	-2.3	-1.4	-10.2%
Glendale	109	2939.2	2100.0	-5.3	-2.6	-1.8	-1.2	-18.0%
Goleta	26	43183.2	18714.8	-32.6	-40.0	-0.8	-2.1	-3.3%
Inland Empire	186	3291.2	2665.2	-61.6	-52.9	-18.7	-19.8	-41.6%
LADWP	477	20974.1	7004.4	-25.4	0.3	-1.2	0.0	-5.5%
Pasadena	17	82335.9	44000.0	-353.6	-234.2	-4.3	-5.3	-8.5%
Santa Barbara	73	40637.6	22112.0	-90.2	-65.0	-2.2	-2.9	-14.7%
Santa Monica	71	2511.2	2400.0	5.7	1.1	2.3	0.4	3.9%
Santa Clara Valley	34	150631.9	8998.7	-694.9	7.2	-4.6	0.8	-8.1%
Sonoma County WA	7	140301.0	3307.0	-340.9	-47.1	-2.4	-14.3	-10.9%
San Diego County WA	401	5333.5	2400.0	-7.4	2.0	-1.4	0.8	-4.4%
Western	115	114775.8	26136.1	-44.2	-90.9	-0.4	-3.5	-1.0%

Impact of Pre-Installation Outdoor Water Use

As will be discussed in the modeling section, the single most significant factor influencing outdoor water savings at a site was the amount of excess irrigation prior to the installation of a smart controller. A site that historically applied twice the TIR clearly has more opportunity to reduce water use through installation of a smart controller than a site that historically applies 50% of the TIR. The modeling results presented later in this report assess the overall impact of the pre-installation application ratio on changes in use.

Table 54 shows the average water savings results for sites that applied 100% of the TIR or less prior to installation of a smart controller and for sites whose pre-installation TIR was greater than 100%. It is important to note that 47% of the study sites had an AR of 100% or *less* during the pre-installation period. The average pre-application rate for these under-irrigating sites was 19.9 inches. The average pre-AR for these sites was 55.2% and the average ΔAR was an increase of .089. Once the weighting of the differing irrigated areas was brought back into the analysis, the overall impact of smart controllers on the under-irrigators resulted in an average per site water use *increase* of 1.49 kgal.

About 53% of the study sites had an AR of *greater* than 100% during the pre-installation period. The average pre-application rate among these sites was 85 inches. The average pre-AR for these sites was 236.6% and the average ΔAR was a decrease of 0.353, which is over twice the reduction observed in the overall study group. Once the weighting of the differing irrigated areas was brought back into the analysis the overall impact of smart controllers on sites that were over irrigating prior to installation was an average per site water savings of 90.6 kgal.

The results shown in Table 54 show the impact of excess water use during the pre-installation period on water savings achieved through installation of a smart controller. The smart controllers installed in this study by and large performed as intended. Sites that historically irrigated less than TIR *increased* their application to come closer to an AR of 100%. Sites that historically irrigated more than TIR *decreased* their application. The data show that even after the installation, these historic over-irrigators were still applying more water as a group than was probably necessary in the post period, but savings rates may improve over time as the smart controllers are fine-tuned to better meet irrigation requirements.

Excess use in sites that over applied during the pre year (pre-AR > 100%) dropped by an average of -90.6 kgal as shown in Table 54, but a significant measure of savings was “left of the table”. When the excess use post-installation at these sites was analyzed it was found that on average 44.0% of the outdoor water use was in excess of the theoretical requirement for the site. The average per site excess use was 487.5 kgal compared to the average post-installation outdoor use of 1,108.3 kgal.

In sites that did not show excess use during the pre year (pre-AR < 100%), excess use during the post-installation period was not observed on average, even though outdoor water use in this group increased slightly.

Table 54: Comparison of Water Savings Results by Pre-Application Ratio and Excess Use Analysis

Statistic	Pre-Application Ratio <=100%	Pre-Application Ratio > 100%
N	1079	1215
N %	47.0%	53.0%
Irrigated area (sf)	30,819	26,225
Avg. Pre-Application Rate (in)	19.9	85
Avg. Post-Application Rate (in)	24.1	77.6
Avg. Pre-Application Ratio (%)	55.2%	236.6%
Avg. Post-Application Ratio (%)	64.1%	201.4%
Avg. ΔAR	0.089	-0.353
Avg. Weather-Normalized Change in Outdoor Use (kgal)	1.49	-90.6
% Change in Weather-Normalized Outdoor Use	0.43%	-7.8%
Avg. Post-Installation Outdoor Use (kgal)	361.4	1,108.3
Avg. Post-Install Excess Use (kgal)	-329.8	487.5
Post-Use that is Excess (%)	NA	44.0%

Performance by Smart Controller Brand

The data assembled in this project allow for a comparison of the performance achieved by each brand of controller installed at the study sites. Controller brands installed at fewer than 15 sites were not included in this analysis (the total number of sites in this category = 7). Controller brand names were made anonymous during the analysis process and were only exposed at the conclusion. This analysis does not attempt to adjust for factors shown to influence water savings such as differences in installation method. However, the water savings percentages are calculated as a percentage of pre-outdoor use, so the impacts of differences in area have been accounted for.[22]

In reviewing and comparing the performance of the controllers in this study it is important to keep in mind that water savings is only one evaluation measure. Another important evaluation parameter to consider is the post-application ratio (post-AR). A primary goal of smart irrigation technology is to reliably match the actual irrigation application to the theoretical irrigation requirement, (to achieve a post-application ratio of 1.0). Controllers that match actual applications to the theoretical requirement can be considered successful even if they do not reduce (or even increase) water use, because they are performing as designed.

[22] Earlier versions of this document presented the controller brand analysis in a different way, based upon a statistical model where ΔAR was the independent variable. Since the meaning of ΔAR is not broadly understood, it was decided to simply present the performance of each controller brand using the average per site water savings and to provide data on pre- and post-application rates and climate to help illustrate the findings.

Table 55 presents basic information on sites, water use, climate, application rates, TIR, and application ratios summarized for each controller brand. Recall that the theoretical irrigation requirement (TIR) is a measure of the water requirements during the pre- and post-installation periods. As shown in Table 55, the post-TIR was generally higher than the pre-TIR for most controller brands indicating that the average climate at these sites was a little hotter and drier during the post-installation period. The exception was HydroPoint/Toro/Irritrol. For that controller, the post-TIR was a little lower than the pre-TIR indicating that the average climate at the HydroPoint/Toro/Irritrol sites was a little cooler and wetter during the post-installation period.

All but one of the smart controller technologies evaluated in this study achieved a reduction in ΔAR on average. There are a number of ways to adapt irrigation applications to match prevailing weather conditions and this study found that the type of control technology, be it signal or sensor based, did not significantly impact savings levels. Within the sensor based systems, the device which achieved the greatest savings used an on-site solar radiation sensor plus a rain sensor.

The variability of the data and potential sources of uncertainty discussed earlier in this report suggest that a nuanced view of controller performance is required. Readers are cautioned against drawing too much from these results. The long-term field performance of smart controllers must be considered and studied and factors aside from water savings must also be weighed.

Table 56 presents the average weather-normalized change in per-site water use by controller brand and the confidence boundaries around this change along with the percent change this represents. All but one controller brand reduced per-site water use on average, but not all of these changes were found to be statistically significant.[23] Statistically significant reductions in weather-normalized per-site water use were found for only two brands – Accurate WeatherSet and ET Water.

Accurate WeatherSet controllers, developed and built by a small company based in Winnetka, California (part of Los Angeles), were the most successful technology at reducing average outdoor demands. Installed at 342 mostly residential sites mostly in southern California, the Accurate WeatherSet achieved an average weather-normalized per site savings of 50.5 kgal which represented a 33.2% reduction. Accurate WeatherSet calculates onsite ET based on data from onsite solar radiation sensor and also includes a rain shutoff device. Accurate WeatherSet works off the premise that solar radiation usually accounts for about 90% of ET and as result, the solar sensor tracks ET. Accurate WeatherSet also adds an eight-percent correction to the solar data.

ET Water Systems was the only other technology to achieve a statistically significant reduction in outdoor water use in this study. Installed at 94 mostly non-residential sites mostly in northern California, ET Water achieved an average weather-normalized per site savings of 185.4 kgal which represented a 6.2% reduction. ET Water uses a web-based interface that

[23] Statistical significance was calculated at the 95% confidence level for this analysis.

controls and monitors irrigation. The web interface collects site information, determines start times based on ET data from public and private weather stations, provides users with detailed watering history and tracks controller information. The ET Water system requires either a phone connection or internet connection between the controller at the site and the server computer, which manages the entire network of sites. Users are able to log onto the server using a password via the internet and monitor or modify the program at will.

Five other controller technologies achieved weather-normalized per site savings in this analysis, but these changes were not statistically significant at the 95% confidence level. With an increased sample size and additional years of data, it is possible that that statistically significant water savings may be achieved with these technologies.

The HydroPoint/Toro/Irritrol controller was the only technology that did not achieve any water savings in the analysis shown in Table 56. However, the persistence of savings - multi-year analysis (presented later in this report) evaluates the performance of smart controllers at over 380 sites. More than 90% of the controllers in this analysis were HydroPoint/Toro/Irritrol technology. By year three, the average water savings found in this group was approximately 16%. In this study, the first available year of post-installation data were used to perform the fundamental evaluation. The HydroPoint/Toro/Irritrol did not reduce demands on average in the first year, but the multi-year analysis indicates substantially improved performance over time.

Changes in water use are highly dependent on the pre-retrofit application ratio, a factor which the manufacturers had no control over (as this study was designed). A good example of this can be seen in the HydroPoint controller group that had a pre-AR of 1.06 and a post-AR of 1.13. Obviously, these controllers could not be expected to reduce the application rate much in this group of customers because the sites were already applying close to the TIR prior to installation. A similar situation existed for the ET Water Systems controllers. In this case the average pre-AR at ET Water sites was 1.03 and the average post-AR was 0.94, which was the closest to the target of 1.0 of all of the controllers in the study.

The potential for additional technologies to achieve statistically significant savings and the performance of the smart controllers over time (presented later in this report) highlight the importance of continuing to monitor the performance of these technologies. The sample developed for this study can have considerable value as additional data become available.

Table 55: Summarized data by controller manufacturer (area, application rate, TIR, AR, ΔAR)

Manufacturer/Brand	N	Avg. Area (sf)	Avg. Pre-Application Rate (in)	Avg. Post-Application (in)	Avg. Pre-TIR (in)	Avg. Post-TIR (in)	Avg. Pre AR	Avg. Post AR	ΔAR
Accurate WeatherSet	342	3,723	83.5	66.1	34.3	40.2	2.47	1.67	-0.80
Aqua Conserve	288	42,856	64.0	61.9	37.9	40.2	1.80	1.68	-0.12
Calsense	17	415,095	47.7	50.8	33.4	37.2	1.42	1.34	-0.08
ET Water	94	152,474	34.5	32.4	33.1	34.1	1.03	0.94	-0.09
Hunter	44	34,521	23.2	20.4	29.8	31.0	0.76	0.66	-0.10
HydroPoint/Irritrol/Toro	642	32,212	36.8	36.7	34.7	32.0	1.06	1.13	0.07
Rain Master	22	85,501	87.3	93.5	33.3	38.8	2.62	2.42	-0.20
Weathermatic	838	6,514	50.2	52.7	34.9	38.4	1.43	1.38	-0.05
All Sites	2287	28,386	52.3	50.3	34.9	36.8	1.51	1.37	-0.14

Table 56: Summarized data by controller manufacturer (weather-normalized change in use, % change in per site outdoor use)

Manufacturer/Brand	N	Avg. Weather-Normalized Change In Use (kgal)	Std. Dev. Weather-Normalized Change In Use (kgal)	95% Conf. Interval	Statistically Significant?	Avg. % Change in Outdoor Use
Accurate WeatherSet	342	-50.5	85.5	+ or - 9.1	Yes	-33.2%
Aqua Conserve	288	-159.4	1492.6	+ or - 172.4	No	-10.0%
Calsense	17	-1114.1	3043.2	+ or - 1446.6	No	-12.0%
ET Water	94	-185.4	810.0	+ or - 163.7	Yes	-6.2%
Hunter	44	-40.1	150.5	+ or - 44.5	No	-13.3%
HydroPoint/Irritrol/Toro	642	4.5	439.2	+ or - 34.0	No	0.5%
Rain Master	22	-270.5	853.7	+ or - 356.7	No	-6.9%
Weathermatic	838	-5.1	85.6	+ or - 5.8	No	-4.2%
All Sites	2287	-47.5	670.0	+ or - 27.5	Yes	-6.1%

Persistence of Savings – Multi-Year Analysis

The results for smart controller sites shown to this point compare a single year of pre-installation data against a single year of post-installation data.[24] While these results are encouraging and show that smart controllers can reduce weather-normalized outdoor use on average, the longer-term performance of smart controllers in the field is of critical importance. Do water savings persist over time after the installation of a smart controller? Do the water savings decay? These important issues must be addressed.

The data assembled by the research team allowed for only a limited examination of the persistence of water savings at smart controller sites. At the outset of the project it was thought that two or even three years of post-installation data would be available for many sites. When the research team examined the data sets provided, it was determined that a multi-year post-installation analysis would only be possible to complete for a smaller subset of smart controller sites, mostly located in southern California, primarily in the LADWP and Santa Monica service areas. Those results are presented below.

To conduct an analysis of the water savings achieved over more than one year, it was first necessary to identify the study sites for which sufficient data were available. From the 2,294 sites included in the overall impact analysis, the following data points were required for a site to be included in this analysis:

- One complete year of pre-smart controller installation water use data
- At least three complete years of post-smart controller installation water use data
- ET and rainfall data corresponding to the same period of time as the water use data.

All other necessary data, such as landscape area, were available for these sites to be included in the set of 2,294.

After reviewing the available water use and climate data it was determined that a reasonable sample size for this analysis could only be obtained if three years of post-installation data were used. Three years of post-installation data were available for 384 smart controller sites. The controllers included in this group were installed from 2002 – 2005, so data from years 2005 and 2006 represent year 1 and 2 for some controllers and year 2 and 3 for other controllers. Weather data were tagged to each customer and date based on location and billing data period as was done in the overall water savings analysis.

The results show that the controllers in this sample did better over time and in particular in the third year following installation. During post-installation year 1, weather-corrected percent change in water use increased by 6%. In year 2, the weather-corrected percent change water use showed a decrease 7.8% vs. the pre-install year. In year 3 the weather-corrected percent change in water use showed a decrease of 16.4% vs. the pre-install year. The key result of the multi-year analysis is presented in Figure 28. These results suggest that over the long

[24] The first complete year of post-installation water consumption data were used to conduct the analyses in this study.

term, water savings from smart controllers may actually improve, but additional research in this area is required to validate these findings.

A list of the controller technologies included in the multi-year analysis sample of 384 sites is presented in Table 57. HydroPoint/Toro/Irritrol controllers were installed at more than 90% of the sites in the multi-year sample so this analysis largely reflect the performance of this technology over time. Aqua Conserve accounted for 8% of the sites in this sample. A smattering of other controller technologies were also included as shown in Table 57.

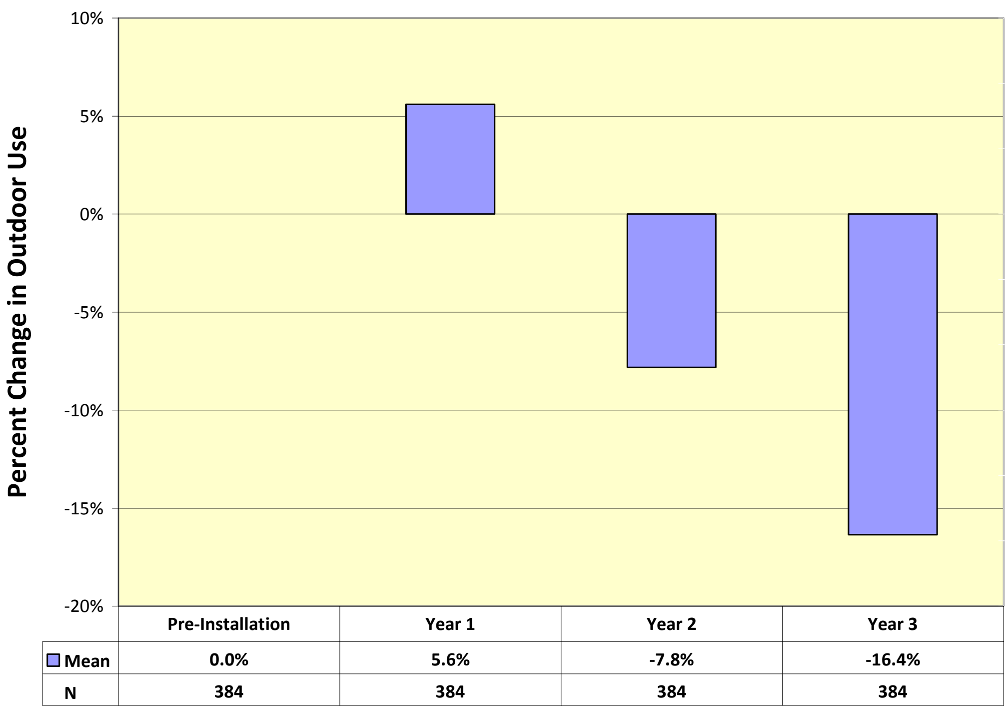

Figure 28: Weather-normalized percent change in outdoor for 3 years post-smart controller installation, n=384

Table 57: Smart controller technologies included in the multi-year analysis

Controller Brand	# of Sites	%	Avg. Area Per Site (sf)
Aqua Conserve	29	8%	59,366
Calsense	1	0%	225,626
ET Water	1	0%	32,000
HydroPoint/Irritrol/Toro	349	91%	7,796
Rain Master	4	1%	103,289
Total	384	100%	13,316

More data on the long-term performance of smart controllers is required. The DWR contract with the participating water agencies in northern and southern California specifies that post-installation water use must be tracked over a five-year period. The agencies in this study plan to continue to monitor the impacts of smart controllers over the coming years and to track the persistence and decay of water savings over that time. As many more controllers were installed that were not able to be included in this study, this offers an important opportunity to increase the sample size and further examine the impacts of smart controllers in the field.

Since much of the critical data on the study sites has already been obtained, long term monitoring of the water use at these sites should not be overly burdensome. The value of a sample of sites such as these, monitored over a period of five years is tremendous and offers an opportunity to evaluate the on-going performance of smart controllers that should not be missed.

Modeling Results from California Smart Controller Programs

Multiple regression analysis was used to determine the factors that did and did not influence changes in water use. Multiple regression analysis was also used to compare the performance of different smart controller technologies on a level playing field because factors that were shown to influence water use could be controlled for as much as possible. All analyses that involved a comparison of one or more factors or groups were completed through the multiple regression effort.

Multiple regression analysis allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and water savings estimates after adjusting for factors known to influence savings such as the application rate prior to installation of the smart controller.

Multiple regression models were developed using two approaches. First, bivariate relationships between water use and factors that might be associated were carefully examined. Where a significant relationship was observed, the factor was deemed appropriate for inclusion in a multiple linear regression model. Next multiple regression models on theoretical grounds using factors the researchers hypothesized could be influential on water savings. Ultimately, the model with the best fit was selected. Separate models were also developed for northern and southern California. The best-fit model for each region is presented in Appendix I.

A multiple linear regression model allows the simultaneous examination of the association of multiple factors with a single outcome measure of interest, often referred to as the dependent variable. In this instance, the estimated annual percent water savings per site was the dependent variable. The factors examined for an association with the dependent variable are referred to as independent or predictor variables. This simultaneous examination allowed researchers to look at a particular association of interest, for example the association of smart controller technology, simultaneously adjusted for all the other variables in the model.

Factors with p-values less than 0.05 were considered statistically significant, at the 95% confidence level.

The results of this analysis are based on mathematical models and other statistical tools that seek to find the center point of a large group of data, or a line that represents the best fit between two variables. Thus, by definition, there will always be data points above and below the values predicted by even the best models. Statistical models often give the impression of great precision, however in reality these models seldom predict water savings for any specific site very well, but if the fit is good they will usually predict water savings for a large group much better. From the perspective of any planning or policy study that deals with large groups, the ability to understand group dynamics (as opposed to individual dynamics) is the key to good decision making.

Factors that Influenced Water Savings

The following factors were examined and determined to have a statistically significant impact on the change in application ratio:

- Pre-smart controller Application Ratio – the pre-application rate relative to the calculated pre-theoretical irrigation requirement
- Installation method (self vs. professional)
- Participating agency (sometimes significant)

The multiple regression model presented here represents the best-fit multiple regression model. The independent variables in the model include the installation method (self vs. professional), participating water agency (LADWP used as referent[25]), and the pre-smart controller Application Ratio (pre-AR). The dependent variable was the Application Ratio change score – ΔAR. Fundamental information and statistics are presented in Table 58. Once constructed, this model was used iteratively to test the influence of other variables of interest.

Table 58: Model #1 summary statistics, coefficient of determination, and significance

R	R^2	Adjusted R^2	Std. Error of the Estimate	Degrees of Freedom	P-value
0.497	0.247	0.241	0.8150	2290	0.000

Predictors: (Constant), pre-AR, installation method, climate zone, water agency
Dependent variable: ΔAR.

The coefficient of variation (R^2) for the model is 0.247. This value indicates that this model explains 24.7% of the variability in the data. The P-value for the model is 0.00 indicating that whatever fit does exist is statistically significant at the 95% confidence level.

The unstandardized B coefficients (or beta coefficients) presented in Table 59 show the magnitude of the effect of the different independent variables in the model. Of particular interest are the coefficients for pre-AR and the installation method. Factors with p-values less than 0.05 were considered statistically significant, at the 95% confidence level.

A Bonferroni Correction procedure was applied to ensure fully robust comparisons of independent variables. In this case the procedure did not impact the findings of statistical significance. Factors that were highly significant remain significant after the Bonferroni

[25] Any agency could be used as a referent without impacting the overall results.

Correction. Factors that were not statistically significant are even less significant after implementing the Bonferroni Correction.

The pre-Application Ratio had a B coefficient of -0.283. This indicates that sites that over-irrigated during the pre-smart controller period were more likely to experience a reduction in water use. Sites with professional installation had a B coefficient of 0.187. This indicates that controllers that were professionally installed reduced water use less than sites that were self installed. Differences between climate zones was not statistically significant.

Agency variables were not included in the model for the purpose of comparing results between agencies. Rather, by including each agency as a variable, the model is able to correct for potential systematic differences between agencies. These differences could include: the manner landscape area was measured and the relative accuracy of that factor between agencies, differences in the accuracy of water use data, water rate structures and pricing, and differences in smart controller program implementation methodology. The agency variable is also a surrogate for the regional variable (northern or southern California) and the programmatic differences between the smart controller distribution efforts discussed in the process evaluation.[26] Correcting for potential systematic differences between agencies increases confidence if the findings related to other variables in the model. For example, the reliability of the difference found between residential and non-residential properties is improved by the fact that the model has corrected for potential differences between utility agencies. It was decided to include the agency factor at the recommendation of Dr. Tom Chesnutt of A&N Technical Services who reviewed early modeling efforts at the 2008 WaterSmart Innovations Conference. The team statistical consultant Dr. Peter Bickel concurred with the recommendation and it was decided to include the agency variable in all models developed for the study to correct for any potential systematic differences in the data provided by the agencies to the research team.

It should be noted that all of the beta coefficients in Table 59 are additive and provide a method to estimate the change in Application Ratio (ΔAR) for a given property. The generic equation including all of the statistically significant factors is in the form:

$$u = C_0 + B_1x_1 + B_2x_2 + B_3x_3 + B_4x_4 + B_5x_5 + \ldots$$

Where:

$u = \Delta AR$
C_0 = Constant
B_1 = B coefficient for pre-AR factor
x_1 = the pre-AR value for the site
B_2 = B coefficient for residential sites
x_2 = 1 if site is designated “professional install”, 0 if not
B_3 = B coefficient for Alameda County WD
x_3 = 1 is site is located in Alameda county WD, 0 if not
B_4 = B coefficient for Contra Costa WD
x_4 = 1 if site is located in Contra Costa WD, 0 if not
etc.

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[26] Region (northern or southern California) by itself was not found to be a statistically significant explanatory variable.

Table 59: Model #1 coefficients and significance of independent variables

Independent Variable	B*	Std. Error	t	P-value	P-value w/Bonferroni Correction
(Constant)	.237	.056	4.230	.000	.000
Pre AR	-.283	.014	-20.218	.000	.000
Professional install	.187	.049	3.792	.000	.000
Intermediate climate zone	-.041	.049	-.831	.406	7.308
Inland climate zone	-.011	.074	-.145	.884	15.912
ACWD	-.947	.367	-2.580	.010	0.18
Burbank	.028	.104	.273	.785	14.13
CCWD	-.214	.152	-1.407	.160	2.88
Eastern	-.229	.097	-2.364	.018	0.324
EBMUD	-.080	.057	-1.408	.159	2.862
Glendale	-.108	.090	-1.198	.231	4.158
Goleta	-.102	.167	-.610	.542	9.756
Inland Empire	-.472	.076	-6.233	.000	.000
Pasadena	.350	.203	1.719	.086	1.548
Santa Barbara	-.248	.107	-2.306	.021	0.378
Santa Monica	.481	.109	4.412	.000	.000
SCV	.768	.148	5.181	.000	.000
SCWA	-.167	.312	-.534	.594	10.692
SDCWA	.300	.058	5.189	.000	.000
Western	-.118	.092	-1.288	.198	3.564

Dependent variable: ΔAR.
*Unstandardized coefficient. Represents the magnitude of each independent variable in change in Application Ratio – AR; (negative = reduction)

Pre-Smart Controller Application Ratio. An important factor influencing water savings at the study sites was the level of over or under irrigation at the site before the installation of the smart controller. Sites that applied a lot more water than was theoretically required before the smart controller was installed tended to exhibit the biggest reductions. Sites that applied less water than was theoretically required before the smart controller tended to exhibit increases. The Pre-AR, which is the pre-smart controller Application Ratio, is a measurement of the application rate compared to the theoretical irrigation requirement. The bivariate and ANOVA analysis showed the pre-AR to be a statistically significant factor in predicting the level of water savings at a smart controller site. In other words, sites using more water than necessary to begin with were the most likely to reduce their water use after installation of a smart controller. This finding is perhaps not surprising, but is important to understand and appreciate when reviewing the modeling results below and when developing smart controller distribution programs with the goal of maximizing water savings. The pre-AR was included as an independent variable in all models developed in this research study.

Installation Method (Self vs. Professional). Two distinct installation methods were identified through this research – self installation and professional installation. Sites designated as "Self-Installed" indicate the customer was solely responsible for installing and programming the controller. However, at self-installed sites, the customer could easily have hired someone to perform these tasks without the knowledge of the agency or the evaluation team. Sites designated as "Professional/Utility" installed indicate that the controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer. This category includes sites where a landscape professional completed all aspects of the installation and sites where the customer physically mounted the clock and a utility representative inspected the installation, reviewed the program, and potentially made changes to the controller set up. Not enough information was available to the evaluation team to distinguish further between these installation methods.

As shown the in the Model #1 results above, the installation method of the smart controller was a statistically significant factor in explaining the change in water use. Controllers that were self-installed reduced water use more on average than sites that were professionally installed.

Participating Agency. The participating agency variable was sometimes found to be statistically significant in the model and sometimes not, as shown in Table 59. Since LADWP was used as the referent group in Model #1, the B coefficient represents the relative change in water use for the specified agency in comparison to LADWP. The selection of referent agency does not change the fundamental outcome of the model. Although the agency variable achieved statistical significance in a number of cases, it was included in the model because of the researcher's desire to account and correct for any potential systematic differences in the provision of data from different agencies. These differences could include: the manner landscape area was measured and the relative accuracy of that factor between agencies, differences in the accuracy of water use data, differences in rates and rate structures, and differences in smart controller program implementation methodology. The agency variable is also a surrogate for the regional variable (northern or southern California) and the programmatic differences between the smart controller distribution efforts discussed in the process evaluation. Correcting for potential systematic differences between agencies increases confidence if the findings related to other variables in the model. For example, the reliability of the difference found between residential and non-residential properties is improved by the fact that the model has corrected for potential differences between utility agencies.

Smart Controller Manufacturer. Differences if the water savings achieved between smart controller products were estimated in this study. These differences were not statistically significant for any controller brand. A detailed analysis and explanation of the comparison of water savings by controller manufacturer is presented below. Great care was taken to try and level the playing field as much as possible for these comparisons, but because the statistical models constructed for this study only explain about 25% of the variability in savings, it is simply not possible to fully correct for all influencing factors. Nevertheless, the results presented in this report do show that some differences in controller performance were measured. Nearly all the controller brands included in this study succeeded in effecting weather-normalized water savings. The results of this study show that as a whole, smart controllers do reduce irrigation applications. The specific technology employed and controller manufacturer is less important to achieving water savings than installing the device at a site where an excess of irrigation water has been historically applied.

As discussed in the analysis below on factors that did not influence water savings, the type of control technology (on-site sensor, historic ET, remote data signal, soil moisture sensor) did not impact water savings. Neither did the ET climate zone where the controller was installed, nor the installation method (self vs. professional).

Factors that Did Not Influence Water Savings

The following factors were examined and determined not to have a statistically significant impact on the change in application ratio through the regression analysis:

- Site classification (residential vs. non-residential)
- Region (northern vs. southern California)
- Climate zone (coastal, intermediate, inland)
- Smart irrigation control methodology (historical ET, on-site readings, remote readings, soil moisture sensor)
- Landscape area

Site Classification (Residential vs. Non-Residential). The classification of a smart controller site as residential or non-residential was not a statistically significant factor in explaining the change in water use. Residential and non-residential sites both reduced water use by a similar amount as shown in Table 48 with residential sites having a weather-normalized percent change in irrigation application of -14.5% and non-residential sites having a change of -15.4%.

Region (northern vs. southern California). The regional location of a study site in either northern or southern California was not a statistically significant factor in explaining the change in water use after installation of a smart controller. Including this factor did not improve the fit of any of the models examined, hence it was excluded from the model presented in earlier in this section.

Climate Zone (coastal vs. intermediate or inland). Smart controller study sites were placed into three distinct ET climate zones based upon the location of the CIMIS station from which climate data were obtained. Stations located in CIMIS zones 1, 2, or 3 were designated as coastal. Stations located in CIMIS zones 4, 5, or 6 were designated as intermediate. Stations located in CIMIS zones 7 or higher were designated as inland. A map of California showing the different CIMIS ET zones is provided in Appendix C.

Water savings in the intermediate and inland climate were greater than in the coastal zone after correcting for agency and the level of over irrigation prior to installation, but the result was not statistically significant.

Smart Irrigation Control Methodology. Statistically, none of the different irrigation control methodologies stood out in terms of water savings. The smart controllers installed for this study used one (or a combination) of four methodologies to adapt irrigation run times to meet prevailing weather conditions. These methodologies were distinguished into the following four categories for analysis:

- On-site data (temperature, precipitation, humidity or other factors measured locally)
- Remote data (signal broadcast to each smart controller from remote source)
- Historical data (locally adjusted ET curve pre-programmed into each smart controller)
- Soil moisture sensor (local measurement(s) of soil moisture levels)

Detailed information about the irrigation control methodologies of the controllers installed in this study is provided in Appendix A. Some smart controller products utilize more than one methodology and were included in multiple categories.

Four separate multiple regression models were constructed to examine the impact of each control methodology separately. The multiple regression models used to examine control methodology included corrections for the Application Ratio during the pre-installation year and for the utility agency from which all relevant data were obtained. None of the four was found to have a statistically significant impact on water savings compared to each other. These results are summarized in Table 60. In all cases the adjusted coefficient of determination (R^2) of the models was 0.547, indicating that the model explains only 54.7% of the variability in the data. The P-value for the model is 0.00 indicating that whatever fit does exist is statistically significant at the 95% confidence level.

Table 60: Smart irrigation control methodology modeling results

Control Methodology	N*	p-value	Statistically Significant?	Overall Model R^2 & p-value**
On-site data	1883	0.633	No	0.547 & 0.000
Remote data	758	0.983	No	0.547 & 0.000
Historical data	327	0.607	No	0.547 & 0.000
Soil moisture sensor	17	0.552	No	0.547 & 0.000

*Some controllers utilize more than one methodology
**A value less than 0.05 indicates statistical significance

Landscape Area. When included as a dependent variable, the landscape area at each site did not improve the fit the of any model where ΔAR was the independent variable. This result is not unexpected given that the calculation of ΔAR involves reducing the influence of area by dividing by the landscape area to calculate both the pre and post-application rate.

Intrinsically, landscape area should not impact the ability of a smart controller to achieve an accurate application ratio or to impact how an installer programs the controller. Area is not a programming parameter for any controller that was studied in this project. Rather, irrigation schedules are typically developed based on a variety of factors such as plant material, precipitation rate, sprinkler type, soil, historic ET, and other landscape characteristics. The model residuals were also examined in relationship to landscape size to test for heteroscedasticity, and this was not found to be an issue with this data set.

Customer adjustments to smart controller after installation. In the customer satisfaction survey, respondents were asked if they made changes to their smart controller after installation. Survey responses from 625 smart controller sites were able to be linked to the water use and savings database enabling the researchers to construct statistical models to examine this and other questions. A total of 96 respondents who indicated that they did make adjustments to their controller after installation were compared against those that did not via the multiple regression procedure described earlier. The model used to examine customer changes to controller programming included corrections for Application Ratio during the pre-installation year. Respondents who indicated that they did change the programming had a lower estimated water savings (i.e. saved less water), but the p-value was 0.391 indicating the finding is not statistically significant at the 95% confidence level.

Repairs to the irrigation system during or after installation of smart controller. Repairing irrigation systems did not result in statistically significant water savings. In the customer satisfaction survey, respondents were asked if they had made changes to their irrigation system at the time the smart controller was installed and then again if any changes had been made to the system in the year since the smart controller was installed. The survey instrument (presented in Appendix E) provided a list of 15 different changes that could have been made to the irrigation system including things such as repairing broken heads, capping unnecessary heads, repairing leaks, eliminating over spray, repairing valves, changing heads, removing zones, etc.

More than 30 separate multiple regression models were constructed to test the impact of each possible response individually. The models constructed to examine changes to the irrigation system included corrections for the Application Ratio during the pre-installation year. In *none* of the models did the change to the irrigation system result in a statistically significant change in the estimated water savings. The changes were also tested in aggregate to determine if respondents who made any change whatsoever to their irrigation system during or after installation of the smart controller saved additional water. Again, no statistically significant change in water savings was found. For the sake of brevity, the details of these models are not presented in this report.

Sensitivity Analysis

Sensitivity analysis can be used to examine how the variation or uncertainty in the output of a mathematical analysis can be apportioned. In this study there are three primary data inputs used to estimate changes in water use. These data inputs are:

1. Water consumption data from billing records
2. Landscape area data (various sources)
3. Climate data - ET and precipitation from CIMIS

Water consumption data were provided by the water agencies and are essentially immutable. There could be errors in these data, but there is no way to find or determine what they are or the magnitude of their effect. Investigating these data beyond the hypothetical questions raised is beyond the scope of this study. It should be noted that the research team has made every effort to assure the quality and integrity of these data through the analytic process.

Landscape area data were provided by each participating agency. Methods for measuring the landscape area varied by agency and in many cases information about the measurement method utilized was not provided to the analysis team. Since landscape area was fundamental to the analytic approach of the study, the analysis team moved forward with the data provided. Like the water use data, the landscape area data are immutable and not subject to interpretation. Future researchers may wish to refine landscape area measurements which may improve overall accuracy of the results, but it was beyond the scope and budget of this study to independently verify the landscape area data provided.

Of the three key data inputs, only climate data offers a real opportunity to investigate the impact of analytic assumptions in the study. Specifically, these analytic assumptions are (1) the calculation of effective precipitation; (2) the selection of landscape coefficient (K_c) value of 0.8 used to formulate the theoretical irrigation requirement (TIR). Please see the Research Methodology chapter for a more complete explanation of these terms including the formulae.

The impact of these assumptions can be tested as part of a sensitivity analysis by changing the theoretical irrigation requirement (TIR). The researchers considered two alternative values for the TIR for this exercise:

Sensitivity Test #1:
Theoretical Irrigation Requirement (TIR) = ETo

ETo in Sensitivity Test #1 means the gross ETo values obtained from CIMIS. Precipitation is not deducted and no landscape coefficient is applied. This *increases* the magnitude of the TIR value during both the pre- and the post-installation years. As shown below, the impact of this assumption is to *reduce* the overall changes in application ratio measured.

Sensitivity Test #2:
Theoretical Irrigation Requirement (TIR) = (ETo*K_c) – effective $precip_{(v2)}$

In Sensitivity Test #2, an alternative method for calculating the amount of effective precipitation is used in which a maximum of 50%, rather than 25%, of the total precipitation considered effective, but values vary by region. For comparison, in the primary analysis presented in this study, an average of 23% of the total precipitation was considered effective. In Sensitivity Test #2, this *decreases* the magnitude of the TIR value during both the pre- and the post-installation years. A similar decrease to the TIR would be achieved by changing the value of K_c from 0.8 to 0.7 as is proposed for the new California Model Landscape Ordinance. In Sensitivity Test #2, the average and median TIR values in this method don't show a big difference from the primary methodology, but the distribution of values between sites is different enough to an effect a significant difference in the overall water savings measured. As shown below, the impact of this assumption is to *increase* the change in application ratio measured.

These two sensitivity tests examine the impact of the theoretical irrigation requirement assumptions by both increasing and decreasing its magnitude to virtually the maximum and minimum that could be deemed reasonable under any rational analytic approach. The research team and the project advisory committee chose the approach method presented because it offered a balance between the two extremes presented in the sensitivity analysis. A comparison of the sensitivity analysis findings is shown in Table 61.

The percent change in application ratio shown in Table 61 is the key finding from the sensitivity analysis. In Sensitivity Test #1, increasing the theoretical irrigation requirement results in a reduction of the estimated overall reduction in ΔAR to -10.9% across all study sites. In Sensitivity Test #2, decreasing the theoretical irrigation requirement results in an increase in the estimated ΔAR to -16.5% across all study sites.

Table 61: Comparison of sensitivity analysis findings

Analysis	Parameter	Mean	Median	Std. Dev.	N
Primary	TIR Pre (inches)	34.9	34.9	5.2	2294
TIR = (ETo*0.8) - eff. Precip	TIR Post (inches)	36.8	36.8	6.4	
eff. Precip ~ 23% of total	% Change in ΔAR	-0.145	-	0.935	
Sensitivity Test #1	TIR Pre (inches)	37.1	37.0	4.8	2294
TIR = ETo	TIR Post (inches)	39.6	38.8	5.1	
eff. Precip ~ 0% of total	% Change in ΔAR	-0.109	-0.127	0.838	
Sensitivity Test #2	TIR Pre (inches)	31.8	31.1	8.8	2294
TIR = (ETo*0.8) - eff. Precip.	TIR Post (inches)	33.9	35.4	6.2	
eff. Precip ~ 50%	% Change in ΔAR	-0.165	-0.235	2.467	

Most significantly, the sensitivity tests show that even with a different methodology for calculating the theoretical irrigation requirement, the key study findings of water use savings through installation of smart controllers is not altered. The magnitude of the savings estimates changes depending up how precipitation is included in the weather correction, but reductions in ΔAR (and consequently water savings) will be found under any reasonable calculation of the theoretical requirement. The research team believed that the primary analysis methodology chosen for this study, which happens to fall squarely in between the two sensitivity tests shown here, was the most objective, horticulturally appropriate, and scientifically valid approach. That is why the analysis presented in this report focused on that calculation of the theoretical irrigation requirement. The sensitivity analysis shows that other approaches were considered and evaluated as well and also resulted in an overall finding of water savings accomplished by the California smart controller programs.

Cost-Effectiveness Analysis

Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product.

In this study, which spanned four years, included multiple smart controller technologies, and involved nearly 30 water utilities, it was simply not feasible to conduct a traditional benefit-cost analysis for all possible conditions. Neither the full costs nor the full benefits of smart controller programs was adequately measured by any party. What was possible was to use the water savings measured through this evaluation study to develop a series of cost-effectiveness analyses with the goal of determining the level of investment (or expenditure) that could be justified for the purpose of providing incentive and purchasing a smart controller.

The cost-effectiveness analysis was developed to examine both the utility and customer perspectives on the purchase and installation of smart controllers. No attempts were made to present the costs of purchasing, installing, and maintaining a controller. Although some retail controller price information (from 2007) is presented in Appendix A, the actual price paid by utilities and customers was only provided to the research team for a limited set of study sites. Utility costs for implementing the program are extremely difficult to account for. Since this was a pilot effort with several changes of course, the agency costs are really not representative of what could be expected for a utility with a fresh start seeking to implement a program today, equipped with the information and guidance provided in this report. Cost-effectiveness analysis would normally extend to social costs like reduced runoff and non-point source pollution, but as data on runoff and pollution were not collected in this study these elements could not be included in this analysis.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. For the customer perspective, cost-effectiveness analysis was used to determine the level of investment it would be reasonable for a customer to make in a smart controller given the anticipated water and cost savings achievable through installation of the device.

Cost-Effectiveness: Utility Perspective

For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study and the marginal annual cost the utility pays for water. In other words, the cost-effectiveness analysis offers an estimate of the amount of money a utility might consider offering as an incentive to randomly selected customers given their avoided annual marginal costs for new water, the smart controller program methodology to be employed, the screening process to focus on over-irrigators, and the anticipated per customer water savings.

In determining which avoided costs to use the utilities should determine the cost for the most expensive water supply (the marginal cost) that they pay for water. Many systems have many different costs for various water supplies. Savings in water use will generally come from the last, and presumably the most expensive water supply. Thus the savings to the utility should be bases on costs for their marginal water supplies; not average costs.

The cost-effectiveness analysis was constructed using the average per customer water savings estimated for all sites with four different landscape areas (4,000 sf, 12,000, 25,000, sf, and 150,000 sf). These areas encompass the range of residential and non-residential landscapes found in northern and southern California and elsewhere. While not specifically designated as residential and non-residential analysis, the smaller landscape sizes are more typical of residential properties and the larger landscape sizes are more typical of commercial and dedicated irrigation properties. In reviewing these tables it should be kept in mind that if the customers had been selected from just the over-irrigators the per site water savings would approximately double (from 1.67 gpsf in the overall group to 3.45 gpsf in the over-irrigators.) This would proportionally increase the savings and benefits for both the utility and the customer.

The basic assumptions and parameters for the cost-effectiveness analysis are presented in Table 62. The mean water savings were considered. A range of values for the avoided annual cost of water were considered. Many different utility agencies participated in this study and since each agency may have their own calculated avoided cost for water, the cost-effectiveness analysis considered a broad range of values. The avoided annual cost of water for the California agencies in this study ranges from approximately $100/acre-foot up to $1,000/acre-foot. For many agencies in other parts of the country the avoided cost for water can be as high as $5,000 per acre-foot in extreme cases. Since it is anticipated that this study will be of interest outside of California, the range of avoided cost values was expanded up to this very high range. The discount rate for present worth analysis was assumed to be 3% in all cases. The expected useful life of a smart controller is estimated at 10 years, so that was the length of time used for the cost-effectiveness calculations.

Table 62: Analysis parameters for utility perspective cost-effectiveness calculations

Landscape Area (sq ft)	Annual Water Savings Per Site (AF)[1]	Avoided Cost Range Considered ($/AF/Yr)	Discount Rate	Duration of Water Savings (years)
4,000	-0.020	$100 - $5,000	3%	10
12,000	-0.060	$100 - $5,000	3%	10
25,000	-0.127	$100 - $5,000	3%	10
150,000	-0.763	$100 - $5,000	3%	10

Note [1] These are water savings for the general population of the study. Water savings for the over-irrigators are twice the amounts shown in the table.

Results for the utility perspective cost-effectiveness analysis are presented in Table 63. Four different per site water saving values were considered against a broad range of utility avoided annual cost values. To determine the estimated amount of cost-effective investment per site a utility should make in a smart controller program, select the appropriate avoided annual cost of water in Table 63. Next select the average landscape size to be targeted. Table 63 provides the net present value of the anticipated water savings over the 10-year useful life of the smart controller product, which is the amount of money it would be cost effective for the utility to offer as an incentive to achieve that level of water savings. If the utility is able to screen for just customers that are over-irrigating then the net savings in the table should be doubled.

For example, a water utility with an avoided annual cost for water of $150/acre-foot that implements a smart controller program aimed at the residential sector and small landscapes (~4,000 sf) would likely achieve cost-effective water savings for a per-site incentive of up to $26. If the same agency implemented a program aimed at large landscapes (~25,000 sf), a $164 incentive would likely result in cost-effective water savings. If the same program were run for over-irrigators the savings for the 4000 sf site would be $52 and for the 25,000 sf site they would be $328.

Utilities with higher avoided marginal costs for water will find smart irrigation control technology to be a cost effective method of reducing demand in new and existing customers. At an avoided annual marginal cost of $1,000 per acre-foot a utility could provide nearly a $500 per site incentive for sites averaging 12,000 sf in size, or $1000 per site for customers drawn from over-irrigators. The economics of smart controller incentives will differ between water agencies. But if average water savings as found in this study are achieved, then many utility programs that encourage smart control technology will be cost effective, especially if they are targeted to over-irrigators.

Table 63: Results for utility perspective cost-effectiveness analysis

Utility Avoided Cost for Water ($/AF/Yr)	Net Present Value of Water Savings Per Site (general population)			
	Area = 4,000 sf	Area = 12,000 sf	Area = 25,000 sf	Area = 150,000 sf
$100	$18	$53	$109	$656
$150	$26	$79	$164	$985
$200	$35	$105	$219	$1,313
$250	$44	$131	$274	$1,641
$300	$53	$158	$328	$1,969
$350	$61	$184	$383	$2,298
$400	$70	$210	$438	$2,626
$450	$79	$236	$492	$2,954
$500	$88	$263	$547	$3,282
$550	$96	$289	$602	$3,611
$600	$105	$315	$656	$3,939
$650	$114	$341	$711	$4,267
$700	$123	$368	$766	$4,595
$750	$131	$394	$821	$4,924
$800	$140	$420	$875	$5,252
$850	$149	$446	$930	$5,580
$900	$158	$473	$985	$5,908
$950	$166	$499	$1,039	$6,237
$1,000	$175	$525	$1,094	$6,565
$1,250	$219	$656	$1,368	$8,206
$1,500	$263	$788	$1,641	$9,847
$5,000	$875	$2,626	$5,471	$32,825

Cost-Effectiveness: Customer Perspective

For the customer perspective, cost-effectiveness analysis was used to determine the level of investment it would be reasonable for a customer to make in a smart controller given the anticipated water and cost savings achievable through installation of the device. In other words, the cost-effectiveness analysis offers an estimate of the amount of money a customer might consider spending to purchase and install a smart controller given the top rate they pay for water on their utility bill and their potential water savings.

The cost-effectiveness analysis was constructed using the average per customer water savings estimated for sites with four different landscape areas (4,000 sf, 12,000, 25,000, sf, and 150,000 sf). These areas encompass the range of residential and non-residential landscapes found in northern and southern California and elsewhere. While not specifically designated as residential and non-residential analysis, the smaller landscape sizes are more typical of residential properties and the larger landscape sizes are more typical of commercial and dedicated irrigation properties.

Fundamental assumptions for the cost-effectiveness analysis are presented in Table 64. Since many different utility agencies participated in this study and because each agency has their own water rate structure and schedule of charges, the cost-effectiveness analysis considered a broad range of values. The cost per hcf of water ranged from $0.50/hcf up to $12/hcf in an effort to provide useful information for a broad range of customers and utility agencies in California and beyond.

Table 64: Analysis parameters for customer perspective cost-effectiveness analysis

Landscape Area (sq ft)	Water Savings Per Site (hcf)	Range of Retail Water Costs Considered ($/hcf)	Discount Rate	Duration of Water Savings (years)
4,000	-8.9	$0.50 - $12.00	3%	10
12,000	-26.8	$0.50 - $12.00	3%	10
25,000	-55.9	$0.50 - $12.00	3%	10
150,000	-335.4	$0.50 - $12.00	3%	10

The basic assumptions and parameters for the cost-effectiveness analysis are presented in Table 64. The mean water savings from the study applied across a variety of landscape sizes. A range of values for the retail cost of water was considered. Many different utility agencies participated in this study and since each agency has their own unique water rates and rate structure, the cost-effectiveness analysis considered a broad range of values. The retail cost of water for outdoor use (typically block 2 and higher in an increasing block rate structure) at the California agencies in this study ranges from approximately $1.50/hcf up to $9/hcf. For agencies in other parts of the country the retail cost of irrigation water may be lower or higher. Since it is anticipated that this study will be of interest outside of California, a wide range of retail irrigation water costs were considered from $0.50/hcd up to $12.00/hcf. The discount rate for present worth analysis was assumed to be 3% in all cases. The expected useful life of a smart controller is estimated at 10 years, so that was the length of time used for the cost-effectiveness calculations.

Results for the customer perspective cost-effectiveness analysis are presented in Table 65. Four different per site water saving values were considered against a broad range of retail water cost values. To determine the estimated amount of cost-effective investment a customer should make to purchase a smart controller, select the appropriate retail cost for water in column A in Table 65. Next select the approximate landscape size of the site. Table 65 provides the net present value of the anticipated water savings over the 10-year useful life of the smart controller product, which is the amount of money it would be cost effective for the customer to spend to purchase, install, and maintain the smart controller to achieve that level of water savings.[27]

Table 65: Results for customer perspective cost-effectiveness analysis

Retail/Customer Marginal Cost for Water ($/hcf)	Net Present Value of Water Savings Per Site (general population)			
	Area = 4,000 sf	Area = 12,000 sf	Area = 25,000 sf	Area = 150,000 sf
$0.50	$38	$114	$238	$1,431
$1.00	$76	$229	$477	$2,861
$1.50	$114	$343	$715	$4,292
$2.00	$153	$458	$954	$5,722
$2.50	$191	$572	$1,192	$7,153
$3.00	$229	$687	$1,431	$8,584
$3.50	$267	$801	$1,669	$10,014
$4.00	$305	$916	$1,907	$11,445
$4.50	$343	$1,030	$2,146	$12,875
$5.00	$381	$1,144	$2,384	$14,306
$5.50	$420	$1,259	$2,623	$15,737
$6.00	$458	$1,373	$2,861	$17,167
$6.50	$496	$1,488	$3,100	$18,598
$7.00	$534	$1,602	$3,338	$20,028
$7.50	$572	$1,717	$3,576	$21,459
$8.00	$610	$1,831	$3,815	$22,890
$8.50	$649	$1,946	$4,053	$24,320
$9.00	$687	$2,060	$4,292	$25,751
$9.50	$725	$2,175	$4,530	$27,181
$10.00	$763	$2,289	$4,769	$28,612
$10.50	$801	$2,403	$5,007	$30,043
$11.00	$839	$2,518	$5,246	$31,473
$11.50	$877	$2,632	$5,484	$32,904
$12.00	$916	$2,747	$5,722	$34,334

[27] This analysis does not consider convenience or improved landscape health or any other non-monetary benefit that a customer might reasonably experience as a result of installing a smart controller.

For example, a residential customer with a 4,000 square foot landscape who pays $3/hcf for irrigation water who achieves average water savings with a smart controller would be justified in spending up to $229 to purchase, install, and maintain a smart controller over the 10-year expected life of the product. A customer with a 12,000 square foot landscape who pays $2/hcf for irrigation water would be justified in spending $458 on a smart controller. These results indicated that customers who achieve average water reductions can realize cost-effective savings from installing a smart controller if the retail cost for water is high enough.

Uncertainty and Cost-Effectiveness Analysis

Each water utility is unique. Each utility normally has its own distinct avoided cost for water and system of water rates and charges, developed over many years through complex processes. In water conservation planning, each utility may place a different value on conserved water. This poses challenges for developing cost-effectiveness analysis for smart controllers that will be broadly applicable across the diverse range of utility agencies that participated in this study and the even large group that may utilize the results. It is most likely that utilities will use the water savings and percentage decrease estimates from this study and apply them to their own cost-effectiveness models. However, the research team was able to develop an approach to cost-effectiveness analysis that provides information for a broad range of agencies and systems of rates and charges.

The cost-effectiveness calculations in this study have been simplified so that they can be utilized by as many water agencies as possible. This analysis should be viewed as providing solid range to the level of investment a utility or customer could place in a smart controller technology that can be economically justified given the stated assumptions of a 3% discount rate and a 10-year useful life of the product.

The water savings measurements obtained in this study can be easily adapted into local cost-effectiveness models to determine what level of program investment might be justified. For most agencies this will be a preferred approach and nothing but a specifically utility-tailored cost-effectiveness analysis would suffice. The California Urban Water Conservation Council has developed tools to assist water utilities in conducting cost-effectiveness analysis for conservation programs and measures. The results from this study should provide useful input for those tools that can be used to tailor cost-effectiveness calculations to meet specific water agency situations.

Additional Benefits Not Considered

Water utilities may wish to promote and install smart irrigation control technology for other reasons besides potential water and cost savings. For water utilities, smart irrigation control offers a number of potential additional benefits including:

- Reduced runoff from urban landscape
- Adaptation of customer demands to calculated water budget allotments
- Potential for peak demand reduction (through coordinated irrigation “brown outs” similar to energy utility peak shaving)

- Improved health and condition of urban landscapes through more proper irrigation applications

For customers and end users, smart controllers offer some of the same potential benefits, but also a few others.

- Convenience – many participants in this study reported enjoying the convenience associated with smart control technology.
- Improved landscape appearance and health. Applying the proper amount of water usually improves landscape quality.
- Better feedback about other problems with the irrigation system. Many smart controllers offer diagnostic tools not available on traditional controllers. Applying the proper amount of water to a zone often reveals distribution uniformity problems that may have been masked by excess application in the past.

This study has shown that smart controllers are cost-effective from both the utility and customer perspective under many (but not all) conditions. The potential benefits listed above suggest that there are additional reasons why this technology may be adopted by both water utilities and customers alike. It is also clear that targeting smart controllers at large sites that have traditionally applied an excess of irrigation water maximizes the benefits of smart control technology for both utilities and customers. The "biggest bang for the buck" lies in identifying excess irrigators and convincing them to adopt smart control technology. Other approaches may save water, but are likely to be significantly less cost-effective.

CONCLUSIONS AND RECOMMENDATIONS

The California Prop. 13 Smart Controller programs are the largest scale efforts to date to distribute and evaluate the impacts of weather-based irrigation control technology, commonly known smart controllers. The evaluation research described in this report provides strong evidence for the following conclusions:

- Weather-based "smart" irrigation controllers, while a valuable tool, are not a "magic bullet" for achieving perfect irrigation control and water savings.
- On average smart controllers are a moderately effective measure for reducing the amount of water applied by automatic irrigation systems, while maintaining the health, and appearance of landscapes.
- When seeking irrigation water savings, the pre-existing level of excess irrigation at the site is the most important factor to consider.
- The water savings achieved through installation of smart controllers can be maximized by targeting the technology to irrigators with historically high irrigation application rates, not simply customers with high irrigation use.
- The many irrigators who historically apply less than the theoretical irrigation requirement for their landscape are likely to *increase* their irrigation application rate after installing a smart controller.
- Survey results indicate that smart controllers are likely to achieve a high degree of customer acceptance once they more broadly penetrate the consciousness of irrigation contractors and the general public.
- The utility programs implemented through the DWR grant have succeed in raising public awareness of this technology, but survey results suggest most consumers have no knowledge of smart irrigation control.
- Smart controllers can achieve cost effective water savings for utilities and irrigators under some cost and pricing scenarios, however this technology will not be cost effective for all utilities and customers.
- Most of the smart control brands and technologies evaluated in this study reduced irrigation demands on average, but not all of these reductions were statistically significant.

These essential findings from this study are discussed in detail in the sections below along with other conclusions drawn from the data analysis. Conclusions and recommendations from the process evaluation and the impact evaluation are presented in separate sections followed by a brief summary.

Conclusions and Recommendations - Process Evaluation

The process evaluation was conducted to measure customer satisfaction with smart controller products and smart controller distribution programs and to examine participating agency program implementation methods, results, successes and lessons learned.

Southern California Smart Controller Programs

The Southern California Smart Controller Programs were made up of a large number of distribution programs developed and implemented by the more than 20 water agencies. To date, 4,629 controllers have been installed through the southern California Smart Controller Programs portion of the DWR grant. This represents 83.9% of the original installation projection.

MWD's member agencies invested significant time and resources to implement and market their programs and tried various approaches and made mid-stream adjustments because of lack of participation. It was originally thought that agencies would develop their own smart controller distribution programs, but MWD quickly recognized that some of the agencies in MWD's service area did not have the resources to develop a program. Ultimately three fundamental smart controller distribution program methodologies were implemented in southern California: (1) rebate and voucher programs, (2) exchange programs, and (3) direct installation.

Rebate and Voucher Programs – Utilities offered a financial incentive ranging from $50 to the full cost of a smart controller to encourage installation of smart controller technology. Installation was typically not included as part of a rebate program, but a number of agencies offered training programs to assist customers with proper installation. In addition, lists of trained and knowledgeable installers were provided. Rebate and exchange programs are generally the least expensive to implement for a water agency, but are not necessarily the least labor intensive. Rebate programs are typically open to any customer with an automatic sprinkler system, although some targeting to higher use customers is possible.

There are some basic challenges associated with smart controller rebate programs: 1) Attracting participants; 2) Product is often not available in retail outlets; and 3) Free-riders. A number of southern California agencies that implemented a rebate program had difficulty publicizing the program and attracting participants. Smart controllers are a new technology and most customers are simply not aware of what they are and what they can do. It is often difficult for an agency to effectively market a rebate program in this situation. Once this technology gains in popularity and reaches deeper into the consciousness of irrigation contractors and the general public, then it should be much easier for an agency to attract participants to a rebate program. Free-riders can be a problem with any rebate program. When promoting a new and largely unknown technology such as smart controllers the problem of free-riders is likely to be much smaller than with a toilet or clothes washer rebate program.

Exchange Programs. Exchange programs offered a free (or substantially subsidized) smart irrigation controller to customers who brought in their old conventional controller. Some exchange events were offered in conjunction with a training class where participants were taken through exercises with the new controller to help familiarize them with the technology and to demonstrate the differences from the old controller. In some cases the exchange was integrated into the Protector Del Agua (PDA) landscape classes offered in southern California. In other cases, separate controller exchange events were organized.

One of the chief benefits of the exchange event concept over a rebate or give-away program is that it increases the likelihood that the new smart controller will be installed quickly because irrigation systems cannot function without a controller. The exchange programs proved to be public relations successes for the agencies as customers received free equipment directly from agency staff. Controller exchanges were also popular events with the public.

Exchange programs were successful at achieving water savings – even though the controllers were typically installed by a customer who had only limited training and experience. These programs provided training in installation and programming to customers and were comparatively inexpensive to implement (on a per controller basis). A hybrid exchange program that targets high demand customers and then distributes controllers with the low cost and ease of implementation of an exchange event could be an option to explore.

Direct Installation Programs. Direct installation programs identify a set of customers to solicit to participate and then the agency either hires a contractor to perform the installations (and other services) or does the installation work with its own staff. Typically the controller and installation is offered for free in this program model. These programs are expensive, as the utility must bear the cost of the hardware and the labor, but high water use customers can be readily targeted and water savings maximized. Direct installation programs can be cost effective under the right set off circumstances, but utilities with limited program budget availability should consider a different approach.

In the southern California smart controller programs, 57.6% of the controllers were residential self-installations from a rebate or exchange event program. 19.7% of the controllers were residential direct-installations, 14.1% were commercial direct-installations, and 8.6% were commercial self-installations. Among the non-residential participants, approximately 60% received their controller through a direct installation program and 40% through a rebate or voucher. Among the residential participants, 70% received their controller through a free distribution program, 25% through direct installation, and only 5% through rebate or voucher. This points out the clear success of the free distribution programs at distributing the smart controller technology to a large number of customers in a relatively short time. The more expensive direct install programs were also successful, but require a substantial commitment of resources. Rebates and vouchers worked well for commercial customers in southern California, but did not prove to be particularly successful at attracting residential participants.

Public Awareness Increase. MWD measured customer awareness of weather-based irrigation control technology in 2005 when the program began and again in 2007 as the distribution and education effort matured. In 2005, only 15% of respondents indicated that there were aware of the existence of weather-based control technology. In 2007, 38% of respondents were familiar with the technology. This substantial improvement was largely due to the MWD and member agency program efforts and bodes well for the future of this technology in the region.

Northern California Smart Controller Programs

The northern California Smart Controller programs were made up of distribution programs at five participating agencies under the leadership of the East Bay Municipal Utility District. Much of the early effort by the agencies was focused on conducting a market research study to develop a strategy and plan, designing smart controller distribution programs, and creating a web-enabled database tool for collecting and centralizing data from the distribution programs. Northern California agencies began their distribution programs in 2005 and 2006. Distribution methods focused on targeted rebates and vouchers. Both professional and self-installation options were available. To date a total of 1,713 smart controllers have been installed as part of the northern California program effort. This represents 65.8% of the original estimated total.

Many of the incentive programs implemented northern California were intended to "transform" consumer behavior by encouraging the adoption of new technologies. The effort at market transformation was a distinct yet complimentary approach to traditional demand management efforts.

To maximize potential water savings, agencies in northern California targeted customers with historically high outdoor water use demands through an analysis of historic billing data. EBMUD identified a target audience of residential and non-residential customers using an average of 750 gallons per day outdoors during the irrigation season. However, landscape area was not included as a targeting factor so the amount of excess irrigation could not be determined and used as a targeting tool. On average the EBMUD participants applied only 93.8% of the theoretical irrigation requirement prior to installation of the smart controllers. This suggests that the targeting effort was not particularly successful at identifying customers who habitually over-irrigate. The EBMUD program saved water overall, but the results could have been even better with an improved targeting effort that included a calculation of the application rate rather than only using volumetric targeting criteria. Other agencies utilized targeting efforts as well.

Some northern California agencies such as the Santa Clara Valley and the Sonoma County provided pre-installation landscape surveys or audits for each participant. Most of the northern California agencies including EBMUD also conducted post-installation inspections of nearly all smart controller sites and adjustments to irrigation schedules and programs were frequently made during those inspections.

Process Evaluation Recommendations

The following are recommendations for utility agency smart controller program implementation.

- **Program Design and Efficiency.** The California Prop. 13 Smart Controller Programs set out to test a variety of distribution methods and technologies to determine which approach makes the most sense moving forward. In both northern and southern California a regional approach was attempted, but in many cases each agency chose to follow its own chosen course while cooperating as much as possible with neighboring agencies. These programs benefited from the more efficient unified regional approach adopted for this study and this effort should be expanded. Leveraging common program elements such as design, marketing, and evaluation, stretched program implementation and evaluation funds and increased regional recognition and public awareness.

- **Marketing.** Smart controller programs must be marketed if they are to attract interest. Smart controllers are a brand new technology and very few people know what they are and what they do. Customers and landscape professionals alike need to be educated about these products and why they are desirable. Marketing materials should explain how the technology works and what benefits it offers. EBMUD found the readily available SWAT marketing materials to effective at explaining the technology and generating interest. Once educated, the public appears quite interested in smart control technology and is willing to give it a try. Customers may need help choosing the smart controller product that best suits their needs. The differences between a signal-based, sensor-based, and historic ET controller are not obvious to the typical customer. Targeted marketing approaches that identify customers with high irrigation demands and focus distribution efforts may be an effective method of placing smart controllers at sites that offer the greatest potential for water savings.

- **Getting Smart Controllers Into the Field.** Public information is critical to success of any utility sponsored smart controller program. Information provided should be clear and concise. A complicated message spanning multiple pages will not be successful. Information provided at the point of sale (e.g. the irrigation supply outlet or retail home and garden center) can be beneficial. Availability of product is essential. It cannot be assumed that smart controllers are easily available. Partnerships with the landscape industry are an excellent way to promote smart controller technology and can be beneficial to customers and landscape professionals alike. Smart controller programs should include a strong education element that focus on proper installation and most importantly programming. Manufacturers and distributors can help educate irrigation contractors and provide incentives for installation of smart controllers. Manufacturers and distributors can also increase marketing efforts in areas where water agencies are offering financial incentives programs that encourage installation of smart controllers. Follow-up inspections can be helpful for assuring maximum benefit, but also increase utility program costs.

- **Market Transformation –** The overall smart controller distribution program design and marketing materials and distribution methodologies developed have the potential to achieve longer lasting impacts on the market. In both southern and northern California, the marketing efforts succeeded in raising public awareness about the technology, although much work remains to be done on this front. Efforts that educate irrigation and landscape contractors can result in increased adoption of the technology, even after the program has ended.

- **Costs.** The type of distribution program a utility chooses to implement impacts program costs tremendously. Direct installation programs are expensive. Exchange programs are typically less expensive, but rely more heavily on customer expertise for installation and programming. The cost of rebate programs varies depending upon the design. Rebates can be set to match expected utility cost savings/avoided costs. Follow-up visits and inspections can be beneficial, but also add to the overall cost of a program. Agencies with prior experience implementing rebate programs for toilets, clothes washers, and other efficiency measures may have an easier time getting a smart controller rebate program underway. If water savings are the desired outcome, targeting program efforts at customers that historically irrigate in excess of the theoretical irrigation requirement is an essential key to success.

- **Irrigation Systems.** The controller is just one piece of a much larger irrigation system. Performance of the controller is limited by the capabilities of the irrigation system. The most water efficient smart controller cannot operate optimally on an irrigation system with poor head spacing and inadequate distribution uniformity. A systems approach is required in to achieve maximum water savings. Some agencies incorporated system repair and upgrades into their smart controller program out of recognition that maximal water savings may not be achieved from poorly designed, maintained or improperly programmed systems.

- **Residential and Commercial Differences.** When implementing a smart controller program it is important to recognize the distinct differences between irrigation sites and to plan accordingly. Small sites such as residential and small commercial properties are distinct from large commercial and institutional sites. At a small site, the financial decision maker and the person in charge of operating and maintaining the landscape and irrigation system are often one and the same. At a large site they are almost always different people who seldom communicate with each other. The smart controller technologies for small and large sites are also different as are the irrigation systems and management arrangements. Smart controller programs targeted at commercial and institutional customers will typically require distinct marketing materials, resources, training, and other program elements. Cost differences and varying potential water savings must be accounted for as well.

- **Program Evaluation.** Effective evaluation of a smart controller program requires fundamental data including: make and model of controller, date of installation, installation method, sufficient water use data (pre- and post-installation), a measurement (or estimate) of the irrigated area, climate data corresponding to the same period as the water billing data, and other data as well. Good program design includes a method for collecting these and other data as part of the distribution and installation effort.

- **Signaling Fees.** Some controller technologies require the customer to pay an annual fee to receive a signal that adapts irrigation applications to prevailing local conditions. Nearly 48% of the mail survey respondents indicated that they would not continue to pay the signaling fee for their smart controller after the conclusion of the utility program. The failure to pay the signaling fee would transform a signal-based smart controller into a conventional controller. Although this result is only based on a total of 46 survey respondents, the high percentage of customers indicating they will not continue to pay the signaling fee after the program ends is of concern and this should be the subject of follow-up research during the on-going program monitoring effort.

Conclusions and Recommendations - Impact Evaluation

The impact evaluation was conducted to answer important questions about installation and performance of smart controllers. Key questions to be answered through the impact evaluation included:

- What water savings resulted from the installation of the smart control technology? What factors influenced water use? How did different smart controller technologies perform in the field?

- Given the water savings achieved, what is the cost effectiveness of smart controller technology? What amount of water utility rebate is justified to encourage adoption of this technology? What level of customer investment in smart controller technology is reasonable given the measured water savings?

Water Savings

The weather-normalized change in outdoor water use was the fundamental change in use measurement used to establish weather-normalized water savings in this research study. Weather-normalized outdoor use was reduced by an average of 47.3 kgal per site, a reduction of 6.1% over pre-smart controller outdoor water use. This average reduction was found to be statistically significant at the 95% confidence level. At smart controller sites in northern California the average reduction in outdoor water use was 122.2 kgal per site (-6.8%), however because of high variability these changes were not statistically significant at the 95% confidence level. At smart controller sites in southern California the average reduction in outdoor water use was 30.9 kgal per site (-5.6%). The average changes for southern California were statistically significant at the 95% confidence level.

Changes in outdoor water use measured at eight agencies were found to be statistically significant at the 95% confidence level, while changes at nine agencies were not statistically significant.

While the overall impact of smart controllers is to reduce irrigation demands, irrigators who historically apply less than the theoretical irrigation requirement for their landscape, can expect their water use to increase use after installing a smart controller. On the individual site level, a total 56.7% of the 2,294 study sites had a statistically significant reduction in weather-normalized application ratio. While 41.8% of sites had a statistically significant increase in application ratio. For 1.5% of sites, there was not a statistically significant change in application ratio.

Factors that Influenced Water Savings

Multiple regression analysis was used to determine the factors that did and did not influence changes in application ratio. This analysis methodology allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and changes in application ratio after adjusting for factors known to influence savings such as the application rate prior to installation of the smart controller.

The following factors were examined and determined to have a statistically significant impact on the change in application ratio:

- Pre-smart controller Application Ratio – the application rate relative to the calculated theoretical irrigation requirement
- Installation method (self vs. professional)

- Participating agency (sometimes)

Factors that Did Not Influence Water Savings

The following factors were examined and determined not to have a statistically significant impact on the change in application ratio:

- Site classification (residential vs. non-residential)
- Region (northern vs. southern California)
- Climate zone (coastal, intermediate, inland)
- Smart irrigation control methodology (historical ET, on-site readings, remote readings, soil moisture sensor)
- Landscape area

Water Savings by Smart Controller Brand

The data assembled in this project allowed for a comparison of the field performance achieved by each brand of controller installed at the study sites. Controller brands installed at fewer than 15 sites were not included in this analysis (the total number of sites in this category = 7). Controller brand names were made anonymous during the analysis process and were only exposed at the conclusion. This analysis did not attempt to adjust for factors shown to influence water savings such as differences in installation method.

Seven of eight controller brands included in the analysis saved water on average, however the overall variability of the data resulted in broad 95% confidence bounds. When the 95% confidence boundary spans zero (i.e. the upper bound is greater than zero), the water savings associated with brand is not statistically significant. Of the eight manufacturers evaluated here, only two achieved statistically significant water reductions – Accurate WeatherSet and ET Water. Accurate WeatherSet achieved an average weather-normalized per site savings of 50.5 kgal which represented a 33.2% reduction. ET Water achieved an average weather-normalized per site savings of 185.4 kgal which represented a 6.2% reduction.

For five of eight manufacturers, statistically significant reductions in weather-normalized water use were not found. This result means that the water savings measured for these three brands was not statistically different from zero (the confidence boundary crossed zero). Consequently, no statistically "reliable" finding of water savings can be made for these three brands (Hunter, Weathermatic, Calsense, Rain Master, and Aqua Conserve). As additional years of post-installation data become available and/or with an increased sample size it is possible that these technologies could achieve statistically significant water use reductions.

The HydroPoint/Toro/Irritrol controller was the only technology that did not achieve water savings in this analysis, but this technology performed better over time as discussed in the multi-year analysis.

Water savings is only one evaluation measure. An important evaluation parameter to consider for smart controllers is the post-application ratio (post-AR). A primary goal of smart irrigation technology is to reliably match the actual irrigation applications to the theoretical irrigation requirement, (to achieve a post-application ratio of 1.0). Controllers that match actual applications to the theoretical requirement can be considered successful even if they do not reduce (or even increase) water use, because they are performing as designed.

Persistence of Savings – Multi-Year Analysis

The primary results for smart controller sites presented in this study compare a single year of pre-installation data against a single year of post-installation data. While these results are encouraging and show that smart controllers can reduce weather-normalized outdoor use on average, the longer-term performance of smart controllers in the field is of critical importance. Do water savings persist over time after the installation of a smart controller? Do the water savings decay? In the three years of post-installation data examined in this study for 384 study sites, water savings were not found in the first year, but savings were found in year 2 and year 3 and actually increased over time. More than 90% of the controllers in this analysis were HydroPoint/Irritrol/Toro so this analysis largely reflects the performance of this technology over time.

After reviewing the available water use and climate data it was determined that a reasonable sample size for this analysis could only be obtained if three years of post-installation data were used. Three years of post-installation data were available for more than 384 smart controller sites. The controllers included in this group were installed from 2002 – 2005, so data from years 2005 and 2006 represent year 1 and 2 for some controllers and year 2 and 3 for other controllers.

The results show that the controllers in this sample did better over time and in particular in the third year following installation. During post-installation year 1, weather-corrected percent change in water use increased by 6%. In year 2, the weather-corrected percent change water use showed a decrease 7.8% vs. the pre-install year. In year 3 the weather-corrected percent change in water use showed a decrease of 16.4% vs. the pre-install year.

Cost Effectiveness Analysis

Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. For the customer perspective, cost-effectiveness analysis was used to determine the level of investment that would be reasonable for a customer to make in a smart controller given the anticipated water and cost savings achievable through installation of the device.

For the water utility perspective, cost-effectiveness analysis was used to determine the incentive levels that could be reasonably justified for a water utility based on the water savings measured in the study. The cost-effectiveness analysis was constructed using the average and median per customer water savings estimated for sites with four different landscape areas (4,000 sf, 12,000, 25,000, sf, and 150,000 sf). These areas encompass the range of residential and non-residential landscapes found in northern and southern California and elsewhere. While not specifically designated as residential and non-residential analysis, the smaller landscape sizes are more typical of residential properties and the larger landscape sizes are more typical of commercial and dedicated irrigation properties.

A water utility with an annual avoided cost for water of $150/acre-foot that implements a smart controller program aimed at the residential sector and small landscapes (~4,000 sf) would likely achieve cost-effective water savings for a per-site incentive of up to $26. If the same agency implemented a program aimed at large landscapes (~25,000 sf), a $164 incentive would likely result in cost-effective water savings.

Utilities with higher annual avoided costs for water may find smart irrigation control technology to be a cost effective method of reducing demand in new and existing customers. At an annual avoided cost of $1000 per acre-foot a utility could provide nearly a $500 per site incentive for sites averaging 12,000 sf in size. The economics of smart controller incentives will differ between water agencies. But if average water savings as found in this study are achieved, then some utility programs that incent smart control technology will be cost effective.

For a residential customer with a 4,000 square foot landscape who pays $3/hcf for irrigation water who achieves average water savings with a smart controller would be justified in spending up to $229 to purchase, install, and maintain a smart controller over the 10-year expected life of the product. A customer with a 12,000 square foot landscape who pays $2/hcf for irrigation water would be justified in spending $458 on a smart controller. These results indicated that customers who achieve average water reductions can realize cost-effective savings from installing a smart controller.

Each water utility is unique. Each utility normally has its own distinct avoided cost for water and system of water rates and charges, developed over many years through complex processes. In water conservation planning, each utility may place a different value on conserved water. This poses challenges for developing cost-effectiveness analysis for smart controllers that will be broadly applicable across the diverse range of utility agencies that participated in this study and the even large group that may utilize the results. It is most likely that utilities will use the water savings and percentage decrease estimates from this study and apply them to their own cost-effectiveness models. However, the research team was able to develop an approach to cost-effectiveness analysis that provides information for a broad range of agencies and systems of rates and charges.

Water utilities and customers may wish to promote and install smart irrigation control technology for other reasons besides potential water and cost savings. For water utilities, smart irrigation control offers a number of potential additional benefits including:

- Reduced runoff from urban landscape
- Adaptation of customer demands to calculated water budget allotments

- Potential for peak demand reduction (through coordinated irrigation "brown outs" similar to energy utility peak shaving)
- Improved health and condition of urban landscapes through more proper irrigation applications

For customers and end users, smart controllers offer some of the same potential benefits, but also a few others.

- Convenience – many participants in this study reported enjoying the convenience associated with smart control technology.
- Improved landscape appearance and health. Applying the proper amount of water usually improves landscape quality.
- Better feedback about other problems with the irrigation system. Many smart controllers offer diagnostic tools not available on traditional controllers. Applying the proper amount of water to a zone often reveals distribution uniformity problems that may have been masked by excess application in the past.

Impact Evaluation Recommendations

The following are recommendations based on the findings from the impact evaluation.

Maximize Water Savings. Smart controllers can save water. Smart controllers are far more likely to effect savings when they are installed at sites that have historically applied excess irrigation applications. Water providers seeking significant volumetric savings should target smart controllers at these customers in particular. To do this a utility must have three critical pieces of data: (1) Estimated outdoor water use at the site; (2) A measurement (or estimate) of the irrigated landscape area at the site; and (3) The specific (or average) evapotranspiration rate for the locale.

In this study, 41.8% of the study sites *increased* their weather-normalized irrigation water use in the first year after installation of the smart controller. Irrigators who historically apply less than the theoretical irrigation requirement for their landscapes are poor candidates for smart controllers and should be pre-screened from utility distribution programs. Most water utilities have the electronic tools required to calculate which customers are good candidates for smart controllers and which are not. A geographical information systems (GIS) linked to historic water billing data are the perfect system for calculating historic application rates. Not all agencies have such tools readily available.

To maximize water savings, the installation and programming of the smart controller is of critical importance. Landscapes are unique. Experience has shown that the initial or default settings used to program a smart controller will likely need to be fine tuned over the first few weeks or even months of operation to ensure optimal performance. This is not a technology that can simply be installed and forgotten, adjustments are often required during the initial set up to calibrate the controller default settings to the specific conditions of the site. Once the controller is properly adjusted for the site few if any adjustments should be needed. Manufacturers, irrigation contractors, water agencies, and consumers must be made aware of this need for fine tuning. Training and tools should be developed to improve the installation and adjustment process to help ensure that the smart controller performs optimally and does not end up unnecessarily increasing water use.

Factors that Influence Water Savings. This study has identified only a few factors that have a statistically significant influence on water savings. Specifically, the pre-Application Ratio at the site, the installation method (self vs. professional), and the participating agency (sometimes a significant factor). Aside from the importance of targeting based on historic application rate (not just volume), these findings offer limited guidance for utility smart controller programs.

Installation and Programming. Remarkably, self-installed smart controllers performed better than professionally installed controllers in this study. It is unclear exactly why this is the case, but a reasonable hypothesis is that customers who installed their own controller were more familiar and comfortable with the technology and hence better able to fine tune the programming to maximize efficiency at their site. Irrigation experts, landscape professionals, and knowledgeable water conservation staff agree that proper installation, programming, and fine tuning are critical to a successful smart controller installation. In northern California utility personnel conducted an inspection of nearly all smart controller sites during which programming adjustments were made. This approach appears to have improved savings for some northern California agencies, but it is unclear if the benefits of these efforts outweigh the additional program costs associated with conducting site inspections. Post-installation inspections are a good idea, but the results from this study show that smart controller programs can achieve significant water savings without conducting site inspections.

Customer training programs at distribution and exchange events in southern California proved that a little training goes a long way. Participants were required to bring their old controller to the exchange event or class and were taken through exercises with the new controller to help familiarize them with the technology and to demonstrate the differences from the old controller. The research finding higher water savings from self-installed controllers bears out the efficacy of this training concept. The verbatim customer survey responses indicate that not all self-installations were successful, and in some cases professional assistance was sought. Because of the relatively low cost of implementing an exchange program, other agencies may opt for this distribution method as a reasonable way to promote smart irrigation control technology. An approach that is able to target customers with a history of applying water in excess of ET and then distributing the smart controllers with the low cost and ease of implementation of an exchange event could be an excellent hybrid program solution.

Smart Irrigation Control Technology. When seeking irrigation water savings, the pre-existing level of excess irrigation at the customer site is the most important factor. Most of the smart control brands and technologies evaluated in this study reduced irrigation demands on average. Brands such as Accurate WeatherSet and ET Water achieved statistically significant water savings in the first year after installation. Other brands did not. It was not possible to say with statistical confidence that any brand saved the most water given the tremendous variability in landscape size and consequently irrigation volumes. Different methods of irrigation control may distinguish themselves as superior over time.

Many irrigation experts agree that the best way to adapt irrigation applications to plant requirements is through local soil moisture measurement. Only a small number of soil moisture sensor-based smart controllers were included in this study, but this is a technology that should be further developed and improved and researched. The moisture level at the root zone of the landscape is the best measurement of the irrigation water requirement. All other smart irrigation control technologies seek to approximate this measurement in some manner.

More data are required to determine any real differences between irrigation controller brands and methodologies. The multiple regression model used to compare controller brands only explained about 25% of the variability in the data. It is certainly possible that under different modeling conditions a different outcome would have been obtained.

SWAT Testing. Seven of the eight controller brands included in this study[28] have published SWAT test results. Only Accurate WeatherSet has chosen not to participate in the SWAT testing process, but still this technology achieved statistically significant water savings. All of the published SWAT scores were above 95% for adequacy. The results from this study indicate that the SWAT testing protocol may be a predictor of reasonable field performance, but is not a guarantee of water savings. The SWAT testing protocol was not designed as a way to assess water savings, but rather is a method to try and ensure controllers apply the right amount of water based on current ET formulation.

Testing is essential. If water efficiency is the primary goal of the testing regime, then a conservation-oriented testing criteria perhaps derived from the current SWAT protocol should be considered. Maintaining acceptable landscape appearance and health while minimizing the amount of water used should be the objective of water conservation-oriented smart controller bench testing. Achieving this objective could possibly be achieved through the SWAT testing protocol, but might require changes including modifications to the way ET is currently formulated.

Cost-Effectiveness – Depends on Avoided Costs and Water Rates. Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product. Programs targeted customers who historically irrigate in excess of the theoretical requirement are far more likely to be cost effective under any avoided cost and pricing scenario. Utilities seeking cost-effective demand reductions should focus their efforts on identifying sites that stand the best chance of reducing demands through installation of a smart controller.

Smart controllers will be cost-effective for many end users, but not all. Utilities could easily provided simple cost-effectiveness calculations for customers to assist them in determining if a smart controller makes sense given their historic outdoor water demands. For some customers, factors besides water and cost savings such as convenience and a desire to enhance landscape health and appearance may convince them to install a smart controller.

[28] Eight smart controller technologies were installed at 15 or more sites in the study, the minimum required for inclusion in the analysis by manufacturer/technology.

Long-Term Performance Data Required. More data on the long-term performance of smart controllers is required. The limited multi-year analysis presented in this report which showed increasing savings over time indicates the potential for long-term water savings from smart controllers is promising, but it is certainly not the final word on this subject. The DWR contract with the participating water agencies in northern and southern California specifies that post-installation water use must be tracked over a five-year period. The participating water agencies should take full advantage of this opportunity to continue to monitor the impacts of smart controllers over the coming years and to track the persistence and/or decay of water savings over that time.

Many more controllers were installed than were included in this study due to missing billing or site data. However, this offers an important future opportunity to increase the sample size and further examine the impacts of smart controllers in the field. It is possible that once longer-term results are available on a greater number of site installations different conclusions about the performance of smart controllers will be reached.

Long-term landscape health and appearance should also be considered. Water use data included in this study was from monthly or bi-monthly billing records. Consequently, this study was not able to examine of how the controllers distribute irrigation events through time (i.e. frequency and duration or irrigation run times over a given period of time). With such coarse data it is possible that a controller might apply an amount of water close to the theoretical irrigation requirement over the course of a month or two, but within a given week the irrigation run times might not be distributed properly. While the distribution of irrigation events through time could not be examined in this study, it is potentially significant in the way smart controllers can affect overall plant health over time and should be the subject of further investigation. Some smart controller technologies only adjust run times and not water days which could result in frequent shallow waterings. Data on the long term appearance and health of landscapes irrigated with smart controllers should be collected.

CIMIS Data for Urban Irrigation. Accurate, consistent, and continuous climate, evapotranspiration, and precipitation data will be increasingly important for effective urban water management in the future. The California Irrigation Management Information System (CIMIS) was originally created to provide critical data to agricultural water users in the state. More recently the system has been adapted to provide evapotranspiration data for urban irrigation management. The researchers relied heavily on CIMIS data to develop the analyses presented in this report and the experience of working closely with these data leads to a series of recommendation for improving the CIMIS system to better serve the needs of urban irrigators.

More CIMIS Stations Needed in Urban Areas. California needs more CIMIS ET stations in urban areas. Los Angeles and the surrounding metropolitan area in particular would benefit from additional CIMIS stations. The research team for this study was forced to obtain supplementary climate data for much of the analysis conducted on sites in the Los Angeles area when problems were detected at the few CIMIS stations located in the LA basin.

Continuous Data are an Important Goal. CIMIS stations are regularly removed from service for repairs and maintenance. When this occurs, climate data during the outage is unavailable and those seeking climate that data must use alternative, often less ideal, CIMIS stations. In this study, discontinuous data proved problematic and in many cases a particular CIMIS station could not be used because of discontinuity during the pre- or post-installation year. Repairs and maintenance are essential to assuring the quality and accuracy of CIMIS data, but there might be ways to complete repairs while still recording data from that location. One idea would be to temporarily replace station components with substitutes while others are removed for servicing.

Formulate ET for Acceptable Landscape Appearance and Health Using the Least Amount of Water. There is a bright future for the use of evapotranspiration data to help manage urban irrigation. The essential goal of this effort will likely be maximizing water efficiency. Currently, CIMIS evapotranspiration data must be modified with various crop and landscape coefficients to adapt it to urban water requirements. There is general agreement on how this is done, but in the long run, something different is needed.

The research team believes in thinking big, and our recommendation is that research be conducted to develop a new urban ET factor designed to maximize water efficiency while maintaining landscape health and appearance. Several recent landscape studies, including this one, have found the current ET formulation with a *Kc* value of 0.8 or even 0.7 is simply too high for many urban landscapes which contain a mixture of turf, trees, and plants (Sovocool, et. al. 2006, White, et. al. 2007). The revised urban ET factor should be developed by agronomists, horticulturalists, and landscape experts from around the country with the goal of developing an ET value designed for the efficient irrigation of urban landscapes. A water conservation-oriented ET factor should be based not on maximizing the growth of plants, as many current ET formulations are, but instead should be developed with the goal of *acceptable landscape appearance and health using the least amount of water*. The new factor must be formulated for different parts of the country, different soils, different plant materials appropriate to the setting, and different climates, but with the same goal of acceptable landscape appearance using as little water as possible. Ideally the new water conservation ET factor could be developed in the university environment at different locations across the country. Many universities already have facilities and programs that could be enlisted in this effort which will probably require federal funding to move forward. If urban landscape water conservation is expected to help stretch and support water supplies, this fundamental tool to help manage water use should be developed.

Once developed, the water conservation ET factor could be incorporated into smart controller scheduling engines and algorithms to improve water savings.

Looking Forward – Future Research, Thoughts, and Perspective

This study represents an important step in the field evaluation of smart irrigation control, but in a sense it is only a beginning. Under the DWR contract, the participating agencies in this study must track changes in water use at these smart controller sites over a five year time period. This should provide significant information on the long term performance of this technology in the field. The limited multi-year analysis presented in this study suggests that water savings may increase over time, perhaps as irrigators make adjustments to their controller to better fine tune applications to the needs of the landscape. The additional data to be collected by the participating agencies should shed further light on this subject.

Beyond this project, there are a number of ideas and areas that could be explored in future research efforts to tackle some of the questions that still remain about smart controllers. Some of these ideas and research concepts are discussed below.

Detailed Site Analysis

One of the weaknesses of this study was that only limited information about the landscape and irrigation system at each site was available. A follow-on study could examine a smaller sub-sample of sites included in this study and perform detailed site audits to obtain important information unavailable to the authors of this report. This could include, but is not limited to, information on the specific irrigated area at each site, the specific plant materials irrigated, the soil type and condition, shading (which has been shown to have tremendous impact of water requirements), slope, irrigation system condition, precipitation rate, distribution uniformity, irrigation schedules both before and after installation of a smart controller, changes made to the landscape and irrigation system at the time of installation, and other information.

Armed with these data it may be possible to better understand the factors that influence water savings or increases in water use at different sites. If additional years of post-installation water consumption data are available it should be possible to gain a better understand of the long term performance of smart controllers and to better understand how best to maximize water savings with this technology. Such a study could be useful in determining how best to deploy smart irrigation control technology and how best to maximize water savings and minimize the number of sites that increase consumption.

Incorporation of Water Budgets

Establishment of ET-based irrigation water budgets for utility customers would greatly improve all efforts at managing outdoor water use, including efforts based on smart controller technology. A number of agencies in California currently use water budgets or are developing them. Research conducted at these agencies in which customers who exceed their annual outdoor water budget are selected to receive a smart controller could show the potential of this type of integrated management program.

Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) can provide insight on when controllers irrigate at a fine time scale (hourly, daily, weekly) and could be used to show what kinds of irrigation schedules a controller calculates, information that is not available when only monthly or bi-monthly billing data are available. A better understanding of the irrigation scheduling practices of customers before and after installation of a smart controller could be helpful in determining which technologies are most appropriate in different situation and could help water agencies to better target program efforts. AMI systems also have devices that can provide the customer with real time water use data. These devices provide the person who is actually controlling the water use—the customer—with the information they need to make intelligent decisions.

Moisture Sensor Based Irrigation Control

Only one soil moisture sensor based controller site was included in this study. Moisture sensor based controllers have shown promise in research dating back to the early 1990s as well as recent work conducted at the University of Florida. Soil moisture sensor based irrigation control may offer some advantages over the climate based control technology examined in this study. Additional field research on the performance of moisture sensor based controllers is needed.

Solar Radiation Sensor Technology

The Accurate Weatherset controller achieved impressive outdoor water savings in this study. This controller uses a combination of on-site solar and rain sensors. The use of on-site solar radiation measurement for irrigation control warrants further investigation as it appears to offer significant potential to achieve water savings.

Transitioning From Conventional to Smart Irrigation Control

Utilities hope that smart controllers offer a prudent investment with real potential to achieve substantial water savings. Although the smart controller sites in this study saved an average of 47.3 kgal per site in outdoor use statewide, it was also found that more that 40% of the smart controller sites in the study ended up applying more water than with conventional control. This study offers some explanations for this finding, but more information is needed. Is the increase in water use due to a defect with the controller technology or is it simply a matter of improper setup or lack of fine tuning to the actual landscape conditions?

One of the most common questions customers ask about smart controllers is, “How do I know if my smart controllers is set up correctly?” A simple procedure to check the appropriateness of smart controller programming would be beneficial to all who install them. If the total weekly run times of the smart controller exceed the total weekly times of the old conventional controller the smart controller is not likely to save water. Proper set up and programming remains a significant issue. In this study it was found that customers who installed the controller themselves saved more water on average compared with professionally installed controllers. This is somewhat troubling. It is important that the irrigation industry figure out how to program smart controllers efficiently and properly to achieve healthy and attractive landscapes that receive the proper amount of water

Smart Controllers of the Future

Smart irrigation control technology, while perhaps not in its infancy, is certainly not fully mature. As the idea of smart control gains traction with consumers these technologies will be refined and improved. The smart controllers of 2020 will almost certainly be different from those evaluated in this study. Currently there are a number of on-going efforts such as WaterSense and AB 2717 that seek to establish performance thresholds and standards for smart irrigation control technology. These well intentioned efforts must develop their protocols carefully so as not to stifle innovation and new ideas that may yield improved field performance.

It is also incumbent upon manufacturers and water utilities to think outside the box in the coming years. A key missing ingredient in the current crop of low cost smart controllers is water use and flow information. A system that could connect to the on-site water meter via wireless technology could take advantage of the water use data to better adapt irrigation applications, identify leaks and broken valves and heads, and to provide useful information to the customer about the performance of their irrigation system. Currently water providers are hesitant to allow much access to water meters and the information available from them. In a future where we must use even less water to accomplish the same tasks, customers must have immediate access to information on their resource usage. As more utilities adopt water budget-based rate structures, customers will have a greater need to understand their consumption patterns on a regular basis. Customer consumption information and feedback technologies currently exist and are being developed and refined for the consumer market. The integration of better information on usage combined with smart control technology may offer opportunities for greater efficiency.

APPENDICES

APPENDIX A – SMART CONTROLLER TECHNOLOGIES

Introduction

Methods for weather-responsive irrigation fall into several broad groups (Table A.1).

Table A.1: Irrigation control method by manufacturer

Company name	Weather data source	Station or zone capacity	SWAT test performance report available	Number of controllers in study
Accurate WeatherSet	On-site solar and rain sensors	8-48	No	342
Aqua Conserve	Historic ET curves with onsite temperature sensor	6-66	Yes	288
Calsense	Onsite ET sensor. Soil moisture sensor	8-48	Yes	17
ET Water Systems	Public and ETWS weather station data managed by centralized computer	1-48	Yes	94
Hunter Industries	On-site weather station with full set of sensors	1-48	Yes	44
HydroPoint	Public and Private Weather stations managed by central computer and wireless delivery	6-48	Yes	537
Irritrol Systems	Public weather stations data managed by centralized computer server	6-24	Yes	37
Rain Master	Automatic, historic or manually entered ET or optional on-site weather station	6-36	Yes	22
Toro Company	Public weather station data managed by central computer server	6-24	Yes	68
Weathermatic	On-site temperature and rain sensors and solar radiation estimated based on location	8 to 48	Yes	838

A few controllers in this study use soil moisture sensors to determine watering needs. These types of controllers represent a small minority of the controllers studied Onsite controllers rely on sensors providing a variety of measurements to determine site-specific ET. Other controllers use ET data from networked weather stations to provide ET data. These data are interpolated for user-specified location.

Site location is only one critical data point of many that is supplied by users. Set up requires users to input accurate information about their site, vegetation and irrigation system.

Controller synopses are given based on the number of controllers in the study. The more heavily a controller is represented, the sooner it appears in this appendix document. Distribution by manufacture was far from uniform. Weathermatic controllers use onsite weather stations and represent about 36% of the controllers in the study. However, the combined number of controllers represented by the Toro / Irritrol / HydroPoint partnership (which uses remote weather station data) represents about 28% of the controllers in this study. In short, two products account for two-thirds of this study's data points.

Similarities Between Controllers

Controllers this study represent a wide array of approaches to weather-based irrigation. However, despite these differences, there are some common characteristics.

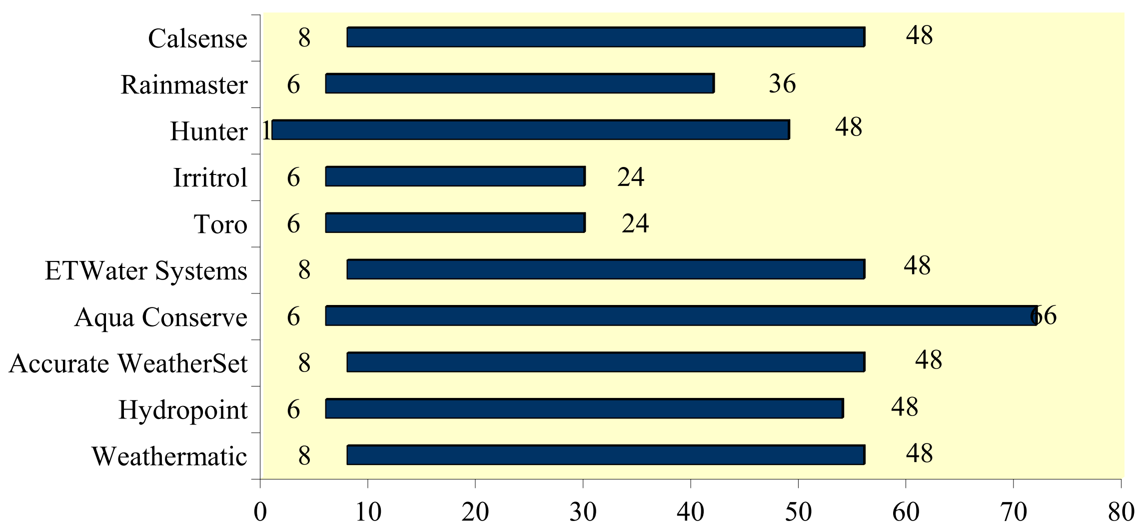


Figure A 1: Zone capacities

While the numbers of zones available on each controller vary, the range of zones overlaps significantly from manufacturer to manufacturer (Figure A.1). It should be noted that most controllers add zones in increments of eight.

Installation recommendations are also uniform. Manufactures recommend, but do not require, professional installation. All products are supported by local distribution and telephone technicians.

Benchmarking and Evaluations

The Smart Water Application Technology (SWAT) test is an assessment of climate-based controllers and sensor-based controllers. A six-zone virtual landscape mimics different plant and soil combinations. The test evaluates to major criteria: how well the controller met the needs of the plants and how much excess water was applied.

The Irrigation Association developed the test. An independent third party, the Center for irrigation Technology at California State University, Fresno, administers the test.

WEATHERMATIC SMARTLINE

Weathermatic controllers use onsite weather monitoring to adjust watering. Parameters used to calculate ET are rain fall, temperature (both collected from the onsite station) and solar radiation (determined as a function of latitude) (DOI 2007).

These controllers comprise approximately 36% of controller sites evaluated in this study.

Figure A 2: Weathermatic weather station

Irrigation Control Method

Weathermatic Smartline controllers use onsite-weather monitoring of temperature and rainfall plus calculated solar radiation to adjust watering run times in response to weather.

During initial set up, users identify sprinkler type, plant type, slope and soil type for each zone from a series of menus. When identifying irrigation set up, users can select from spray, rotor or drip (sprinkler type). More advanced users can also skip these menu-inputs and use precipitation rates to describe sprinkler efficiency. Advanced users can skip the plant-type menu and describe the crop coefficient using percentages, but basic programmers select from cool turf, warm turf, annuals, shrubs, native or trees (plant type). Users also input other site characteristics such as soil type (sand, clay, loam) and slope for each zone.

The controller calculates basic watering times for each zone from these data. Users also select watering start times and days (DOI 2007).

It should be noted that at this point, weather control is optional; this basic program can run without the onsite-weather station.

Users also input their zip code information. The zip code is used to calculate solar radiation for the site. If located outside of the U.S., users can input latitude rather than zip code to calculate the solar radiation at a given site (Weathermatic 2008).

The Smartline controller uses the entire inputted site and system data to determine how much water is needed for each zone. The inputted system allows the controller to determine how that water will be delivered. This is the method for calculating the basic run times for each zone.

The weather-based controlling takes over from there.

A hygroscopic disc rain sensor collects precipitation data and provides a rain delay. The temperature sensor, which is encased in a solar shield, tracks high and low temperatures. Using temperature and rainfall, the Weathermatic controller uses a Hargreaves-based ET calculation.

The Hargreaves equation estimates solar radiation based on the daily temperature range, extraterrestrial (i.e. above atmospheric conditions) solar radiation (which is solely a function of latitude) and an empirical constant. This constant may vary as a function of location. In short, this equation yields ET values that do not require on-site measurements of solar radiation. The performance of this equation and measuring system has been found to correspond with CIMIS data. (Figure A.3) (Weathermatic 2008).

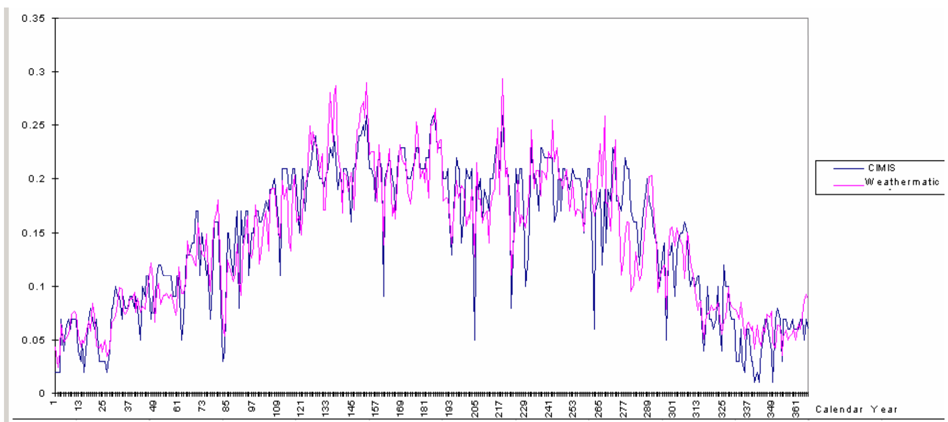


Figure A.3: Weathermatic ET compared to CIMIS ET data

Evapotranspiration data allows the controller to determine the watering deficit. Based on this deficit, the controller adjusts zone run times.

After the system is operating in weather control-mode, users can employ a percent adjust feature to alter calculated run times for each zone. Run times can be reduced by as much as 50% or increased by 25% (DOI 2007).

Other Product Features

Weathermatic controllers come in four-zone increments up to 48-zone sizes. Installing modules to add zones can expand many of these systems. The controllers may run up to four programs.

Four of the five Smartline controllers can be installed indoors or outside. The smallest controller, the SL800, requires indoor installation. Surge/lightening protection is also a standard feature of the controllers.

Weathermatic's onsite temperature gauge is also tied to a freeze shut off. The onsite rain gauge is likewise part of a system rain-shut off feature.

For a more complete list of features, see the end of this appendix.

Installation, Maintenance, Service Pricing and Warranty

Weathermatic recommends professional installation, however homeowners may install the controllers. Weathermatic also has online video tutorials to help users set up their system.

In addition to programming the controllers, the weather station also requires proper installation. The weather station should be located where it can accurately capture rainfall. Because the temperature sensor has solar shielding, it can be installed in shade or sunlight (Weathermatic *Smartline* undated). Care should be taken installation to keep the sensors away from heat sources such as chimneys or vents. The manufacturer recommends installing the weather station where there is open-air flow. For example, the station should not be set up in a corner (DOI 2007).

Weathermatic offers a two-year warranty. Battery replacement is part of the required maintenance. The product is supported be telephone technicians and local distributors (DOI 2007).

Figure A 4: Weathermatic control panel

Weathermatic, which went into business in 1945, provides irrigation hardware such as rotors, sprayers and valves. The Smartline, Weathermatic's weather-based controller, entered the market in 2004. Not all of Weathermatic controllers are weather-based. However, all controllers can be converted to weather-based control (DOI 2007).

The controller ranges in price from $299 to $816.80. The weather station, which is necessary for weather-controlled irrigation, costs $199 to $299. Since weather monitoring is onsite, no subscription serves is needed (DOI 2007).

Benchmarking and Evaluations

Weathermatic controllers have published SWAT test results. For the six test zones, the controller (a SL1600 model) met 100% of the irrigation adequacy, on average. Irrigation excess averaged 0.4% for those six zones (IA *Weathermatic* 2007). SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). Weathermatic has also performed significant testing of its Hargreaves equation-based ET calculation in comparison with CIMIS ET data. In addition, Weathermatic controllers have been incorporated into other independent studies. Marin Municipal Water district studied 13 controllers in 2002 and 2003. The reported water savings was 26% in the 2002 results and 32% in 2003 (Weathermatic 2008, DOI 2007).

HYDROPOINT WEATHERTRAK

HydroPoint Data Systems' WeatherTRAK controllers use ET data from public and private stations as the bases for weather-responsive irrigation. HydroPoint controllers do not use a base schedule for irrigation. Rather, user entered site data are combined with ET data to create dynamic irrigation schedules. HydroPoint's weather service is ET Everywhere (DOI 2007).

WeatherTRAK is in partnership with Toro / Irritrol. HydroPoint is the software partner, while Toro / Irritrol provides hardware (Starr 2008). For that reason, some HydroPoint controllers have some software features that are not available on Toro / Irritrol controllers. Internet-based management features (e.g. flow and runtime reports) are not available on Toro / Irritrol controllers (HydroPoint HydroPoint 2008).

HydroPoint WeatherTRAK controllers account for about 23% of the controller sites in this study. Toro and Irritrol controllers account for about four percent of controller sites in this study.

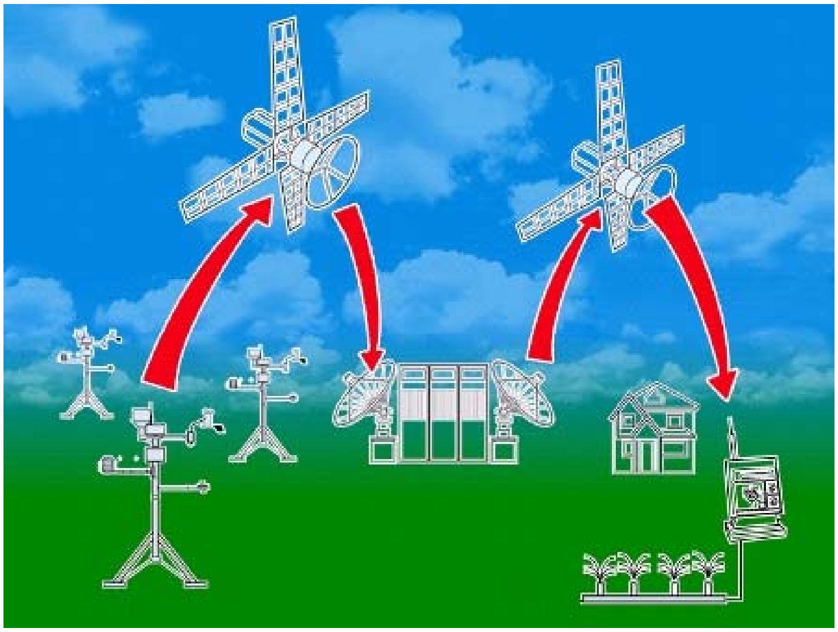


Figure A 5: HydroPoint's data system

Irrigation Control Method

User-provided site characteristics allow HydroPoint to evaluate the water needs of the site on a zone-by-zone bases. HydroPoint's ET Everywhere service collects ET data from weather station networks and evaluates those data. Once data are evaluated, ET information is sent to controllers. User defined site data and ET data are combined to create an assessment of soil-moisture depletion. Once soil moisture is depleted to a certain level, runtimes are calculated for each zone (HydroPoint HydroPoint 2008).

Site characteristics include the landscaping as well as the irrigation system. For system information, users input sprinkler type or precipitation rates for each zone. Users also describe system efficiency using a percent adjust feature. Plant type (or crop coefficient), root depth, soil type, slope and microclimate data are parameters used to describe the landscape characteristics. (DOI 2007)

ET Everywhere, HydroPoint's weather information service, networks with over 40,000 weather stations. This includes public and private stations. HydroPoint downloads weather data from NOAA and other satellites. These data are used by HydroPoint to calculate ET data with a reported resolution of one square kilometer. (HydroPoint HydroPoint 2008).

Figure A 6: HydroPoint controller

These ET data, in conjunction with site and landscape information, is used to track soil-moisture depletion. Once depletion reaches 50%, a new schedule is calculated to re-normalize the water balance. Days to water, run times and soak/cycle times are all parameters that can be adjusted to meet soil-moisture targets. This information is sent to each controller via satellite signal. While data transmission is wireless, some controllers may require optional antennas to receive signal (HydroPoint HydroPoint 2008).

Using a percent adjust, users can vary how much water each zone receives. This variation can range 50% lower than calculated to 25% higher.

Other Product Features

HydroPoint controllers have a variety of scheduling options. The number of watering programs is unlimited. Two programs can also be run simultaneously. The controller offers eight different start times with 20 repeat cycles. Start times can over lap. Controllers can be programmed to prohibit watering on different days to meet with local watering restrictions and regulations (DOI 2007).

Through an optional service, WeatherTRAK.net, controllers can be managed from a personal computer, mobile phone or personal data assistant. WeatherTRAK.net allows for two-way communication with the controller. This service notifies users of watering adjustments and alerts. A single account can manage one or more controllers. This service is a standard part of the commercial controller service (HydroPoint HydroPoint 2008).

HydroPoint offers controllers in a range of sizes. These range from a nine-zone residential model to a 48-zone pedestal commercial controller. All controllers can be installed outside or indoors.

Additional onsite sensors can be added to HydroPoint controllers. These include rain (for rain shut off), wind, freeze (freeze shut off), and flow sensors. Rain shut off is available through this onsite sensor, but can also be done by contacting HydroPoint (DOI 2007). For a more complete list of features, see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

HydroPoint recommends professional installations, but it is not required.

No battery replacement is required, which is a common maintenance requirement in other controllers. HydroPoint offers a variety of support. Users can call telephone technicians. Local distributors are also available for support. If needed, onsite technicians are also available (DOI 2007).

Residential models have three-year warranties and commercial controllers have five-year warranties. Residential / light commercial controllers cost between $509 and $759. Prices for commercial controllers run from $1,600 to $2,450. Weather-responsive irrigation requires subscription to the ET Everywhere service. For residential controllers this starts at $48 and runs up to $84. For commercial controllers, the service prices range from $84 to $225. Multi-year discounts are available (HydroPoint HydroPoint 2008).

Benchmarking and Evaluations

HydroPoint reports that its controllers reduce water use by 59 to 71% (DOI 2007). HydroPoint controllers have been part of numerous water efficiency studies (Table A.2). HydroPoint completed SWAT testing in 2005. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged zero percent for six zones (IA *WeatherTRAK* 2006).

Table A.2: Studies incorporating HydroPoint WeatherTRAK controllers

Study Name / Authors	Study Sites	Year
Residential Runoff Reduction Study (R3 Study)	112	2004
Report on Performance of ET Based Irrigation Controller	10	2003
Weather Based Controller Bench Test Report	9	2004
Evaluation of Weather-Sensing Landscape Irrigation Controllers	24	2004
Residential Water Savings Associated with Satellite-Based ET Irrigation Controllers	27	Undated
City of Bend, Oregon		2004-2005
University of Nevada, Las Vegas (UNLV) and Southern Nevada Water Authority,		2004-2005
LA Dept. of Water & Power	80	2002-2003
Santa Barbara County,	100+	2001-present
IRWD/MWD,		1998-1999
LA Dept. of Water & Power	500	2004
University of Nevada Reno Cooperative Extension ET Satellite Irrigation Controller Study		2001-2002
University of Arizona		On going
Metropolitan Water District		2004
Colorado State University		2003
Soquel Creek Water District		2005
Santa Clara Valley Water District		2004-present
Victor Valley Water District		2004-2005
Newhall County Water District		2005

(HydroPoint 2008, DOI 2008)

ACCURATE WEATHERSET

Accurate WeatherSet's weather-based irrigation controller is the Smart Timer. These controllers account for about 15% of the controller sites in this study. The Smart Timer uses onsite weather sensors to determine ET values. These sensors include Accurate WeatherSet's SunFall sensor and a rain sensor. Once ET values are determined, the controller adjusts base schedule run times on a zone-by-zone bases. Accurate WeatherSet's residential controllers entered the market in 2001. Accurate WeatherSet offers the most economical controller in the study (DOI 2007).

Figure A 7: Accurate WeatherSet controller

Irrigation Control Method

Accurate WeatherSet calculates onsite ET based on data from onsite sensors. Accurate WeatherSet works off the premise that solar radiation accounts for about 90% of ET when there is little wind. Wind does affect ET, but even during high winds, solar radiation still accounts for 85% of ET, Accurate WeatherSet reports. As a result, the solar sensor tracks ET. Accurate WeatherSet also adds an eight-percent correction to the solar data. This makes the data more accurately match ET (Accurate WeatherSet WeatherSet 2008).

The solar sensor, the SunFall sensor, is manufactured by Accurate WeatherSet. It records data every two minutes. According to Accurate WeatherSet, solar radiation reduces by about two-thirds as the seasons change and the sun stays lower in the sky. Accurate WeatherSet uses self-adjusting programs to account for these changes (DOI 2007).

The rain sensor, which is collects data every two minutes, is a Rainbrain. This sensor was originally manufactured by Ecological. Weathermatic acquired Ecological (Weathermatic Weathermatic 2008). The rain sensor is used for rain shut off as well as scheduling; the controller accounts for the length of rain shut off when calculating irrigation schedules.

Users have four watering modes to choose from when programming the controller. These modes are selected for each zone. Users select from "flowers," "lawn," "shrubs" and "LWU," which stands for low water use. This program is for plants that expect no rain from May through September and winter rain from October to April. Three of these modes are designated with different plant types. However, root depth is also an important factor in how the modes water. "Flowers" is for shallow-root plants. "Lawn" is for medium root-depth plants and the "shrubs" setting is for plants with deep roots. Users may also prevent run off by setting a maximum run time for each zone (Accurate WeatherSet WeatherSet 2008).

Based on the user-inputted root depth, the solar radiation (which tracks ET) and the measured precipitation, the controller determines when to run the irrigation systems and how long each zone should run (DOI 2007).

Other Product Features

Accurate WeatherSet, which has been making weather-base irrigation controllers since 1979, has two models of residential controllers and seven models of commercial controllers.

Run-off control is a part of Accurate WeatherSet's selling points with theses controllers. Users can set the maximum each zone may run in an hour. This limits run off for each zone. The number of cycles a zone runs is a function of the controller-calculated run time divided by the user-set time limit (Accurate WeatherSet WeatherSet 2008).

Accurate WeatherSet's largest controller can manage as many as 48 zones. The smallest controller manages eight zones (Accurate WeatherSet WeatherSet 2008). For a more complete list a features see the end of this appendix.

Figure A 8: WeatherSet's solar radiation and rain sensors

Installation, Maintenance, Service, Warranty and Pricing

The SunFall sensors require installation in primarily sunny locations. However, adaptive logic control gives the solar sensor the ability to work in partial shade. The rain sensor is bundled with the solar radiation sensor. The Smart Timer 8R and the Smart Timer 12R must be protected from precipitation. However, the commercial-grade models may be installed out doors (Accurate WeatherSet WeatherSet 2008).

Accurate WeatherSet's smallest controller costs $148, which includes the solar radiation and rain sensors. The most expensive controller costs $960; again, the sensors are included in this price. Sold separately, sensors cost $50 (DOI 2007).

Accurate WeatherSet offers a three-year warranty. Local distributors and on-site technicians support these controllers in select areas in the west. Telephone technicians are also available.

Benchmarking and Evaluations

No SWAT report is available for the Accurate WeatherSet controller. However, Accurate WeatherSet controllers have been included in at least two other studies (Table A.3).

Table A.3: Studies incorporating Accurate WeatherSet controllers

Study Name / Authors	Authors	Study Sites	Year
Weather Based Controller Bench Test Report	Metropolitan Water District of Southern California	9	2004
Evaluation of Weather-Sensing Landscape Irrigation Controllers	Pittenger, et al.	24	2004

(DOI 2008)

AQUA CONSERVE

Aqua Conserve uses historical ET data to modify user-entered irrigation schedules. Historical ET curves are based on data from various public weather station networks. These data correspond to 17 geographical regions. The historical ET data are adjusted by onsite temperature readings. Models range from six zones to 66 zones. This makes Aqua Conserve one of the largest capacity controllers in this study. Twelve percent of the controllers in this study were Aqua Conserve controllers.

Figure A 9: Aqua Conserve controller

Irrigation Control Method

First, a base schedule should be programmed into the controller. This schedule should be the maximum water needed (essentially water needs dictated by July weather conditions). Users can either use a pre-existing schedule, consult their landscaper, get information from local water authorities or access data on the Aqua Conserve website. On the site, users can select their area and download regionally tailored guidance for various run times. These guidelines cross-reference four plant types with two sprinkler types. Based on sun or shade, Aqua Conserve recommends the number of times an area should be watered per week. Aqua Conserve also provides users with a chart to limit cycle times based on site slope and soil type (Aqua Conserve *Setup* undated).

Once maximum run times are determined for each zone, ET control takes over. Users select which historic regional ET curve will be used to modify their watering schedule. Historical ET values come from various weather station networks such as CIMIS. ET data are highly dependant on local weather patterns. Aqua Conserve uses region codes to identify with historical ET curves to use (DOI 2007). Those regions are:

- Southern California Inland to Desert
- California Low Desert
- California Central Valley
- Northern California costal
- California High Desert
- California Coastal
- Phoenix, Arizona
- Reno, Nevada
- Las Vegas, Nevada
- Denver, Colorado
- Northern Colorado
- Albuquerque, New Mexico
- Las Cruces, New Mexico
- Seattle, Washington

- Logan, Utah
- San Antonio, Texas
- Dallas / Fort Worth, Texas

The controller performs regression analysis using the historic ET data and temperature data provided by the onsite temperature sensor to determine site-specific and weather-specific irrigation requirements. These irrigation requirements are then used to reduce the previously programmed maximum irrigation schedule. Historic ET data are updated two times per month (Addink, Addink 2005, Aqua Conserve 2008).

Other Product Features

Aqua Conserve controllers can track the accumulated water needs for periods when ET dictates low watering. In winter months, run times are typically short (for example a zone may require only one minute of operation). Rather than run for a moment, the accumulation feature allows the controller to skip watering for a few days and then apply the accumulated water requirement all at once (for example running for seven minutes once a week). The accumulation feature allows for deeper watering of the soil (US Patent 2005, Aqua Conserve *User's Guide* 2004).

Residential models include rain sensors and commercial controllers have the option of adding rain sensors. These sensors provide rain shut-off. If rain delay is triggered, the controller will not water for 24 hours after rain stops.

Figure A 10: Aqua Conserve controller (Ultimo series)

Three residential models require indoor installation. Two residential models can be installed out side. All 16 commercial models may be installed outside.

For a more complete list a features see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

Professional installation is recommended but not required for residential controllers. Professional installation of commercial controllers is highly recommended.

Maintenance of the controllers includes battery replacement. Telephone technicians and local distributors provide product support. Aqua Conserve controllers have a three-year warranty.

With model sizes ranging from six zones to 66 zones (the largest range of any manufacturer in the study) it is not surprising that there are a wide range of prices for Aqua Conserver controllers. The smallest controller starts at $264 and the largest controller is $6,193. No annual service costs are associated with controllers (DOI 2007).

Benchmarking and Evaluations

Aqua Conserve has published SWAT test results. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged 0.2% for six zones (IA *Aqua Conserve* 2007). Aqua Conserve controllers have been part of several studies (Table A.4). Studies in California and Colorado have shown water savings ranging from 21 to 28% (DOI 2008).

Table A.4: Studies incorporating Aqua Conserve controllers

Study Name / Authors	Authors	Study Sites	Year
Residential Landscape Irrigation study Using Aqua ET Controllers	Addink and Rodda	74	2002
Water Efficient Irrigation Study Final Report	The Saving Water Partnership	24	2003
Weather Based Controller Bench Test Report	Metropolitan Water district of Southern California	9	2004
Evaluation of Weather-Sensing Landscape Irrigation Controllers	Pittenger et al.	24	2004

(DOI 2008)

TORO / IRRITROL

Toro / Irritrol controllers use ET data from public and private stations as the bases for weather-responsive irrigation. These controllers do not use a base schedule for irrigation. Rather, user entered site data are combined with ET data to create dynamic irrigation schedules. Toro / Irritrol controllers use the ET Everywhere service to manage ET data.

Figure A 11: Toro controller

The Toro Company owns and partners with a number of other WBIC manufacturers. Toro owns Irritrol and manufactures Irritrol Smart Dial weather-based irrigation controllers. Toro partners with HydroPoint Data Services. Both Toro and Irritrol controllers use HydroPoint's ET Everywhere data service. Toro also owns Rain Master. However, Rain Master's controllers are manufactured separately and have different functionality. Toro's Intelli-Sense controllers are only one part of Toro's business; Toro manufactures a wide variety of landscape and irrigation products (Starr 2008).

Toro controllers represent 2.9% of the controller sites in this study. Irritrol controllers represent another 1.6%. HydroPoint controllers account for 23% of controller sites in this study, so combined this irrigation control method accounts for about 28% of the controller sites in this study.

Figure A 12: Irritrol controller

Irrigation Control Method

User-provided site characteristics allow Toro / Irritrol controllers to evaluate the water needs of the site on a zone-by-zone bases. HydroPoint's ET Everywhere service collects ET data from weather station networks and evaluates those data. Once data are evaluated, ET information is sent to controllers. User defined site data and ET data are combined to create an assessment of soil-moisture depletion. Once soil moisture is depleted to a certain level, runtimes are calculated for each zone (DOI 2007).

Site characteristics include the landscaping as well as the irrigation system. For system information, users input sprinkler type or precipitation rates for each zone. Users also describe system efficiency using a percent adjust feature. Plant type (or crop coefficient), root depth, soil type, slope and microclimate data are parameters used to describe the landscape characteristics.

ET Everywhere, HydroPoint's weather information service, networks with over 40,000 weather stations. This includes public and private stations. HydroPoint downloads weather data from NOAA and other satellites. These data are used by Toro / Irritrol to calculate ET data with a reported resolution of one square kilometer (HydroPoint HydroPoint 2008).

These ET data, in conjunction with site and landscape information, is used to track soil-moisture depletion. Once depletion reaches 50%, a new schedule is calculated to re-normalize the water balance. Days to water, run times and soak/cycle times are all parameters that can be adjusted to meet soil-moisture targets. This information is sent to each controller via satellite signal. While data transmission is wireless, some controllers may require optional antennas to receive signal (DOI 2007).

Using a percent adjust, users can vary how much water each zone receives. This variation can range 50% lower than calculated to 25% higher. For a more complete list a features see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

As with most manufacturers, Toro/Irritrol recommends but does not require professional installation. Maintenance consists of battery replacement. Local distributors and telephone technicians provide support for products. Both lines of controllers have five-year warranties. The price ranges from $399 to $899. Subscription to the ET Everywhere service is required and costs between $48 and $84 per year (DOI 2007).

Benchmarking and Evaluations

SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged zero percent for six zones for the Intelli-Sense controller (IA *Toro* 2006). The Smart Dial controller had identical results (IA *Irritrol* 2006).

Table A.5: Studies incorporating Toro / Irritrol / HydroPoint technology

Study Name / Authors	Study Sites	Year
Residential Runoff Reduction Study (R3 Study)	112	2004
Report on Performance of ET Based Irrigation Controller	10	2003
Weather Based Controller Bench Test Report	9	2004
Evaluation of Weather-Sensing Landscape Irrigation Controllers	24	2004
Residential Water Savings Associated with Satellite-Based ET Irrigation Controllers	27	Undated
City of Bend, Oregon		2004-2005
University of Nevada, Las Vegas (UNLV) and Southern Nevada Water Authority,		2004-2005
LA Dept. of Water & Power	80	2002-2003
Santa Barbara County,	100+	2001-present
IRWD/MWD,		1998-1999
LA Dept. of Water & Power	500	2004
University of Nevada Reno Cooperative Extension ET Satellite Irrigation Controller Study		2001-2002
University of Arizona		On going
Metropolitan Water District		2004
Colorado State University		2003
Soquel Creek Water District		2005
Santa Clara Valley Water District		2004-present
Victor Valley Water District		2004-2005
Newhall County Water District		2005

(HydroPoint HydroPoint 2008, DOI 2008, Starr 2008)

Since Toro/Irritrol controllers use the same irrigation control method as HydroPoint, it is reasonable to assume the numerous studies involving HydroPoint controllers provide some information on how Toro/Irritrol controllers function (Starr 2008). Table A.5 shows a list of studies incorporating HydroPoint controllers.

ETWATER SYSTEMS

ETWater Systems uses ET and precipitation data from existing public and private weather stations. ETWater uses more than 10,000 stations. The company has plans to offer its service nation wide in 2009.

A major feature of ETWater's irrigation control is a Web-based interface that controls and monitors irrigation. The web interface collects site information, determines start times based on ET data from public and private weather stations, provides users with detailed watering history and tracks controller information. Obviously, these features require the user to have a computer with an Internet connection.

ETWater Systems controllers account for about 4.1% of controllers in this study.

Irrigation Control Method

Computer servers at ETWater Systems compile and check data from various weather networks (CIMIS, Florida Automated Weather Network, and NOAA) (Snow 2008). These data are combined with a user's online account information to create a seven-day watering plan that is sent to the irrigation controller. Watering plans are sent daily, with each message having a rolling seven-day plan. Two-way communication allows ETWater to track controller history and communication. These data are sent back to the user.

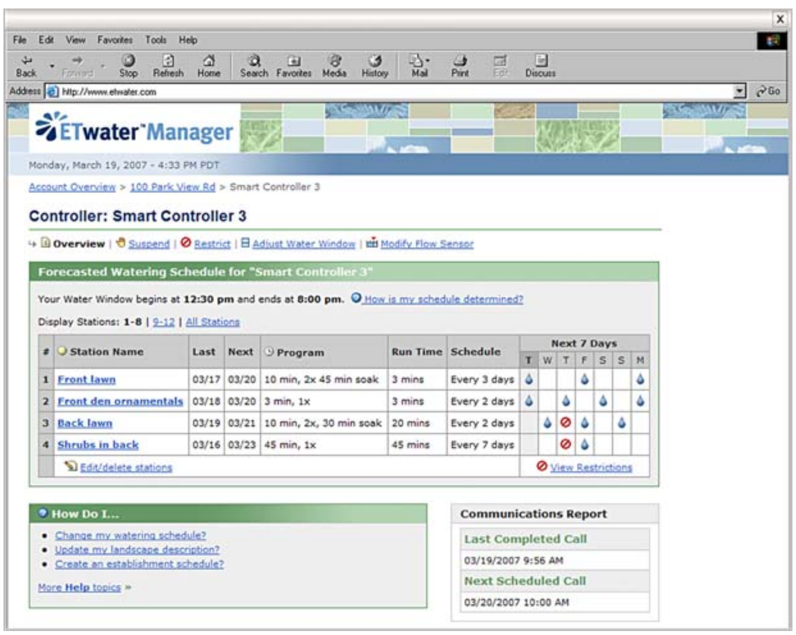


Figure A 13: ETWater manager interface

During initial set up, users set up an account on ETWater's website. Users enter landscape and site information via ETWater's website. Pictorial menus allow users to select site information. Alternatively, users may input data via drop down menus. Users identify site characteristics such as plant type, irrigation system (or application rate), soil type, slope, root depth, sun exposure and distribution uniformity. Default parameters are also suggested. Users can also adjust many other parameters of the watering program. Users can block watering on certain days, which is done by a series of check boxes, and blocking can be station-by-station or globally. The ETWater interface also allows users to set time frames when stations are allowed to water (DOI 2007, ETWater ETWater 2008).

Once set up is complete, ETWater System's computers develop irrigation schedules based on ET data, rainfall and site-specific information. The basic approach is the water balance method. Zone-by-zone run times are calculated from user-inputted data. These run times do not change. Rather, the controller runs the predetermined irrigation program once the soil moisture depletion reaches a certain level. ETWater uses proprietary algorithms to determine soil moisture depletion. Different algorithms maybe used for different plant types. Users may set different depletion targets, but the typical setting is 50%. Once this target is met, the controller runs the irrigation program (DOI 2007).

Scheduling information is sent to the controller via wireless connection, telephone line or power line. If communication is interrupted, the controller continues watering according to the most recent schedule it received. The controller may be set up in an offline mode if telephone service is unavailable.

The web interface also provides information back to the user. For example, it tracks 30 days of watering history in a calendar format. The interface shows station-by-station start times and durations. Each user's account has a page for messages. These messages can include updates on how well the controller is communicating with ETWater's servers.

ETWater's commercial program allows similar management for multiple sites. Multiple site management provides the user with an account overview that lists all the sites managed through that account (ETWater ETWater 2008).

Other Product Features

ETWater Systems offers controllers with 8 to 48 zones. Additional station modules may be added to some controllers in eight-zone increments. It should also be noted that one ETWater online account has the ability manage multiple controllers, so if more than 48 zones are needed, a configuration of multiple controllers could still be managed from one account (Snow 2008).

ETWater reports that users are frequently networked to a weather station in their town or even in their suburb. However, if no weather stations are nearby, ETWater has an exclusive contract with WeatherBug. WeatherBug has more station locations, and if necessary, a weather station maybe set up onsite and used in conjunction with the ETWater controller.

ETWater Systems controllers do not require indoor installation. The controllers also offer surge protection. Programs to establish new turf and deliver fertilizer are also available (DOI 2007).

Figure A 14: ETWater controller

Several sensors can be added to the irrigation controller. Flow sensors can be added to valves in the irrigation system, and using the online irrigation manager, users can set flow limits. If the flow limit is exceeded, they receive an email message. An optional rain sensor can be added to the system to create a rain shut off (Snow 2008).

For a more complete list a features please see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

ETWater Systems does not require professional installation, however professional installation is recommended. Estimated costs for professional installation range from $75 to $225 (DOI 2007).

ETWater offers three- or five-year warranties. Maintenance involves battery replacement. Product support includes local distributors, telephone technicians and on-site service. Because ETWater is largely a web-based product, telephone technicians can log into a user's account to view watering protocols and the watering history of the site (Snow 2008).

As of 2008, commercial controllers (model Smart Controller 205) range from $1429 up to $2609 for a 48-zone wireless model. Residential controller (the Smart Controller 105 model) prices, for 2008, range from $499 to $819 for models with 8 to 16 zones. A service contract is required for online features and weather-based irrigation. For commercial, the contract run $199 per year, but purchase of multiple years can lower the price to $97 per year. Residential costs are $75 per year, but multi-year plans can reduce costs to $50 per year (DOI 2007).

Benchmarking and Evaluations

ETWater self reports average water savings from their controllers in the range of 20 to 50%. ETWater completed SWAT testing in 2004. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged 1.5% for six zones. (IA *ETWater* 2006) ETWater System's controllers are also part of an ongoing study conducted at the University of Florida (DOI 2008).

HUNTER

Hunter manufactures a weather-based control system that works with existing Hunter irrigation controllers. The weather-based irrigation product, the ET System, consists of an onsite weather station and an ET module that is added on to a previously installed Hunter irrigation controller. The weather station includes a solar radiation sensor, temperature sensor and a relative humidity sensor. An optional wind sensor can be added for increased accuracy (DOI 2007).

Hunter controllers account for 1.9% of controller sites in this study.

As of November 2008, Hunter's ET System was unavailable (Hunter Hunter Industries: The Irrigation Innovators 2008).

Figure A 15: Hunter controller

Irrigation Control Method

Using solar radiation, air temperature and relative humidity, the ET System calculates ET for the site. The rain sensor is a tipping bucket type gauge. An optional anemometer can also be added to the system to improve ET measurements (DIO 2007).

The ET Module runs the irrigation system through the pre-existing Hunter controller. It overrides an existing program (typically program A) with the climate-controlled watering schedule.

Figure A 16: Hunter weather station

Users enter site-specific conditions. They can select from 12 grass types, four shrub types, four ground cover types, four vine types, four tree types, four perennial types and two categories of desert plants. Possible sprinkler types are rotor, spray, drip, bubbler or a custom rate entered by the user. More sophisticated users can enter crop coefficients instead of plant type and Application Ratio instead of sprinkler type. Users can select from eight soil types (sand, loamy sand, sandy loam, loam, clay loam, clay, silt, and silty clay) to describe their site. Slope and microclimate (sun/shade) data can be entered as percent. The controller also accepts data about plant maturity. If users identify plants as new, the system will allow for more water for these plants. The system will revert to watering times appropriate for mature plants after a period. This time period depends on the type of plant identified. These data are entered for each zone. Users also enter which days the system may run (Hunter *Instructions* 2008).

The ET System then combines real-time ET data with zone-specific information to determine soil moisture depletion. The system also looks at the allowed watering days when calculating the irrigation schedule. These factors are combined to determine the manageable allowed depletion of water. Target depletion is 30% to 50%. If the calculated run time is below a certain minimum, the system will not run. This prevents shallow watering (DOI 2007).

Other Product Features

The Hunter ET System is not a stand-alone irrigation controller. Rather, this system is added on to an existing Hunter irrigation controller. The ET System is compatible with most Hunter controllers less than ten years old. It will work with any model that has a SmartPort. These ports are found on several models: SRC/SRC Plus, Pro-C, ICC and ACC. It does not work with other brands of controllers.

Onsite sensors allow for several different shut-off thresholds. The rain gauge trips the system off if precipitation is detected. If temperatures drop below 35^{o} F, the control module shuts off the irrigation system (Hunter *Instructions* 2008).

High temperatures can also trigger watering. The ET System will run the irrigation system when extreme conditions threaten plant health. This WiltGuard feature will run the system regardless of time day. The optional anemometer can also shut off watering during high winds (Hunter *Instructions* 2008).

For a more complete list a features see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

As with most controllers professional installation is recommended but not required. Setup reportedly takes about two hours. The ET Module uses power from the SmartPort and requires no additional wiring. The weather sensors should be surround by pants representative of the site's vegetation. Full-sun turf is recommended. The sensor station should be on a pole or a post 6.5 feet above the ground with 6.5 feet of vegetation surrounding it on all sides. The weather station should be installed within 100 feet of the ET Module (Hunter *Instructions* 2008).

As with many controllers, the Hunter ET system requires battery replacement. Other maintenance includes cleaning sensors. Hunter recommends wiping the platform and sensors every 30 days (Hunter *Instructions* 2008). Technical support is available by telephone or from local distributors. Hunter offers a two-year warranty. The ET System costs $429. No on-going fees are required (DOI 2007).

Benchmarking and Evaluations

Hunter has a published SWAT test. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged 0.5% for six zones (IA *Hunter* 2007).

RAIN MASTER

Rain Master controllers offer a wide variety of methods for weather-based irrigation. Daily ET can come from public weather stations via Internet connection. Rain Master's Weather Center II weather station is another option for obtaining onsite ET data. ET data can be directly inputted into the controller (DOI 2007).

Rain Master's basic weather-responsive irrigation controller is the Eagle model. Rain Master also has a larger commercial product, the Oasis Water Management System (using the Evolution DX controller) that also provides weather-responsive irrigation control.

It should be noted that Toro owns Rain Master. However, the two companies use different methods for weather-based irrigation control (Starr 2008).

Rain Master controllers account for 0.9% of controller sites in this study.

Figure A.18: Rain Master controller (pedestal mount)

Irrigation Control Method

Rain Master controllers can receive ET data from a variety of sources. Data can come from remote weather station networks or an onsite weather station.

Data from remote weather station networks can be sent to the controller using Rain Master's ZipET service. The Rain Master controller must be configured with Rain Master's iCentral two-way wireless card. Once the controller is Internet enabled, there are two possible sources for data. Users located in California can obtain daily ET data from CIMIS. Users outside California can use Rain Master's ZipET service. The ZipET services collects data from Federal Aviation Administration and NOAA stations. These data are evaluated for quality and if necessary converted to a uniform format. Based on the user-supplied zip code, the ZipET service interpolates ET data for a given controller's location. Then these ET data are sent to the controller (DOI 2007).

Alternatively, ET data can come from an onsite weather station. Rain Master's ET Weather Center WSII. This weather station includes a solar radiation sensor, rain gauge, relative humidity sensor and wind gauge. This weather station calculates ET every 10 seconds.

Users can also manually enter ET data. In this scenario, manually entered data are typically used in tandem with historical ET data stored in the controller. The manual data over rides historical data for one week and then the controller reverts to historical ET data (DOI 2007).

These historical data also provide backup ET data in the event communication with other ET sources is interrupted.

During set up, users enter two types of data. Scheduling constraints define allowed watering times and days. Site attributes include plant type, soil type, root depth, precipitation rate, distribution uniformity, zone efficiency and allowable soil moisture depletion.

Once ET data are supplied to the unit, station run times are adjusted. Adjustments are made on a daily bases.

Other Product Features

If two-way wireless Internet communication is enabled, Rain Master's iCentral web service can email users information about changes in irrigation and the irrigation control system itself.

Sensors on the controller can shut off irrigation if conditions are not favorable. Rain delay and high wind shut features can be enabled. High and low temperatures (freezing) can also trigger a shutdown of the irrigation system. Flow sensors can also be added to the irrigation system. If the controller senses a mainline break or unscheduled flow irrigation is suspended (DOI 2007).

For a more complete list a features see the end of this appendix.

Installation, Maintenance, Service, Warranty and Pricing

Rain Master recommends but does not require professional installation. However, AC power to the unit requires hard wiring. The weather station comes with a ten-foot high pole for mounting. It should be located away from high obstructions such as buildings or trees. Multiplying the height of such obstructions by a factor of ten gives the distance the station should be placed from the given obstruction. Rain Master recommends locating the station in an area where it will be surrounded by turf (Rain Master *Manual* undated).

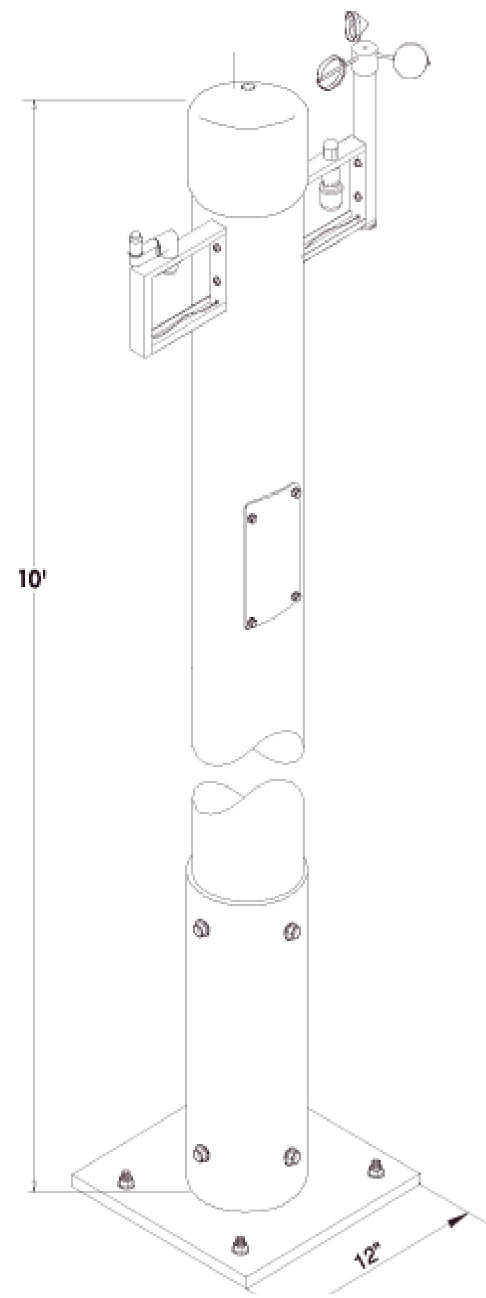


Figure A 17: Rain Master weather station

Maintenance consists of yearly (or once per irrigation season) cleaning of the sensors. Cleaning is straightforward; users should inspect the sensors for debris (Rain Master *Manual* undated). The anemometer's bearings should be checked once per year as well. Controllers have a five-year warranty. Telephone technicians and local distributors provide support. Prices range from $640 to $4,264. Annual service costs range for $0 to $180 (DOI 2007).

Benchmarking and Evaluations

A study done by Solano County Water Agency found 27% decrease in average water use after installing Rain Master controllers in parks in four cities in its district (Solano 2005).

Rain Master self reports water savings in the 25-percent to 40-percent range. Rain Master has published SWAT test results. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged zero percent for six zones (IA *Rain Master* 2008).

CALSENSE

Calsense controllers can receive ET data from a variety of sources. Onsite measurements of ET or weather conditions can be used. CIMIS data may also be used. Soil moisture sensors also provide additional control of the irrigation system.

As a company, Calsense's primary market is larger institutions such as universities or transportation departments. They do not make a product tailored for the typical residential customer.

Calsense controllers account for 0.7% of controller sites in this study.

Figure A 20: Calsense controller

Irrigation Control Method

Onsite ET data can come from Calsense's own ET gauge. This is an atmometer consisting of a canvass covered ceramic plate on a reservoir of water. The canvass covered ceramic plate reproduces the characteristics of plant Evapotranspiration (Irmak, et al 2005).

Figure A 19: Calsense anemometer

As an alternative, onsite ET conditions can be monitored by a weather station manufactured by Campbell Scientific.

The controller can also use CIMIS data. However, if onsite weather station data or CIMIS data are used, the controller must be networked with a personal computer that calculates ET and communicates it to the controller. Historic ET data are preprogrammed into the controller as backup (D.O. I. 2007).

Onsite sensors provide additional feed back. A tipping bucket rain gauge (optional) can measure amount and rate of rainfall so this data can be taken into account when the controller calculates the zone run times. A wind gauge and rain switch can be added to the system to provide irrigation shut-offs during adverse watering conditions. A flow meter can be connected to the irrigation system. This monitors the system for mainline breaks, no flow situations and high flows.

Once ET data are provided, the controller adjusts a preprogrammed watering schedule. This is a run-time based schedule entered by the user. Users can select watering days. Users can also program cycle/soak times (Calsense *Quick set Up* 2007).

Soil moisture sensors are also an optional part of the Calsense system. Calsense uses a densitometer soil sensor. Such sensors can over-ride the ET-calculated watering schedule (D.O. I. 2007).

Other Product Features

Calsense controllers support eight to 48 zones, but can also be networked to personal computer via modem, hardwire, Ethernet or radio signal. It can function as a field control component in a larger system or as a stand-alone controller.

Calsense controllers have a water budget feature. A monthly budget volume is programmed into the controller. The controller tracks use and extrapolates future use (over the course of the month). It alerts the user if water usage will exceed budget.
For a more complete list a features see the end of this appendix. (D.O. I. 2007)

Installation, Maintenance, Service, Warranty and Pricing

As with other manufacturers, professional installation is recommended. The controller can be installed indoors or outside, but the various sensors, gauges and meters require specific installation locations. The recommended height of the wind gauge is 10 feet above the ground, and clear of obstructions (Calsense *Wind Gauge* 2007). Calsense's ET sensor should be mounted three feet to 3.33 feet above the ground. Mounting on a post is recommended, but the top of the post should be below the top of the ET sensor (Calsense *ET Gauge and Enclosure Installation* 2006). This sensor must also be protected from freezing, so it should be installed after the last frost of spring and removed before the first frost of fall (Calsense *ET Gauge and Enclosure Information* 2006). Calsense field technicians make the determination on where to place the soil moisture sensor. Prior to the field technician's site visit, the irrigation contractor should have the controller installed, all lateral lines complete and heads installed. In addition, any shrubs should already be planted (Calsense *Moisture* 2001). Calsense also recommends routine maintenance of the sensors.

Onsite technicians, local distributors and telephone technicians are all available to support the Calsense products. Onsite technicians also provide hands-on training for Calsense products. Calsense controllers have a ten-year warranty. Prices range from $999 to $3,660 (D.O. I. 2007).

Benchmarking and Evaluations

Calsense has a published SWAT test result. SWAT results can be found at the Irrigation Association Website (http://www.irrigation.org/). The average irrigation adequacy of six test zones was 100%. Irrigation excess averaged zero percent for six zones (IA *Calsense* 2007).

Table A 6: Controller features

Manufacturer	Accurate WeatherSet	Aqua Conserve	Calsense	ET Water Systems	Hunter Industries	HydroPoint Weather TRAK	Irritrol Systems	Rain Master	Toro Company	Weathermatic
Telephone	(818) 993-1449	(951) 352-3891	(800) 572-8608	(415)945-9383 ext. 205	(760)591-7344	(800) 362-8774	(800) 664-4740	(805) 527-4498	(800) 664-4740	(972)278-6131
Contact person	Andrew Davis	Dan Oshaben	Rick Capitanio	Greg Black	Dave Shoup	Chris Manchuck	Robert Starr	Steve Springer	Robert Starr	BrodieBruner
Website	www.weatherset.com	www.aquaconserve.com	www.calsense.com	www.etwater.com	www.hunterindustries.com	www.weathertrak.com	www.irritrol.com	www.rainmaster.com	www.toro.com	www.smartline.com
Number of residential model types	2	2	0	2	1	1	1	0	1	2
Number of commercial model types	1	2	1	4	1	1	1	1	1	1
Date product(s) entered market	1994	1998	1993	Mar-05	Feb-06	1997	2005	2002	2005	2004
Method of operation and water savings										
Historical data		●	●			back up		●		
On-site sensor(s)	●	●	●	●	●	Optional	Optional	●	Optional	●
Remote weather station(s)/sensors				●		●	●	●	●	
Weather data source	On-site solar and rain sensors	16 preprogrammed ET curves with on-site temperature sensor	Historic ET data, evaporative atmometer type ET sensor, weather station or CIMIS data. Soil sensor	Public and ETWS weather station data managed by centralized computer	On-site weather station with full set of sensors	Public and Private Weather stations managed by central computer and wireless delivery	Public weather stations data managed by centralized computer server	Automatic, historic or manually entered ET or optional on-site weather station	Public weather station data managed by central computer server	On-site temperature sensor and solar radiation estimated based on location
Manufacturer reported water savings (percent)	Not Available	21 to 28	20 to 40	20 to 50	30	16 to 58	Not available	25 to 40	Not available	20 to 50
Product support and warranty										
Warranty	3 years	3 years	10 years		2 Years	Res: 3 yrs, Comm 5 yrs	5 years	5 years	5 years	2 years
On-site service technicians	In Southern California		●	●		●				
Telephone technicians	●	●	●	●	●	●	●	●	●	●
Local distributors	In Southern California	●	●	●	●	●	●	●	●	●
Installation and maintenance requirements										
Professional installation & programming recommended	●	Commercial models	●	●	●	●	●	Recommended	Recommended	
Ongoing maintenance required			Clean sensors		Clean sensors			Clean sensors		
Battery replacement required		●		●	●		●		●	●

Manufacturer	Accurate WeatherSet	Aqua Conserve	Calsense	ET Water Systems	Hunter Industries	HydroPoint Weather TRAK	Irritrol Systems	Rain Master	Toro Company	Weathermatic
Stand-alone or add-onto existing stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Add-on	Stand-alone	Stand alone	Stand alone	Stand alone	Stand alone
Station or zone capacity	8-48	6-66	8-48	1-48	1-48	6-48	6-24	6-36	6-24	8 to 48
Master valve or pump circuit(s)	1	1-4	2	2	Not applicable	1	1	1	1	1
Internal power transformer	Outdoor models only	Commercial only	yes	yes	Not applicable	yes	•	•	•	
Station circuit current rating (Amperes)	0.75 and 1.5	1.0	1.5	1.1	Not applicable	0.375 and 0.5	0.5		0.5	1.5
Terminal wire size range (gauge)	12-20	12-18	14	12 and smaller	Not applicable	12-20	12-18			14-18
Outdoor installation	•	All commercial & 2 residential	•	•	•	•	•	•	3 models	•
On-site rain gauge or sensor w/ rain shut-off/ delay	•	res. Optional on comm.	•	•	•	•	•	•	•	•
Rain shut-off/ delay by remote sensor					•	•	•	•		
Rain-fall irrigation schedule compensation	•		•	•	•	•	•	•		•
On-site wind gauge w/ high wind shut-off			•		•	•	•			
High wind shut-off by remote sensor					•	•		•		
On-site temperature sensor w/ freeze shut-off		•			•	•	•	•	•	•
On-site temperature sensor w/ high temp on or off					•			•		
Freeze or high temp shut-off by remote sensor						•		•		
On-site evaporative atmometer type "ETSensor"			•							
On-site solar radiation sensor	•		•		•			•		
On-site humidity sensor			•		•			•		
Flow sensor(s) connectivity	5 models	12 models	•	•		•		•		
Additional sensor terminals		with adaptor	•	•		•		•		•
Internet or computer interface			•	•						
Remote control device(s) for controller			•	•	•	•		•		
Two-way communication between server and receiver				•	Not applicable	Commercial model		•		
Station circuit testing	5 models		•		Not applicable	•	•	•	•	
Surge and/or lightning protection	5 models		•	•	•	•	•	•	•	•
SWAT test performance report available		•	•	•	•	•	•	•	•	•

Manufacturer	Accurate WeatherSet	Aqua Conserve	Calsense	ET Water Systems	Hunter Industries	HydroPoint Weather TRAK	Irritrol Systems	Rain Master	Toro Company	Weathermatic
Scheduling features										
Fully automatic schedule (no base schedule required)				•	•	•	•	Optional	•	
Base irrigation schedule required	•	•	•	Optional				•		•
User may define non-irrigation days	•	•	•	•	•	•	•	•	•	•
Operable in manual clock mode	•	•	•	•	•	•	•	•	•	•
Manual operation by station or program	•		•	•	•	•		•		•
Variable total run times	•	•	•	•	•	•	•	•	•	•
Irrigation schedule period(s)	Weekday or daily to 40 days	Week or odd/even	7, 14, 21 or 28 ay	Unlimited days	Weekday, 1-31 day, odd/even	8 weeks, odd/even & weekday	Not applicable	7 or 30 days	Not applicable	Up to 31 days & odd / even
Available start times	10	4 to 8	6 per manual program	9		8 starts with 20 repeat cycles		5		
Cycle / soak manual input	•	•	•			Optional		•		•
Cycle / soak periods automatically calculated				•	•	•	•	•	•	•
Runs concurrent stations	•		•			•		•		•
Number of programs	5	4	7	Unlimited	Not applicable	Unlimited	Up to 64 cycles	4	Up to 64 cycles	4
Percent irrigation adjust feature		•	% ET adjust per station	•	•	•	•	•	•	•
Station distribution uniformity / efficiency setting				•		•		•		
Syringe cycle or program	•	•	•	•		•		•		
New landscape establishment / fertilizer program		•	•	•	•					
Review of weather information			•	•	•	•	•	•	•	•
Review of irrigation or water use information	•	•	•	•	•	•	•	•	•	•
English and Spanish languages display			•							•
Cost										
Suggested retail price	$220 to $1,440	$240 to $5,630	$1,290 - $3,660	$419-$2,399	$429	$449 - $3,675	$399 - $899	$640 - $4,264	$399 - $898	$299.90-$816.80
Annual service cost	$0	$0	$0	$40 - $199	$0	$48 - $225	$48 - $84	$0 - $180	$48 - $84	$0

(D.O.I. 2007, Aquacraft 2009)

APPENDIX B – WEATHER NORMALIZATION PLAN

As discussed in our conference call on Friday, February 10, 2006, the research team has developed this brief explanation of our proposed methodology for working with differences in weather conditions during the pre- and post-WBIC installation periods. It is important to note that we do not intend to "normalize" on weather. Normalization implies that the results would be divided by a weather variable, such as inches of net ET, and expressed as something like Kgal of savings/inch of net ET. This is not the plan, rather, our intention is to use weather as one of the variables in explaining WBIC performance in the regression analyses. In this respect, weather will be one of several variables that will be used in order to explain both efficiency of the systems as the ratio of the actual to theoretical irrigation applications, and actual water savings in Kgal.

The Problem

When working with irrigation consumption data from different time periods it is essential to take weather conditions into consideration so that changes in usage patterns are accurately attributed. For example, let's assume the baseline (pre-installation) period was hot and dry and the post-installation period was cool and wet and irrigation water use at the site decreased by 50%. The question is, what portion of the 50% reduction is attributable to the WBIC and what portion is properly attributable to the change in weather patterns.

The Solution

The researchers propose two methods for controlling for the "confounding" weather variable.

Method 1 – The primary approach envisioned in our proposal for the project is to use site information and pertinent ET data to calculate a variable for each WBIC site called the "Theoretical irrigation requirement" - V_t.

V_t *(kgal or HCF)* is the actual irrigation requirement for the site based on ET, landscaped area, and other available factors.

V_a *(kgal or HCF)* is the actual volume of water applied to the site during the pre or post-WBIC period obtained through historic billing data.

Application Ratio (*AR*) = V_a / V_t. This value can be expressed as a percentage and is a measure of the percent of the theoretical irrigation requirement that was actually applied to the site. A value of 120% would indicate that 20% more water was applied than was theoretically required. A value of 50% would indicate that only half of the theoretical requirement for the site was applied. For each site we will calculate AR_{pre} and AR_{post} for the pre and post-WBIC installation periods.

The difference between AR_{pre} and AR_{post} - (i.e. $AR_{pre} - AR_{post}$) represents a change in the percent of the theoretical requirement applied to each site. This is a change value that has been "corrected" for changes in weather and can be used as the dependent variable in regression analysis. It can also be used in the place of change in water use in t-tests.

For example, if we know that a certain WBIC treatment reliably gives a 15% reduction in the average Application Ratio(*AR*) then this result can be applied to whatever theoretical irrigation requirement exists for the local site in order to determine the corresponding volume of water saved. Obviously, the result will first be calculated for the WBIC study group in order to determine the volumes of water saved for the two time periods involved in the study.

Method 2 – We also want to test to see if there is a relationship between weather the observed changes in AR at the site. This could happen if certain technologies do better or worse as ET changes. Our second approach will be to simply calculate the change in ET for each site (pre to post) and then to use this value as an independent variable in the multiple regression analysis. Ideally both Method 1 and Method 2 will yield identical (or at least similar) results. However, in the real world of field data analysis this may not prove to be the case. For example, a WBIC without a rain sensor may not able to respond to rainfall properly and would show a lower change in AR during wet periods than dry periods, while a "perfect" WBIC would

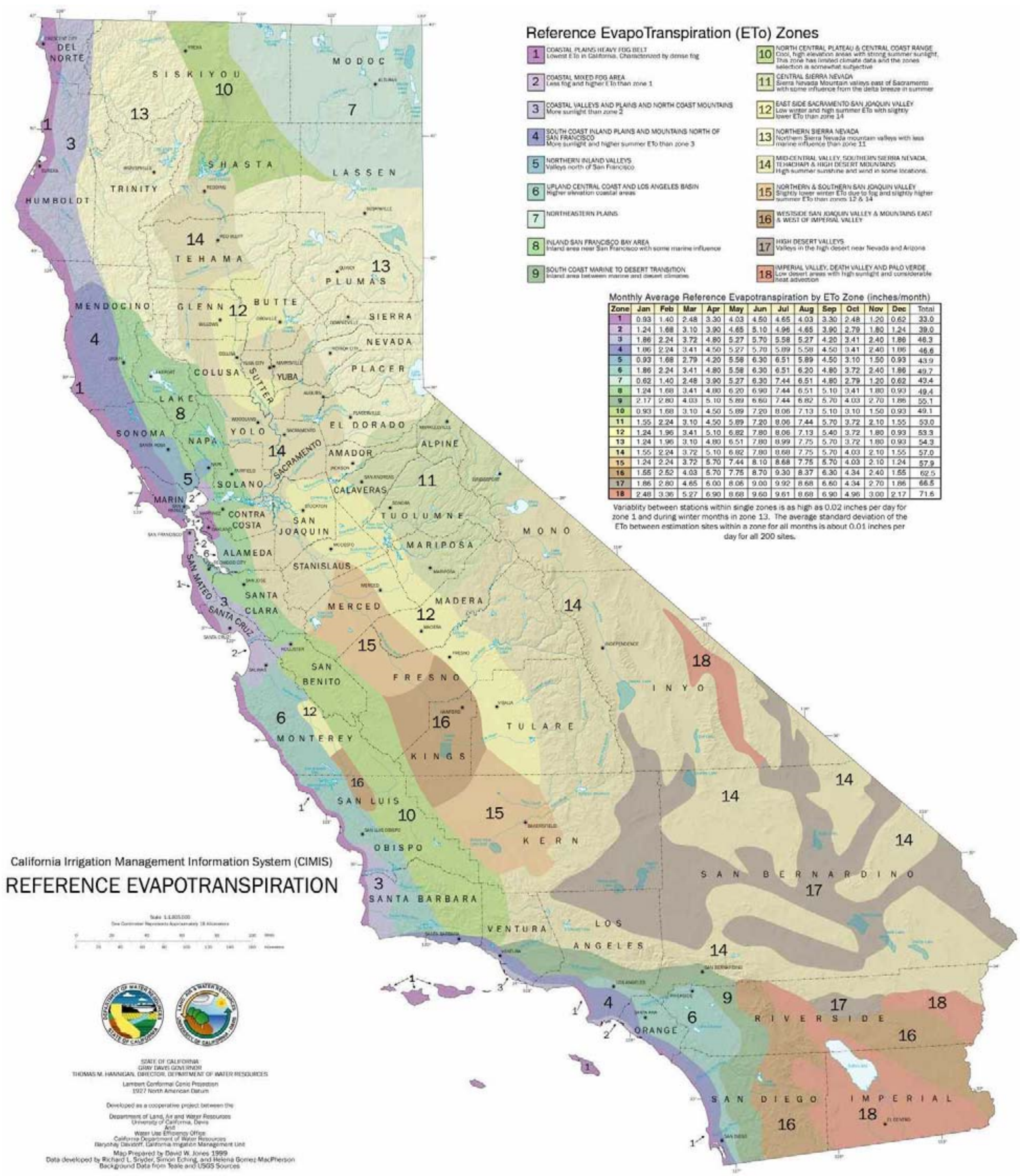
Landscape Changes

Concern has been expressed about the possibility of landscape changes occurring concurrently with the installation of a WBIC at various study sites. This could result it significant changes to water use patterns that could then (incorrectly) be attributed to the WBIC. This issue is specifically addressed in the customer survey. The survey asks about any changes to the landscape that the customer has undertaken concurrently with installing and using the WBIC. The survey also asks about any and changes and improvements to the irrigation system that might have been made. This will allow the consultants to perform separate analysis on sites that changed their landscape and sites that did not as well as sites that modified their irrigation system and sites that did not.

It should be understood that the research team will not obtain survey responses from all sites and there will certainly be analysis for which these factors cannot be taken into consideration. Using the combination of utility billing data, installation data, landscape area data, and survey data the consultants will do their best to tease out these and other important factors and to develop an un-biased analysis of the impact of weather based controllers under a variety of conditions.

1 The installation goal is a maximum ("up to") target number to be achieved.
2 Estimated savings were included in the original grant proposal and reflect various individual agency assumptions and rough estimates based on the types of controllers to be installed and the water demand in each area. Actual savings are anticipated to differ substantially.
3 A minimum of two years of pre-smart controller installation billing data are required (five years preferable). At least one year of post-smart controller installation billing data are also required.
4 The site Application Ratio equals the ratio of the actual irrigation application to the theoretical application requirement, based on the landscape characteristics. AR = Va/Vt
5 At least 2 years pre smart controller and 1 year post smart controller are recommended.
6 DeOreo, W.B. et. al. 2003. Weather-Based Irrigation Controller Research and Support. Aquacraft, Inc., Boulder, CO.

APPENDIX C – CIMIS ET ZONES



Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

APPENDIX D - STATISTICAL SAMPLING PLAN

In order to include a smart controller site in the study, two fundamental pieces of data are required to determine the change in total water used for irrigation and change in irrigation application rates: (1) *historic water billing data* from which irrigation use either can be directly determined or inferred with reasonable accuracy; and (2) *a reasonable estimate of the irrigated area at the sites* (irrigated area). The original RFP and final scope of work assigns EBMUD and MWD the task of providing the evaluation team with these data.

The Northern California Program has indicated that they intend to collect these (and other) data from every participant in their project. The southern California Program anticipates that obtaining these data could be difficult and only wishes to collect them from a sample of their participants. Hence the scope of work includes developing a statistical sampling plan.

There are two key components to the sampling plan:

1. Determination of sample size required for statistical confidence
2. Sampling approach and strategy

Determination of Sample Size Required

Calculating Sample Size for a Paired Sample (Determining Whether Water Savings Have Been Achieved)

The formula for determining an appropriate sample size to give a specified probability of correctly concluding that a difference of a given size is statistically significantly different from 0 is:

$$n = \frac{(z_{1-\alpha} + z_{1-\beta})^2 \sigma_{\Delta}^{\ 2}}{\Delta^2}$$

where:

n = sample size

z = z-score of the desired confidence interval and the z-score of the statistical power of the inference; these can also be notated as:

$z_{1-\alpha}$: where α = probability that a detected difference is due to chance alone, 1- α is in essence the type of confidence interval, e.g., 95% confidence interval. α is the quantification of a Type I error, which is the error of noting a difference as statistically significantly greater than 0 when in reality no such difference exists. In this case, α is not divided by two because we are assuming a one-sided test (whether the smart controllers save water).

$z_{1-\beta}$: where 1-β is the statistical power i.e., the probability of detecting a difference if one exists; 95% indicates that there is a 95% probability of indicating a difference is statistically different from 0 when it actually is. β is the quantification of a Type II error, which is the error of NOT noting a difference as statistically significantly different from 0 when in reality it is.

σ_Δ = the standard deviation of the differences observed (in this case, the standard deviation of the difference between pre-installation water application rates and post-installation water application rates)

Δ = the size of the change desired to be detected (in this case, the difference between pre-installation water application rates and post-installation water application rates)

The value for z is determined by the confidence level one wishes to attain and by the statistical power one wishes for the test of statistical inference. For a 95% confidence level and 95% statistical power, where $\alpha = 0.05$ and $\beta = 0.05$, $z = 1.64$.

Assumptions of Normality: This formula relies on the assumption that the distribution of changes in application rates are normally (Gaussian) distributed, or can be normalized using appropriate mathematical techniques. This means the distributions would take on the approximate shape of a bell curve. Experience has shown that municipal water use data are almost always not Gaussian, but is instead lognormally distributed. However, we are interested in the distribution of the ***differences*** in water application rates. Lognormally transforming the data becomes more problematic, as the differences between lognormally transformed rates do not represent the lognormally transformed difference in rates but the ratio of the rates. Thus, sample size calculations in this document have been made only using non-transformed data. Using the LADWP smart controller study data, a natural logarithm transformation was completed and the water savings calculated. The log transformation resulted in a much better fit of the data to a normal distribution. The average reduction in application rate for the transformed data were only 10.5% and no improvement/reduction in the required sample size could be made. In fact sample size calculations on the transformed data suggest a sample size of 100 sites would be required to achieve the desired statistical confidence.

Sample Size Needed for Paired Sample

Three scenarios are considered here and the results presented in use actual data from smart controller studies. The first scenario presents results from the Los Angeles Department of Water and Power (LADWP) smart controller study of 507 homes equipped with WeatherTRAK controllers. This is the best available information on the performance of a large number of smart controllers in the field and the careful methodology and large sample size makes it a powerful tool for evaluating future sample size requirements in southern California. The second scenario uses data from a small sample of smart controller installations in Colorado ("Colorado smart controller").

The LADWP smart controller study data provides the best information currently available on automatic irrigation patterns in southern California. *All results presented in this document should be considered preliminary and should not be reported or shared in any form.* LADWP was kind enough to provide us with these data for the purpose of assisting in sample size determination for the remainder of the southern California smart controller project. The

LADWP sites will be included in the overall evaluation. Data from the LADWP is considered to be reliable and accurate. Landscape area was carefully measured (and re-measured in several cases) and the smart controllers were professionally installed. This may mean that these preliminary results represent the "best case scenario" in terms of needed sample size, as the standard deviation may be smaller than we might expect to observe across all the sites to be included in the evaluation.

In the LADWP study, the mean observed application rate pre-installation was 64.6" and the standard deviation was 35.6". The mean change in observed application rates was a reduction of 7.2" (11.2%) and the standard deviation of the change in application rate was 19.8". For the LADWP scenarios shown in , the values for the sample size formula are:

σ_{Δ} = 19.8"

Δ = 7.2" (which represents a decrease of 11.2%).

For the "Colorado smart controller" scenario, it was assumed that the standard deviation of the difference would be about that observed in a sample of 10 sites examined by Aquacraft in their Colorado smart controller study. In the Colorado sample, the mean observed application rate pre-installation was 34.9" and the standard deviation was 20.8". The mean change in observed application rate was a 6.7" (19.2%) reduction and the standard deviation was 15.7". However, the evaluation team believes a 10% change in application rate (as observed in the LADWP study) is more likely primarily because most of the Colorado savings occurred on a single site. Thus for the Colorado smart controller scenario the values for the formula are:

σ_{Δ} = 15.7" (about the standard deviation observed in the Colorado smart controller study)

Δ_1 = 3.1" (about a 10% change from the baseline observation in the Colorado smart controller Study) and

Δ_2 = 6.7" (the actual change observed from baseline in the Colorado smart controller Study, which represents about a 19% change).

The needed sample size to detect changes of the size noted for each scenario is shown in below. Using the actual data from the LADWP study it was determined that a sample size of 82 would be sufficient to detect the observed application rate reductions at a 95% confidence level, with a 95% probability of noting such a difference as statistically significant. If the "power" is reduced to an 80% probability of detecting a difference as large as 7.2," the required sample size is only 47.

If, however, the size of the difference that might be expected is smaller, such as the "Colorado smart controller 1" scenario, the required sample size is 278 to have a 95% probability of noting such a difference as statistically significantly different than no change.

Table H-1 : Sample size calculation scenarios

Scenario	1-β (power)	α	Δ	σ_Δ	Sample Size Needed
LADWP actual	0.95	0.05	7.2”	19.8”	82
	0.80	0.05	7.2”	19.8”	47
Colorado smart controller 1	0.95	0.05	3.1”	15.7”	278
	0.80	0.05	3.1”	15.7”	159
Colorado smart controller 2	0.95	0.05	6.7”	15.7”	59
	0.80	0.05	6.7”	15.7”	34

Clearly, there will be sufficient sample size to answer the first evaluation question about whether there was an impact on water consumption across all the programs. The total sample that will be available from southern California will likely also be sufficient to answer the second question, whether there was an impact in the southern California programs. However, there may not be sufficient sample from each agency to answer the third evaluation question about impacts within each agency.

Calculating Sample Size for Differences between Paired Samples (Evaluation Question #4)

It is important to understand that the sample sizes above are calculated to determine whether smart controller technologies have an impact on water consumption. However, the study also proposes to evaluate whether there are differences in water savings by model of controller, climate zone, customer class, installation method, etc. It is understood that achieving a sample size of 82 or even 47 for each possible combination of categories may be difficult. Instead, the goal shall be to obtain sufficient sample size within the most important categories – those being: model of controller, customer category (residential, non-residential), and utility agency. Other factors such as installation method, climate zone, etc. will be evaluated and utilized in the analysis, but will not be used as a criteria for determining required sample size. The study team can conduct analyses to determine whether each customer category, technology model, etc. has realized water savings, but a more interesting question may be whether these water savings are higher or lower by these various categories. For example, two types of Smart controllers may both produce water savings (that are statistically significant). However, one may save more water than another. In order to examine this type of question, the savings achieved will need to be compared.

The equation below shows the sample size needed in each group to be compared. It assumes an equal number of sites in each group (unlikely, but such a scenario simplifies the formula):

$$n = \frac{(\sigma_1^{\,2} + \sigma_2^{\,2})(z_{1-\alpha/2} + z_{1-\beta})^2}{(\Delta_1 - \Delta_2)^2}$$

where

n = sample size for each group

$z_{1-\alpha/2}$ = z-score of the desired confidence interval (α = probability that a detected difference is due to chance alone, it is divided by 2 because we are assuming a two-tailed test for this type of inference; 1- α is in essence the type of confidence interval, e.g., 95% confidence interval)

$z_{1-\beta}$ = z-score of the desired power (i.e., the probability of detecting a difference if one exists)

$\sigma_{\Delta 1}$ = the standard deviation of the differences observed in group 1(in this case, the standard deviation of the difference between pre-installation water application rates and post-installation water application rates in group 1)

$\sigma_{\Delta 2}$ = the standard deviation of the differences observed in group 2

$\Delta_1 - \Delta_2$ = the size of the differences between the two groups desired to be detected (in this case, the difference between pre-installation water application rates and post-installation water application rates in groups 1 and 2)

In calculating the sample sizes needed, the following values were used:

α = 0.05 (the most typical value; this means that any differences indicated as statistically significant would have less than a 5% probability of being due to chance alone)

1-β = 0.80 (again, a very typical value; this means that the "power" to detect a difference is 80%; or that there is an 80% probability of detecting a difference if one exists)

Sample Size Needed for Detecting Differences Between Paired Samples

As shown in below, the sample size needed in each group to find a difference between technologies as large as that found from pre-installation to post-installation in the LADWP sites installed thus far would be 119. However, it is unlikely that the differences between technologies would be so large; to find a difference half that large would require almost 500 in each group; to find a difference a quarter of that size would require a sample size of nearly 1,900.

Table H-2 : Sample Size Needed to Detect Statistical Differences Between Two Types of Smart Controller Technologies or Installation Processes, Etc.

1-β (power)	**α**	**Δ_1-Δ_2**	**$\sigma_{\Delta 1}$**	**$\sigma_{\Delta 2}$**	**Sample Size Needed in Each Group**
0.80	0.05	7.20	19.8	19.8	119
0.80	0.05	3.60	19.8	19.8	475
0.80	0.05	1.80	19.8	19.8	1,899

Sampling Approach and Strategy

The sampling methodology developed by the evaluation team is designed to maximize the analytic capability within each utility program and between the two primary customer categories (residential and non-residential), and among different smart controller technologies. As of the date of this report, the sampling approach has only been developed for the southern California smart controller programs. However, the conclusions drawn from this analysis are applicable to the northern California smart controller program and should be considered prior to program implementation.

Possibly Limited Generalizability

It should be noted that the sites that will be included in this study are clearly not a random sample of all water customers in an agency. Rather the sites have either been recruited or have volunteered to take part in this program. As such these customers are unlikely to be representative of the population of which they are members (i.e. agency customers, California irrigators, etc.). This may limit the generalizability of the study results to all water customers in an agency or in California. However, it may be that these participants are typical of the types of customers that could be expected to take part in similar programs in the future or who are likely to install a smart controller in the future. Such issues of generalizability are common in pilot research projects such as this one and should not be considered a stumbling block in the overall success of the program of the evaluation effort.

Recommended Sampling Approach

The sample sizes required to detect the water savings likely to be observed in the smart controller program shown in and Table 2 are based on the best available information. These data suggest that in order to report statistically significant water savings within each participating agency's program, a minimum sample size of approximately 80 smart controller sites will be needed for each. If a single technology/program is implemented within *groups* of agencies such that the total equals at least 80 sites, then statistically reliable results will likely be obtainable if the same deltas and standard deviations obtain as those from LA.

However, the goal of the evaluation is not only to gauge whether installation of smart controllers results in significant water savings overall, but also to determine whether certain types of smart controller technology are more effective than others. It is likely that the differences in water savings between types of controllers will be smaller than the overall difference. (For example, one type of technology may save 8.5" from pre-installation to post-installation, while another may save 6.5" from pre- to post-installation.) Larger sample sizes within technology types will be needed in order to detect these technology effects.

Based on the sample size calculations shown above and the estimates of smart controller sites in each agency, the evaluation team recommends that a saturation sampling approach be used wherever possible for this evaluation. This means that every smart controller site from every participating agency will be included in the evaluation. This approach will maximize the power to detect statistically significant changes in water use within each agency and within all of the different possible sub-groups and categories.

The evaluation team understands that it was MWD's desire to use a sampling approach in southern California to reduce the required effort in obtaining customer level data from smart controller program participants. The sample size analysis conducted by the evaluation team indicates that the desired level of statistical confidence likely will not be achieved if the sample size is reduced below the saturation level. Even with a saturation sample, it is possible that results within some agencies that have only installed a few smart controllers may not be statistically significant (unless they can be grouped with data from similar programs in other agencies). This can not be known until the data are collected. Agencies that complete 30 to 50 smart controller site installations will likely have statistically reliable results (although the results may or may not show a water savings). If different technologies are employed, then results must be combined with data from other sites to form a large enough sample of sites employing the same technology with (preferably) the same installation method. For these reasons we strongly suggest that any agency with a small sample of sites (<50) make their program uniform so that all of the sites can be analyzed as a single group.

Maximizing the sample size from each participating agency in the southern California smart controller Program should improve the evaluation team's ability to perform meaningful analyses across the entire region and state. For example, an analysis on the most (and least) effective smart controller technologies for conserving water will not be possible unless sufficient numbers of smart controller sites fitted with each make of controller are available for study. There will easily be adequate numbers of residential WeatherTRAK controller sites to evaluate since this was the technology utilized by LADWP. It is not clear how many sites using other products will be available. Since the comparison of technologies is an important part of this study and the number of sites is limited, it is critical that as many sites be included as possible.

Agreed Upon Sampling Plan

As of November 2007, both the northern and southern programs have agreed to provide data on all WBIC installations for which they can obtain the minimum required data. There will be no sampling, but rather a total enumeration approach.

APPENDIX E - SURVEY INSTRUMENTS

Customer Satisfaction Survey Instrument

Smart Controller Evaluation

This survey will be used to help evaluate customer's experiences with the Smart Controller (Weather-Based Irrigation Controller) technology and with water utilities' smart controller distribution programs.
The person most directly involved with the installation of the controller should complete the questionnaire.
Thank you very much!

	very satisfied	somewhat satisfied	somewhat dissatisfied	very dissatisfied	don't know
1. Overall, how satisfied are you with the performance of the smart controller(s)?	1	2	3	4	5

	excellent	good	fair	poor
2. How would you rate the health or quality of your landscaping before installation of the smart controller(s)?	1	2	3	4
3. How would you rate the health or quality of your landscaping after installation of the smart controller(s)?	1	2	3	4

4. By when, if at all, do you expect to recover the costs of purchasing and installing the smart controller?
- ❑ More than 5 years
- ❑ About 4 years
- ❑ About 3 years
- ❑ About 2 years
- ❑ About 1 year
- ❑ No costs – smart controller and installation were free

ABOUT YOUR WEATHER-BASED IRRIGATION CONTROLLER(S)

5. The cover letter indicates the make, model and number of the smart controller(s) installed on the property. Is this information correct?
- ❑ Yes
- ❑ Not Sure
- ❑ No→ **What type and/or how many were installed?**

Make: ______________________

Model: ______________________

Number of controllers: ______________

6. Does your smart controller have an external sensor?
- ❑ Don't know
- ❑ No
- ❑ Yes → **What type of sensor(s) is it? (Please indicate all that apply.)**
  - ❑ Rain sensor
  - ❑ Temperature sensor
  - ❑ Solar sensor
  - ❑ Soil moisture sensor
  - ❑ Don't know
  - ❑ Other ____________

7. Why did you (or the organization for which you work) decide to install a smart controller? (Please indicate all that apply.)
- ❑ It was free
- ❑ Saves time and effort
- ❑ Saves money
- ❑ Water efficiency for myself or my organization
- ❑ Environmental benefits
- ❑ Improved landscape health/benefit
- ❑ Liked the new technology
- ❑ Needed a new controller
- ❑ There was a controller exchange program
- ❑ Incentive program offered by the utility
- ❑ To avoid watering during rainstorms
- ❑ Automatic scheduling to avoid having to change the program when weather changes
- ❑ Other ________________

8. Which, if any, of the following do you perceive as a benefit of having a smart controller? (Please indicate all that apply.)
- ❑ Saves time and effort
- ❑ Makes programming the settings easier
- ❑ Saves money
- ❑ Water-efficient
- ❑ Cost-efficient
- ❑ Improves the health of the landscape
- ❑ Other ________________

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9. What influenced you to select your particular irrigation controller model? (Please indicate all that apply.)
- ❑ Price
- ❑ Helped me set correct schedule
- ❑ Recommendation
- ❑ Advertising
- ❑ Only one offered on rebate, voucher, or exchange program
- ❑ Features
- ❑ No fee for signal
- ❑ Other________________________________

10. How did you hear about the smart controller program? (Please indicate all that apply).
- ❑ Utility bill insert
- ❑ Solicitation letter
- ❑ Newspaper article
- ❑ Newspaper advertisement
- ❑ A public service announcement on the radio or television
- ❑ Friend, neighbor or coworker
- ❑ Irrigation contractor/professional
- ❑ Lawn maintenance service
- ❑ Other ________________________________

____

11. Did you choose a model for which you have to pay a signaling fee?
- ❑ No
- ❑ Yes

12. Did a signaling fee influence your choice of controller? (Please indicate all that apply.)
- ❑ Signal fee did not impact my decision
- ❑ I chose a controller with signal fee because the potential benefits outweigh the extra cost.
- ❑ I chose one without a signal fee because the fee makes the controller too expensive over the long term
- ❑ The water agency is paying for the signaling fee. → **Will you continue to pay for it after the program ends?**
  - ❑ Yes
  - ❑ No
  - ❑ Not Sure
- ❑ Other reason(s)

Installation and Set-Up Process

13. Who installed and set-up your new smart controller?
- ❑ Self → *go to question #16*
- ❑ Other family member → *go to question #16*
- ❑ Manager or owner's staff → *go to question #16*
- ❑ Manager or owner's hired contractor/electrician/handyman → *go to question #16*
- ❑ A manufacturer representative
- ❑ A professional installer from the water utility
- ❑ Other ____________________________

Manufacturer or Water Utility Installation and Set-Up Process

14. To what extent do you agree or disagree with each of the following statements about the installation and set-up process?

	strongly agree	somewhat agree	somewhat disagree	strongly disagree	don't know	not applicable
It was easy to schedule the appointment to install the smart controller	1	2	3	4	5	6
The installer showed up on time	1	2	3	4	5	6
The installer provided a good explanation of the smart controller	1	2	3	4	5	6
The installer could not answer my questions about the smart controller	1	2	3	4	5	6
The installer did a professional job	1	2	3	4	5	6
The smart controller was installed where I wanted it to be	1	2	3	4	5	6
The irrigation schedule set-up seemed appropriate for the landscape being watered	1	2	3	4	5	6
The smart controller worked immediately after it was installed and set up	1	2	3	4	5	6
There have been problems with the smart controller since installation	1	2	3	4	5	6
The problems with the smart controller have been resolved (if applicable)	1	2	3	4	5	6
Overall, I was pleased with the installation and set-up process	1	2	3	4	5	6

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15. Have you changed the programmed watering schedule since installation?

- ❑ No
- ❑ Yes → **Why did you change it? (Please indicate all that apply.)**
  - ❑ It underwatered
  - ❑ I didn't trust its performance
  - ❑ It overwatered
  - ❑ Other _______________

  How easy or difficult was it to change the programming?
  - ❑ Very easy
  - ❑ Somewhat easy
  - ❑ Neither easy nor difficult
  - ❑ Somewhat difficult
  - ❑ Very difficult

If your smart controller was installed by a manufacturer representative or an installer from the water utility, please go to question #25

SELF-INSTALLATION AND SET-UP PROCESS

If you, a family member, a staff member or a hired contractor installed the smart controller, please answer questions #16 through #18, and then continue with the survey with question #19.

16. To what extent do you agree or disagree with each of the following statements about the self-installation process?

	strongly agree	somewhat agree	somewhat disagree	strongly disagree	don't know	not applicable
The installation instructions were clear	1	2	3	4	5	6
It was difficult to install the smart controller	1	2	3	4	5	6
I was able to successfully install the smart controller	1	2	3	4	5	6
The smart controller was installed where I wanted it to be	1	2	3	4	5	6
It was easy to understand the smart controller programming instructions	1	2	3	4	5	6
Setting the irrigation schedule was easy	1	2	3	4	5	6
The smart controller worked immediately after it was installed and set-up	1	2	3	4	5	6
There have been problems with the smart controller since installation	1	2	3	4	5	6
The problems with the smart controller have been resolved (if applicable)	1	2	3	4	5	6
Overall, I was pleased with the installation and set-up process	1	2	3	4	5	6

17. Did you need to ask for assistance with the installation process or set-up of the irrigation schedule?

- ❑ No → *go to question #32*
- ❑ Yes → **Did someone come out to the site to assist you?**
  - ❑ No
  - ❑ Yes → **Who came?**
    - ❑ A manufacturer representative
    - ❑ A professional installer from the water utility
    - ❑ Other: ____________________

18. How satisfied were you with the installation or set-up assistance you received?

- ❑ Very satisfied
- ❑ Somewhat satisfied
- ❑ Somewhat dissatisfied
- ❑ Very dissatisfied
- ❑ Don't know

MORE ABOUT THE INSTALLATION PROCESS

19. How long did the installation and set-up of the smart controller take?

_______ hours and _______ minutes

20. How would you rate the amount of time the installation of the smart controller took?

- ❑ About right
- ❑ Somewhat too long
- ❑ Far too long
- ❑ Don't know

21. Did you follow the manufacturer's instructions for setting the watering schedule for the smart controller?

❑ Yes ❑ No → **How did you program the smart controller schedule?**

- ❑ Changed the schedule
- ❑ Changed the site information
- ❑ Changed the weather input
- ❑ Changed the landscape information
- ❑ Other ________________

22. Have you called the smart controller manufacturer for technical support on installation or setting the irrigation schedule?

❑ Yes ❑ No → *go to question #24*

23. How would you rate the support you received?

- ❑ Excellent
- ❑ Good
- ❑ Fair
- ❑ Poor

24. How confident are you that the irrigation schedule set for your smart controller is correct?

- ❑ Very confident
- ❑ Somewhat confident
- ❑ Not very confident
- ❑ Don't know

ABOUT YOUR PROPERTY AND LANDSCAPE

25. Is the property where the smart controller was installed a . . .

- ❑ Single-family private residence
- ❑ Multi-family housing complex (e.g., apartments or condominiums/townhouses)
- ❑ Park, playground, or median
- ❑ Commercial, industrial or institutional property → Type ________________

26. Are any of the following a part of the outdoor landscape?

	yes	no
Outdoor swimming pool	❑	❑
Outdoor spa/hottub	❑	❑
Recirculating water feature (e.g., fountain)	❑	❑
Non-recirculating water feature	❑	❑

27. Which best describes the landscape watered by the irrigation system for which the smart controller was installed?

- ❑ 100% grass/turf → *go to question #29*
- ❑ 75% grass/turf
- ❑ 25% grass/turf
- ❑ 0% grass/turf

28. Please describe the sections of the landscape watered by the irrigation system for which the smart controller was installed that are not grass or turf by selecting all that apply:

- ❑ Trees
- ❑ Shrubs
- ❑ Flower gardens/beds
- ❑ Vegetable gardens/beds
- ❑ Low-water use plants
- ❑ Ground cover (non-grass)
- ❑ Other ____________________

29. What percentage of the watered landscape is usually watered manually and what percent by the automatic irrigation system? (Do not include portions not watered at all.)

Percent watered manually: .... _________%

Percent watered by irrigation system: .. _________%

Total: .... _________%

30. Are any areas hand-watered that are covered by the irrigation system for which the smart controller was installed?

- ❑ No
- ❑ Yes → **Why?** ________________________

31. How is your landscaping maintained? (Please indicate all that apply.)

- ❑ Self
- ❑ Mowing service
- ❑ Full landscape service
- ❑ Other ________________________

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IRRIGATION SYSTEM CHANGES

32. What changes, if any, were made to your irrigation system at the time the smart controller was installed? (Please indicate all that apply.)

- ❑ Repaired broken sprinkler heads/nozzles
- ❑ Repaired broken drip emitters
- ❑ Capped unnecessary sprinkler head(s)
- ❑ Capped unnecessary drip emitter(s)
- ❑ Changed out sprinkler heads/nozzles
- ❑ Changed out drip emitters
- ❑ Adjusted the spray heads
- ❑ Repaired system leaks
- ❑ Adjusted system to eliminate overspray
- ❑ Changed all sprinklers within a zone to the same sprinkler type
- ❑ Added a sprinkler and/or drip emitter to irrigate a dry spot............ how many? ____________
- ❑ Repaired broken valve(s)........................... how many? ____________
- ❑ Added new zone(s) .... how many? ____________
- ❑ Removed a zone(s) .... how many? ____________
- ❑ Other ________________________________

____

33. What changes, if any, have been made to your irrigation system in the last year after the installation of the smart controller(s)? (Please indicate all that apply. Do not include changes made at the time of installation.)

- ❑ Repaired broken sprinkler heads/nozzles
- ❑ Capped unnecessary sprinkler head(s)
- ❑ Changed out sprinkler heads/nozzles
- ❑ Adjusted the spray heads
- ❑ Repaired system leaks
- ❑ Repaired broken valve(s) → how many? ________
- ❑ Added new zone(s) → how many? ____________
- ❑ Removed a zone(s) → how many? ____________
- ❑ Other ________________________________

EXPERIENCE WITH THE SMART CONTROLLER TECHNOLOGY

34. To what extent do you agree or disagree with each of the following statements your experience with the smart controller(s)?

	strongly agree	somewhat agree	somewhat disagree	strongly disagree	don't know	not applicable
The smart controller(s) have performed without any glitches..................	1	2	3	4	5	6
The glitches with the smart controller(s) have been resolved (if applicable)	1	2	3	4	5	6
Using the smart controller(s) has helped us to save water......................	1	2	3	4	5	6
The smart controller is a labor saving device	1	2	3	4	5	6

35. Have you called the smart controller manufacturer for technical support in the past year?

❑ No ❑ Yes → **How would you rate the support you received?**

- ❑ Excellent
- ❑ Good
- ❑ Fair
- ❑ Poor

36. Have you called the [water utility] for technical support in the past year?

❑ No ❑ Yes → **How would you rate the support you received?**

- ❑ Excellent
- ❑ Good
- ❑ Fair
- ❑ Poor

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THE SMART CONTROLLER PROGRAM OFFERED BY YOUR WATER UTILITY

37. What type of incentive did you receive from your local water utility for the smart controller? (Please indicate all that apply; rebates are programs where some or all of the purchase price is refunded after the time of purchase; a voucher is a certificate that can be redeemed at the time of purchase for some or all of the cost of the purchase.)

- ❑ A rebate for the entire purchase and installation costs of the smart controller
- ❑ A rebate for the entire purchase costs of the smart controller
- ❑ A voucher for the entire purchase and installation costs of the smart controller
- ❑ A voucher for the entire purchase costs of the smart controller
- ❑ Free installation of the smart controller
- ❑ A rebate for a portion of the purchase and installation costs of the smart controller
- ❑ A rebate for a portion of the purchase costs of the smart controller
- ❑ A voucher for a portion of the purchase and installation costs of the smart controller
- ❑ A voucher for a portion of the purchase costs of the smart controller
- ❑ A free smart controller provided by the water agency
- ❑ Rebates for the signal fee cost
- ❑ Some other incentive________________________________
- ❑ Don't know

38. How satisfied or dissatisfied were you with the following aspects of the smart controller program offered by your local water utility?

	very satisfied	somewhat satisfied	somewhat dissatisfied	very dissatisfied	don't know	not applicable
The amount of the voucher, rebate or other financial incentive	1	2	3	4	5	6
The helpfulness of the local water utility staff when I first contacted them about the program	1	2	3	4	5	6
The helpfulness of the staff throughout the entire process	1	2	3	4	5	6
The "turn-around" time from my first contact to installation of the smart controller	1	2	3	4	5	6
The amount of information provided about the smart controller program	1	2	3	4	5	6
The ease of completing the smart controller program paperwork	1	2	3	4	5	6

	very likely	somewhat likely	somewhat unlikely	very unlikely	don't know
39. How likely or unlikely would you have been to purchase the controller without the rebate, voucher or other incentive program offered by your water utility?	1	2	3	4	5
40. How likely or unlikely would you be to recommend the smart controller program to a neighbor, friend or co-worker?	1	2	3	4	5
41. How likely or unlikely would you be to recommend a smart controller to a neighbor, friend or co-worker?	1	2	3	4	5

California Smart Controller Programs Customer Survey
National Research Center, Inc.

42. How would you rate each of the following characteristics of your new smart controller compared to your old controller?

	much better	somewhat better	about the same	somewhat worse	much worse	not applicable
Reliability	1	2	3	4	5	6
Performance of the controller (how well it waters the landscape)	1	2	3	4	5	6
Water-efficiency of the controller (uses less water)	1	2	3	4	5	6
Understanding of how to use it	1	2	3	4	5	6
Ease of use overall	1	2	3	4	5	6
Ease of programming the watering schedule	1	2	3	4	5	6
Overall satisfaction	1	2	3	4	5	6

43. What improvements, if any, would you recommend to the water utilities for the smart controller program?

____

____

____

44. What improvements, if any, would you recommend to the manufacturer of your smart controller?

____

____

____

Thank you very much for participating in this survey.
Please send this questionnaire in the enclosed postage-paid envelope to:
National Research Center, Inc., 3005 30th Street; Boulder, CO 80301

Agency Survey Instrument

Participating Agency Preliminary Interview Script

Agency: ______________________________	Respondent:
Telephone: ____________________________	e-mail
Interviewed by: ________________________	Date:

INTRODUCTION:

Thank you for agreeing to talk with me. I anticipate that this interview will last about 30 to 60 minutes, and appreciate any information you can provide.

As you know, we are helping to evaluate the weather-based irrigation controller programs being implemented in California. A very important part of this evaluation is a customer satisfaction survey of those who have participated in these WBIC programs. Thus, the major goal for our conversation today is to understand how to make the customer survey process work for your agency and its programs.

In addition, as a part of the evaluation we are not only examining the potential water savings that may be realized by this technology, we are also looking at how each utility program has been implemented, the costs associated with implementing a program to increase utilization of this technology, and what parts of the process are going smoothly and what obstacles may have been encountered. To help with the interim progress report, it would be helpful if you could complete the interim worksheet we sent to you.

It is helpful for accuracy and data analysis to make an audio recording your responses. Is it okay if I record this interview?

[GET CONSENT]

[NOTE TO INTERVIEWERS: QUESTIONS MARKED WITH AN ASTERISK ARE THOSE WHERE AT LEAST PART OF THE QUESTION CAN BE ANSWERED FROM THE WORKSHEET.]

First, I'd like to start by having you describe the WBIC program as it is being implemented by your agency.

When did the program start?

What WBIC technologies are included?

Briefly describe how your program works (or will work).

Do you have a rebate program where a customer buys a WBIC, submits a receipt to the utility and receives a cash rebate.

Or do you have an agency distribution program where the agency buys and distributes WBICs and perhaps installs them (or pays someone to install them).

Who does the installations?

What types of incentives are offered?

Do you maintain records of the customers who have participated in your programs? (names, addresses, customer type, etc)

Is this program being implemented by your agency alone or are you working with other agencies? If yes, please describe the nature of your cooperation (i.e. distribution, marketing, installation, etc.?

Do you require non-homeowner (3rd party) installers to obtain training prior to allowing them to participate in the program?

If so, please describe.

Tell me about what types of customers you are targeting for this program, and how they are recruited.

What types of customers are targeted (for example, residential, commercial, municipal, other)?

Do you target potential customer on the basis of their water use? (in other words to you attempt to find candidate customers who are heavy irrigators?)

Do you target on the basis of irrigated area, or lot size?

Are you seeing different kinds of customers participating in the program than originally anticipated? If so, why?

What types of marketing programs do you use to recruit participants? (How do potential participants learn about the program?)

Direct mail, radio, print advertising, television ? etc

How has this changed since you first began implementing the program?

Have you had problems recruiting customers?

Any other issues in recruiting customers?

Now I want to discuss the customer survey questionnaire and process with you.

In looking at the customer survey you should have received at the end of December, tell me how well it will work "as is" for all the customers participating in your program.

Do we need different surveys/parts for different programs?

How will you provide contact information for your WBIC program participants? If there are multiple programs, how will you identify which program they participated in (i.e., what survey we should send)?

What name(s) should we use to identify the program in the cover letter?

Who would be the signatory on the cover letter? What is that person's title?

Do you want to participate in the incentive? (for which programs?)

In order to customize the survey, I need an electronic copy of your logo and/or letterhead. I also need an electronic copy of the signature. If you don't have an electronic one, than I need you to fax me the signature, and I will scan it in. By when will you be able to give me these items?

That's all my questions. Thank you very much for your time. Your responses are very important to this project.

Sometimes, individuals we interview have additional comments they'd like to make after the end of the call. If in the next few days, you feel there is additional information you'd like to share with me, here's my phone number if you'd like to give me a call, 1-877-467-2462. Again, my name is ______. Thanks for participating in the survey.

Agency Progress and Cost Reporting Worksheet (Interim, as of January 2006)

Item	Amount
INSTALLATION PROCESS	
How many WBIC units have been installed through your program?	__________________ *units*
At about how many **sites** have WBIC units been installed through your program?	__________________ *sites*
What is the total number of WBIC units expected to be installed through your program?	__________________ *units*
What is the total number of WBIC **sites** expected to be installed through your program?	__________________ *sites*
What was the total number of WBIC units **originally** expected to be installed through your program?	__________________ *units*
At about how many sites were repairs or other interventions performed on the irrigation systems?	__________________ *sites*
For about what percent of installations do you receive customer maintenance calls and questions?	__________________ *%*
AGENCY INVESTMENT IN THE WBIC PROGRAM	
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	__________________ *person-hours*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	__________________ *person-hours*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	__________________ *person-hours*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	__________________ *person-hours*
About how much money has your agency invested in the program thus far?	$__________________

APPENDIX F – CUSTOMER SATISFACTION SURVEY RESPONSES

This appendix contains the complete set of results from the Customer Satisfaction Survey.

Overall, how satisfied are you with the performance of the smart controller(s)?	**Percent of Respondents**	**Number of Respondents**
very satisfied	45.9%	N=612
somewhat satisfied	33.4%	N=445
somewhat dissatisfied	9.5%	N=127
very dissatisfied	8.5%	N=113
don't know	2.8%	N=37
Total	100.0%	N=1334

Health of landscape before and after installation of smart controller	**excellent**	**good**	**fair**	**poor**	**too soon to tell**	**N/A**	**Total**	
How would you rate the health or quality of your landscaping ***before*** installation of the smart controller(s)?	13.2%	58.1%	25.8%	2.9%	0.0%	0.0%	100.0%	N=1336
How would you rate the health or quality of your landscaping ***after*** installation of the smart controller(s)?	23.9%	58.5%	13.4%	4.2%	0.0%	0.0%	100.0%	N=1318

By when, if at all, do you expect to recover the costs of purchasing and installing the smart controller?	**Percent of Respondents**	**Number of Respondents**
more than 5 years	6.2%	N=79
about 4 years	2.9%	N=37
about 3 years	4.4%	N=57
about 2 years	4.9%	N=63
about 1 year	5.7%	N=73
no costs -- smart controller and installation were free	75.9%	N=972
Total	100.0%	N=1281

The cover letter indicates the make, model and number of the smart controller(s) installed on the property. Is this information correct?	Percent of Respondents	Number of Respondents
Yes	84.7%	N=1070
not sure	10.8%	N=136
No	4.5%	N=57
Total	100.0%	N=1263

Does your smart controller have an external sensor?	Percent of Respondents	Number of Respondents
don't know	8.2%	N=83
No	9.9%	N=100
yes	81.8%	N=824
Total	100.0%	N=1007

What type of sensor(s) is it?	Percent of Respondents	Number of Respondents
Rain sensor	78.0%	N=622
Temperature sensor	22.3%	N=178
Solar sensor	13.0%	N=104
Soil moisture sensor	3.1%	N=25
Don't know	8.4%	N=67
Other	2.6%	N=21
Total*	100.0%	N=797

**Actual totals will equal more than 100% as respondents could give more than one answer*

Why did you (or the organization for which you work) decide to install a smart controller?	**Percent of Respondents**	**Number of Respondents**
It was free	65.1%	N=871
Saves time and effort	30.6%	N=409
Saves money	46.0%	N=615
Water efficiency for myself or my organization	57.3%	N=766
Environmental benefits	48.1%	N=643
Improved landscape health/benefit	31.2%	N=417
Liked the new technology	36.2%	N=484
Needed a new controller	12.4%	N=166
There was a controller exchange program	45.4%	N=607
Incentive program offered by the utility	26.1%	N=349
To avoid watering during rainstorms	45.1%	N=603
Automatic scheduling to avoid having to change the program when weather changes	51.5%	N=689
Other	3.4%	N=45
Because of the controller exchange program	3.1%	N=41
Total*	100.0%	N=1337

**Actual totals will equal more than 100% as respondents could give more than one answer*

Which, if any, of the following do you perceive as a benefit of having a smart controller?	**Percent of Respondents**	**Number of Respondents**
Saves time and effort	52.7%	N=661
Makes programming the settings easier	33.5%	N=420
Saves money	49.0%	N=614
Water-efficient	80.7%	N=1012
Cost-efficient	37.4%	N=469
Improves the health of the landscape	34.9%	N=438
Other	7.1%	N=89
Total*	100.0%	N=1254

**Actual totals will equal more than 100% as respondents could give more than one answer*

What influenced you to select your particular irrigation controller model?	**Percent of Respondents**	**Number of Respondents**
Price	20.1%	N=267
Helped me set correct schedule	7.7%	N=102
Recommendation	16.3%	N=216
Advertising	5.6%	N=75
Only one offered on rebate, voucher, or exchange program	54.7%	N=727
Features	15.7%	N=209
No fee for signal	6.7%	N=89
Other	10.4%	N=138
Total*	100.0%	N=1328

**Actual totals will equal more than 100% as respondents could give more than one answer*

How did you hear about the smart controller program?	Percent of Respondents	Number of Respondents
Utility bill insert	38.4%	N=501
Solicitation letter	12.7%	N=166
Newspaper article	18.5%	N=241
Newspaper advertisement	6.4%	N=83
A public service announcement on the radio or television	1.7%	N=22
Friend, neighbor or coworker	16.0%	N=209
Irrigation contractor/professional	4.7%	N=62
Lawn maintenance service	.5%	N=7
Other	1.4%	N=18
Landscape education class (e.g. "Protector del Agua")	14.5%	N=189
Total*	100.0%	N=1306

**Actual totals will equal more than 100% as respondents could give more than one answer*

Did you choose a model for which you have to pay a signaling fee?	Percent of Respondents	Number of Respondents
no	87.1%	N=686
yes	12.9%	N=102
Total	100.0%	N=788

Did a signaling fee influence your choice of controller?	Percent of Respondents	Number of Respondents
Signal fee did not impact my decision	48.4%	N=179
I chose a controller with signal fee because the potential benefits outweigh the extra cost	11.9%	N=44
I chose one without a signal fee because the fee makes the controller too expensive over the long term	25.4%	N=94
The water agency is paying for the signaling fee	10.5%	N=39
Other reason(s)	8.9%	N=33
Total*	100.0%	N=370

**Actual totals will equal more than 100% as respondents could give more than one answer*

Will you continue to pay for it after the program ends?	Percent of Respondents	Number of Respondents
yes	19.6%	N=9
no	47.8%	N=22
not sure	32.6%	N=15
Total	100.0%	N=46

Who installed and set-up your new smart controller?	**Percent of Respondents**	**Number of Respondents**
Self	61.7%	N=780
Other family member	6.0%	N=76
Manager or owner's staff	1.7%	N=22
Manager or owner's hired contractor/electrician/handyman	8.2%	N=104
A manufacturer representative	2.1%	N=26
A professional installer from the water utility	11.4%	N=144
Other	8.1%	N=102
A landscape contractor	.9%	N=11
Total	100.0%	N=1265

To what extent do you agree or disagree with each of the following statements about the installation process?	strongly agree	somewhat agree	somewhat disagree	strongly disagree	don't know	N/A	Total	
The installation instructions were clear	35.1%	42.8%	7.4%	5.0%	3.3%	6.4%	100.0%	N=1121
It was difficult to install the smart controller	6.4%	15.3%	23.8%	38.3%	4.2%	12.0%	100.0%	N=1080
I was able to successfully install the smart controller	59.3%	18.4%	3.2%	3.2%	1.5%	14.3%	100.0%	N=1060
It was easy to understand the smart controller programming instructions	27.9%	38.9%	18.2%	11.9%	1.3%	1.9%	100.0%	N=1111
Setting the irrigation schedule was easy	14.0%	27.9%	26.4%	26.3%	2.0%	3.4%	100.0%	N=707
Setting the irrigation schedule was difficult	9.7%	23.2%	24.2%	31.4%	3.6%	7.9%	100.0%	N=392
It was easy to schedule the appointment to install the smart controller	29.2%	30.8%	6.7%	8.3%	.8%	24.2%	100.0%	N=120
The installer showed up on time	49.4%	25.0%	.6%	6.7%	.6%	17.7%	100.0%	N=164
The installer provided a good explanation of the smart controller	36.0%	26.8%	11.0%	6.7%	1.2%	18.3%	100.0%	N=164
The installer could not answer my questions about the smart controller	7.1%	14.9%	13.6%	37.0%	4.5%	22.7%	100.0%	N=154
The installer did a professional job	49.6%	15.6%	3.1%	3.3%	2.4%	26.1%	100.0%	N=456
The irrigation schedule set-up seemed appropriate for the landscape being watered	39.5%	31.5%	11.7%	8.0%	1.2%	8.0%	100.0%	N=162
The smart controller was installed where I wanted it to be	72.0%	18.9%	2.5%	1.2%	1.0%	4.5%	100.0%	N=1234
The smart controller worked immediately after it was installed and set-up	53.2%	25.7%	8.5%	8.4%	1.8%	2.2%	100.0%	N=983
There have been problems with the smart controller since installation	16.1%	20.1%	9.8%	44.5%	2.6%	7.0%	100.0%	N=1208
The problems with the smart controller have been resolved (if applicable)	18.9%	17.5%	6.8%	12.3%	3.2%	41.3%	100.0%	N=1053
Overall, I was pleased with the installation and set-up process	48.4%	33.5%	7.9%	7.1%	.7%	2.4%	100.0%	N=1247

Have you changed the programmed watering schedule since installation?	Percent of Respondents	Number of Respondents
no	31.5%	N=51
yes	68.5%	N=111
Total	100.0%	N=162

Why did you change it?	Percent of Respondents	Number of Respondents
It underwatered	51.9%	N=56
I didn't trust its performance	13.9%	N=15
It overwatered	30.6%	N=33
Other	20.4%	N=22
Total*	100.0%	N=108

**Actual totals will equal more than 100% as respondents could give more than one answer*

How easy or difficult was it to change the programming?	Percent of Respondents	Number of Respondents
very easy	23.0%	N=26
somewhat easy	28.3%	N=32
neither easy nor difficult	14.2%	N=16
somewhat difficult	19.5%	N=22
very difficult	15.0%	N=17
Total	100.0%	N=113

Did you need to ask for assistance with the installation process or set-up of the irrigation schedule?	Percent of Respondents	Number of Respondents
no	61.4%	N=732
yes	38.6%	N=461
Total	100.0%	N=1193

Did someone come out to the site to assist you?	Percent of Respondents	Number of Respondents
no	40.0%	N=170
yes	60.0%	N=255
Total	100.0%	N=425

Who came?	Percent of Respondents	Number of Respondents
A manufacturer representative	21.9%	N=59
A professional installer from the water utility	41.3%	N=111
Other	36.8%	N=99
Total	100.0%	N=269

How satisfied were you with the installation or set-up assistance you received?	Percent of Respondents	Number of Respondents
very satisfied	59.0%	N=281
somewhat satisfied	21.2%	N=101
somewhat dissatisfied	8.6%	N=41
very dissatisfied	7.4%	N=35
don't know	3.8%	N=18
Total	100.0%	N=476

How long did the installation and set-up of the smart controller take?	Average	Minimum	25th Percentile	Median (50th Percentile)	75th Percentile	Maximum	Number of Respondents
How long did the installation and set-up of the smart controller take?	2:44	0:00	1:00	2:00	3:00	45:00	N=1032

How would you rate the amount of time the installation of the smart controller took?	Percent of Respondents	Number of Respondents
about right	71.2%	N=824
somewhat too long	14.5%	N=168
far too long	5.4%	N=62
don't know	8.9%	N=103
Total	100.0%	N=1157

Did you follow the manufacturer's instructions for setting the watering schedule for the smart controller?	Percent of Respondents	Number of Respondents
yes	84.8%	N=958
no	15.2%	N=172
Total	100.0%	N=1130

How did you program the smart controller schedule? (if did not follow manufacturer's instructions	Percent of Respondents	Number of Respondents
Changed the schedule	48.7%	N=76
Changed the site information	10.9%	N=17
Changed the weather input	5.1%	N=8
Changed the landscape information	23.7%	N=37
Other	25.6%	N=40
Total	100.0%	N=156

Have you called the smart controller manufacturer for technical support on installation or setting the irrigation schedule?	Percent of Respondents	Number of Respondents
yes	29.0%	N=343
no	71.0%	N=840
Total	100.0%	N=1183

How would you rate the support you received?	Percent of Respondents	Number of Respondents
excellent	51.9%	N=167
good	26.4%	N=85
fair	11.2%	N=36
poor	10.6%	N=34
Total	100.0%	N=322

How confident are you that the irrigation schedule set for your smart controller is correct?	Percent of Respondents	Number of Respondents
very confident	39.2%	N=447
somewhat confident	40.0%	N=456
not very confident	16.1%	N=183
don't know	4.7%	N=53
Total	100.0%	N=1139

Is the property where the smart controller was installed a . . .	Percent of Respondents	Number of Respondents
single-family private residence	95.6%	N=1222
multi-family housing complex	1.6%	N=20
park, playground or median	1.3%	N=17
commercial, industrial or institutional property	1.5%	N=19
Total	100.0%	N=1278

Are any of the following a part of the outdoor landscape?	yes	no	Total	
Outdoor swimming pool	29.1%	70.9%	100.0%	N=1136
Outdoor spa/hottub	29.2%	70.8%	100.0%	N=1107
Recirculating water feature (e.g., fountain)	26.1%	73.9%	100.0%	N=1093
Non-recirculating water feature	5.7%	94.3%	100.0%	N=966

Which best describes the landscape watered by the irrigation system for which the smart controller was installed?	**Percent of Respondents**	**Number of Respondents**
100% grass/turf	14.3%	N=182
75% grass/turf	50.9%	N=650
25% grass/turf	27.1%	N=346
0% grass/turf	7.8%	N=99
Total	100.0%	N=1277

Please describe the sections of the landscape watered by the irrigation system for which the smart controller was installed that are not grass or turf by selecting all that apply:	**Percent of Respondents**	**Number of Respondents**
Trees	71.5%	N=796
Shrubs	84.8%	N=945
Flower gardens/beds	78.1%	N=870
Vegetable gardens/beds	22.4%	N=250
Low-water use plants	33.3%	N=371
Ground cover (non-grass)	41.3%	N=460
Other	2.9%	N=32
Total*	100.0%	N=1114

**Actual totals will equal more than 100% as respondents could give more than one answer*

What percentage of the watered landscape is usually watered manually and what percent by the automatic irrigation system? (Do not include portions not watered at all.)	**Average Percent**
Percent watered manually	10%
Percent watered by irrigation system	90%
Total	N=1351

Are any areas hand-watered that are covered by the irrigation system for which the smart controller was installed?	**Percent of Respondents**	**Number of Respondents**
no	81.5%	N=981
yes	18.5%	N=223
Total	100.0%	N=1204

How is your landscaping maintained? (Please indicate all that apply.)	**Percent of Respondents**	**Number of Respondents**
Self	58.6%	N=689
Mowing service	32.8%	N=385
Full landscape service	23.7%	N=278
Other	5.1%	N=60
Total*	100.0%	N=1175

**Actual totals will equal more than 100% as respondents could give more than one answer*

What changes, if any, were made to your irrigation system at the time the smart controller was installed? (Please indicate all that apply.)	Percent of Respondents	Number of Respondents
None indicated	40.2%	N=543
Repaired broken sprinkler heads/nozzles	24.8%	N=335
Repaired broken drip emitters	7.9%	N=107
Capped unnecessary sprinkler head(s)	10.9%	N=147
Capped unnecessary drip emitter(s)	3.3%	N=44
Changed out sprinkler heads/nozzles	18.1%	N=244
Changed out drip emitters	4.1%	N=55
Adjusted the spray heads	31.3%	N=423
Repaired system leaks	11.9%	N=161
Adjusted system to eliminate overspray	24.6%	N=333
Changed all sprinklers within a zone to the same sprinkler type	4.6%	N=62
Added a sprinkler and/or drip emitter to irrigate a dry spot	7.2%	N=97
Repaired broken valve(s)	8.8%	N=119
Added new zone(s)	7.6%	N=103
Removed a zone(s)	2.6%	N=35
Other	7.2%	N=97
Total*	100.0%	N=1351

**Actual totals will equal more than 100% as respondents could give more than one answer*

What changes, if any, have been made to your irrigation system in the last year after the installation of the smart controller(s)? (Please indicate all that apply. Do not include changes made at the time of installation.)	Percent of Respondents	Number of Respondents
None indicated	30.3%	N=409
Repaired broken sprinkler heads/nozzles	42.3%	N=571
Capped unnecessary sprinkler head(s)	10.1%	N=137
Changed out sprinkler heads/nozzles	24.0%	N=324
Adjusted the spray heads	43.4%	N=586
Repaired system leaks	19.6%	N=265
Repaired broken valve(s)	13.1%	N=177
Added new zone(s)	6.1%	N=82
Removed a zone(s)	1.9%	N=26
Other	6.1%	N=83
Total*	100.0%	N=1351

**Actual totals will equal more than 100% as respondents could give more than one answer*

To what extent do you agree or disagree with each of the following statements your experience with the smart controller(s)?	strongly agree	somewhat agree	somewhat disagree	strongly disagree	don't know	N/A	Total	
The smart controller(s) have performed without any glitches	36.9%	34.6%	12.5%	12.6%	2.1%	1.3%	100.0%	N=1305
The glitches with the smart controller(s) have been resolved (if applicable)	20.7%	23.2%	8.8%	11.8%	4.2%	31.3%	100.0%	N=1091
Using the smart controller(s) has helped us to save water	31.0%	32.9%	8.6%	9.6%	16.2%	1.7%	100.0%	N=1285
The smart controller is a labor saving device	40.3%	35.3%	7.4%	8.5%	5.5%	3.1%	100.0%	N=1262

Have you called the smart controller manufacturer for technical support in the past year?	Percent of Respondents	Number of Respondents
no	78.2%	N=1031
yes	21.8%	N=287
Total	100.0%	N=1318

How would you rate the support you received? [from the manufacturer]	Percent of Respondents	Number of Respondents
excellent	48.2%	N=136
good	28.7%	N=81
fair	12.8%	N=36
poor	10.3%	N=29
Total	100.0%	N=282

Have you called the [water utility] for technical support in the past year?	Percent of Respondents	Number of Respondents
no	87.8%	N=1154
yes	12.2%	N=161
Total	100.0%	N=1315

How would you rate the support you received? [from the water utility]	Percent of Respondents	Number of Respondents
excellent	54.8%	N=86
good	17.2%	N=27
fair	17.8%	N=28
poor	10.2%	N=16
Total	100.0%	N=157

What type of incentive did you receive from your local water utility for the smart controller? (Please indicate all that apply.)	Percent of Respondents	Number of Respondents
A rebate for the entire purchase and installation costs of the smart controller	4.9%	N=42
A rebate for the entire purchase costs of the smart controller	6.4%	N=55
A voucher for the entire purchase and installation costs of the smart controller	.5%	N=4
A voucher for the entire purchase costs of the smart controller	3.3%	N=28
Free installation of the smart controller	13.6%	N=116
A rebate for a portion of the purchase costs of the smart controller	1.9%	N=16
A voucher for a portion of the purchase costs of the smart controller	10.4%	N=89
A free smart controller provided by the water agency	1.6%	N=14
Rebates for the signal fee cost	6.8%	N=58
Some other incentive	53.3%	N=456
Don't know	.9%	N=8
Total*	9.3%	N=80

**Actual totals will equal more than 100% as respondents could give more than one answer*

How satisfied or dissatisfied were you with the following aspects of the smart controller program offered by your local water utility?	very satisfied	somewhat satisfied	somewhat dissatisfied	very dissatisfied	don't know	N/A	Total	
The amount of the voucher, rebate or other financial incentive	62.8%	14.1%	2.2%	1.0%	1.9%	18.1%	100.0%	N=1243
The helpfulness of the local water utility staff when I first contacted them about the program	65.3%	15.3%	3.4%	.9%	1.9%	13.3%	100.0%	N=1252
The helpfulness of the staff throughout the entire process	62.6%	19.4%	3.0%	1.0%	1.9%	12.2%	100.0%	N=1240
The "turn-around" time from my first contact to installation of the smart controller	50.9%	21.6%	3.9%	1.8%	1.9%	19.9%	100.0%	N=1209
The amount of information provided about the smart controller program	52.0%	32.0%	6.4%	2.6%	2.1%	4.9%	100.0%	N=1258
The ease of completing the smart controller program paperwork	56.9%	27.3%	4.2%	1.3%	3.1%	7.2%	100.0%	N=1252
The amount of information available about choosing a controller	39.8%	39.0%	11.4%	7.3%	.8%	1.6%	100.0%	N=123

How likely or unlikely would you . . .	very likely	somewhat likely	somewhat unlikely	very unlikely	don't know	Total	
have been to purchase the controller without the rebate, voucher or other incentive program offered by your water utility?	6.9%	23.0%	26.8%	38.8%	4.5%	100.0%	N=1316
be to recommend the smart controller program to a neighbor, friend or co-worker?	53.9%	28.3%	6.2%	10.0%	1.7%	100.0%	N=1320
be to recommend a smart controller to a neighbor, friend or co-worker?	49.7%	30.1%	7.6%	10.9%	1.7%	100.0%	N=1293

How would you rate each of the following characteristics of your new smart controller compared to your old controller?	much better	somewhat better	about the same	somewhat worse	much worse	not applicable	Total	
Reliability	29.1%	21.7%	36.8%	4.3%	5.2%	3.0%	100.0%	N=1287
Performance of the controller (how well it waters the landscape)	35.9%	25.7%	26.8%	4.5%	4.4%	2.7%	100.0%	N=1286
Water-efficiency of the controller (uses less water)	40.8%	29.0%	17.1%	4.4%	4.6%	4.0%	100.0%	N=1260
Understanding of how to use it	19.7%	23.7%	26.3%	17.3%	10.5%	2.5%	100.0%	N=1290
Ease of use overall	25.9%	26.5%	22.8%	13.9%	8.3%	2.6%	100.0%	N=1284
Ease of programming the watering schedule	23.7%	23.8%	21.7%	16.7%	11.4%	2.7%	100.0%	N=1288

APPENDIX G – AGENCY SURVEY RESPONSES: 2006 INTERIM SMART CONTROLLER PROGRAM DESCRIPTIONS

Smart controller program descriptions were developed for the Interim Progress Report submitted to DWR at the mid-point of this project. The following summaries are from that report. Many of the programs changed during the later part of the implementation process and the numbers of controllers distributed increased. Those changes are not reflected in this appendix. Summaries of the programs implemented in northern and southern California along with the number of smart controllers distributed are provided in the body of the report.

Summary of Southern California Agency Smart Controller Programs (2006)

Agency: Central Basin Municipal Water District

Type of customers targeted: Large landscapes; large water users whose water use is above the water allocation. Primarily cities, water agencies and HOAs.

WBIC technologies included: HydroEarth.

Program start date: October 2004

Type of incentive or rebate: The end user receives equipment, programming and installation, and pays $1 per valve for management services.

Who else is involved in addition to agency: HydroEarth.

Marketing and recruitment strategies: A direct, targeted approach, whereby the manufacturer directly contacts potential customers.

Program description: The end user receives a server, the controllers and the communication system. They also receive installation of the controllers by the manufacturer. The customer is charged $1 per valve.

Program or marketing & recruitment challenges: CBMWD has had difficulty dedicating sufficient internal resources to the program. CBMWD expects to hire a vendor in the future to market the program more intensively and work with additional qualified vendors.

Central Basin Municipal Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	17 *units*	
At about how many **sites** have WBIC units been installed through your program?	6 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	6 *commercial sites* 0 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	30 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	10 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	60 *units*	*Funding reduced due to reallocation by MWD*
At about how many sites were repairs or other interventions performed on the irrigation systems?	*sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	10 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*person-hours*	*Customer service handled by HydroEarth*
About how much money has your agency invested in the program thus far?	$ 2,000	*Staff time only for meetings and site visits*
Through what date is this information current?	May 2006	

Agency: Eastern Municipal Water District

ET Controller Program (Commercial Direct Install)

Type of customers targeted: Commercial customers with an irrigation meter who have gone over their water budget.

Controller technologies included: AquaConserve, HydroEarth, and Toro.

Program start date: October 2004

Type of incentive or rebate: Free controller and installation.

Who else is involved in addition to agency: San Jacinto Conservation District

Marketing and recruitment strategies: Eastern staff member makes initial phone call, and then San Jacinto Conservation District staff follow up.

Program description: Eastern staff member initiates the communication with the targeted customer, often talking to several people until finding someone who knows about the landscape maintenance for the property. The Eastern staff member determines whether the customer does in-house maintenance, or contracts the maintenance. He explains the program lets them know that another contractor will be contacting them to schedule an appointment. However, if the landscape maintenance company is contracted, a customer representative and the landscape contractor need to be present for the appointment. San Jacinto Conservation District (SJCD) staff then schedule the appointment. At that time, an audit is performed and the square footage of landscape is measured. A report of needed repairs is created and given to the customer. Once the repairs are made, SJCD staff returns to make sure they have been completed. If necessary, this process goes on for a bit. Once the repairs are approved, the controller is ordered. The Eastern staff member hand delivers the controller to SJCD, who installs the controller for the customer. Eastern staff members inspect the controller after installation to ensure it has been installed correctly.

Program or marketing & recruitment challenges: No initial marketing or recruitment challenges. However, the process often bogs down once the report of needed repairs is sent to the customer. It is their responsibility to take care of those repairs. They may be having scheduling problems with their maintenance companies.

Eastern Municipal Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	64 *units*	78 pending verification
At about how many **sites** have WBIC units been installed through your program?	52 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	52 *commercial sites* 0 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	172 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	50 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	40 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	27 *sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	4.5 *%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	294 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	0 *person-hours*	outsourced
About how much time (person-hours) have contracted installers invested thus far in the installation process?	256 *person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	40 *person-hours*	
About how much money has your agency invested in the program thus far?	$20,000	
Through what date is this information current?	5/26/2006	

Agency: Foothill Municipal Water District

Program #1: Rebate program

Type of customers targeted: Residential and commercial.

Controller technologies included: All that meet the Irrigation Association definition.

Program start date: June 2005

Type of incentive or rebate: Pass through of amount from MWD and DWR.

Who else is involved in addition to agency: All water agencies in Foothill's service area.

Marketing and recruitment strategies: The water agencies are employing various strategies; one advertises on the web site, one puts it in the agency's newsletter, others rely on "word of mouth."

Program description: Customer of a member agency buys a qualified smart controller, submits application to the member agency, then receives a rebate. The member agency submits the information to Foothill, who in turn submits it to MWD.

Program or marketing & recruitment challenges: None reported

Program #2: Controller exchange program

Type of customers targeted: Residential

Controller technologies included: Weathermatic Smartline SL1600

Program start date: April 2006

Type of incentive or rebate: Free controller and training.

Who else is involved in addition to agency: Armstrong Nurseries, MWD's consultant and all local water agencies.

Marketing and recruitment strategies: The member agencies are employing various strategies; one advertises on the web site, one puts it in the agency's newsletter, others rely on "word of mouth." Press release was issued by MWD and picked up by some local newspapers.

Program description: Customer proves they are in Foothill's service area A toll-free number is set up for customers to register before the day of the distribution event The customer then goes at the time of the event, where they sign a release, turn in their old controller, have a short training on installation and programming, and get a new smart controller.

Program or marketing & recruitment challenges: None reported

Foothill Municipal Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	181 *units*	16 *rebate;* 165 *distribution (exchange) with MWD*
At about how many **sites** have WBIC units been installed through your program?	181 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	0 *commercial sites* 181 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	200 *units*	*with the exchange program*
What is the total number of WBIC **sites** expected to be installed through your program?	200 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	200 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	0 *sites*	*all rebate or exchange program -- self-install*
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	*Member agencies get the calls*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	5 *person-hours*	*it's all handled by the member agencies*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	0 *person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	0 *person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	0 *person-hours*	*calls would go to the member agencies*
About how much money has your agency invested in the program thus far?	$0	*it's all coming from MWD*
Through what date is this information current?	4/4/2006	

Agency: Los Angeles Department of Water and Power

Program #1: Direct Install Program

Type of customers targeted: Primarily residential customers with large lot size and high water use.

Controller technologies included: HydroPoint WeatherTRAK

Program start date: February 2004

Type of incentive or rebate: Free controllers and free installation

Who else is involved in addition to agency: An installation contractor.

Marketing and recruitment strategies: Larger lot size customers with good water use seasonality were identified. Targeted customers were sent a letter. There was also some word of mouth.

Program description: An appointment with targeted customers was set and pre-surveys completed to ensure the sites were suitable. At sites meeting the criteria, a controller was installed and programmed. The irrigation system was assessed and recommendations for changes were provided, although no actual changes were performed by the contracted installers.

Program or marketing & recruitment challenges: No big challenges, although it was conducted as a pilot. The program proved too costly to continue on an on-going basis. The mail-out of the letters was staged so as not to overwhelm the program.

Program #2: Controller Exchange Program

Type of customers targeted: Residential.

Controller technologies included: Accurate WeatherSet (a smart controller that uses an on-site weather sensor that includes solar radiation with a rain shutoff – no weather signal required).

Program start date: November 2005

Type of incentive or rebate: Exchange of old controller for new smart controller with short training on installation and programming. New controllers were provided to participating customers free of charge.

Who else is involved in addition to agency: Armstrong Nurseries, MWD staff, LADWP staff, consultant for training. Local community based organizations (CBOs). MWD did the heavy lifting for this event including administrative tasks, controller procurement, event planning and coordination. The CBOs provided limited customer outreach.

Marketing and recruitment strategies: Program flyer handed out at the local garden center two weeks prior to the event. The local CBOs handed out flyers. There was limited sign up. MWD and LADWP issued a press release and an article was written in the local daily newspaper. The article generated the most interest in the exchange program.

Program description: Program distribution was done at an Armstrong Nursery. Residential customers brought in their old controllers and exchanged them for a new one. Participants were scheduled appointments and attended a training session about how to install and program the controller and sensors before being given the smart controller.

Program or marketing & recruitment challenges: LADWP had a difficult time with recruitment until the newspaper article appeared. Then the voice mail system was overloaded with potential participants.

Los Angeles Department of Water & Power: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	620 *units*	*Includes the 120 distributed with MWD*
At about how many **sites** have WBIC units been installed through your program?	620 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	0 *commercial sites* 620 *residential sites*	*There may have been a few commercial, but targeted at SF residential*
What is the total number of WBIC units expected to be installed through your program?	700 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	700 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	6000 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	0 *sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	10 *%*	*it is a combination of the agency, contractor and manufacturer that receives the calls*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	20 *person-hours*	*contractor -- doesn't have an estimate* *agency -- about 15 hours*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	0 *person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	2000 *person-hours*	*contractor, about 2 hours per install -- 2,000*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	150 *person-hours*	*all agency*
About how much money has your agency invested in the program thus far?	$360,000	
Through what date is this information current?	5/31/2006	

Agency: Long Beach Water Department

Program #1:Residential? Rebate /agency installation program

Type of customers targeted: The program started out being available to all customers, but it is now targeted to those accounts that use the most water, and where LBWD has been allowed to go out and do a water audit on the property. The water audits are marketed to the residential customers that use the most water – that is, the single highest residential customer is offered a free audit, then the next highest, then the next, etc. The controller is marketed directly (letters and cold calls) to those high water users who participated in the audit.

Controller technologies included: AquaConserve

Program start date: December 2004

Type of incentive or rebate: Rebate and then moved to free smart controller and free installation. The rebate was set to cover the cost of the controller, but not to exceed $225.

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Recruitment through the residential audit program; cold calls to high water users; word of mouth.

Program description: Started as only a rebate program, where customer would receive a rebate when purchasing a new smart controller. Then moved into a more intensive program where staff person was more involved with the customers and provides the installation. They cold call selected accounts or they receive calls from interested customers. The program is also tied into the residential water audit program; for those customers participating in the water audit program, an offer is made of the smart controller where appropriate.

For all eligible customers, the staff member makes arrangements to visit the property and determine what equipment is needed. The existing controller is examined to determine how many stations there are, whether the controller needs to be installed inside or outside, whether the situation requires a wireless sensor and rain gage, or if it can use a wired one. The equipment is ordered on-site. Two to three days later, the staff member goes back to the property to install and program the smart controller. For those customers that received a water audit, the irrigated landscape area was measured.

Program or marketing & recruitment challenges: The rebate program was the first program and it wasn't advertised very heavily (two reasons: it's hard for the non-expert to know which controller to choose and where to buy it; and who to hire and how much to pay for the installation). Consequently it generated almost no interest. Program really took off once LBWD had a staff person responsible for the installations and the LBWD selected a single vendor for its installations. The contacts are carefully targeted so as not to overwhelm the agency.

Program #2: Large landscape program

Type of customers targeted: Large landscapes/irrigation accounts, e.g., parks, medians, school districts, HOAs

Controller technologies included: AquaConserve, ET Water

Program start date: July 2005

Type of incentive or rebate: Free smart controller and free installation

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: With most landscape irrigation accounts, agency contacts eligible accounts via mail and follow-up phone calls. With the school districts, agency worked closely school district staff throughout process to help insure its success; educating staff about WBICs, reviewing options, etc., chosen vendor was ET Water, which has an arrangement with "WeatherBug,". ET Water uses the signal from the WeatherBug so the kids' weather station controls the irrigation.

Program description: Selected accounts are contacted by the agency. The staff member makes arrangements to visit the property and determine what equipment is needed. The existing controller is examined to determine how many stations there are, whether the controller needs to be installed inside or outside, whether the situation requires a wire wireless weather and rain gage, or can use a wired one. The equipment is ordered on-site. Two to three days later, the staff member goes back to the property to install and program the smart controller. Irrigated areas were not measured as part of this program.

Program or marketing & recruitment challenges: None currently, carefully targeted so as not to overwhelm the agency

Program #3: Exchange program

Type of customers targeted: Residential customers participating in landscaping classes

Controller technologies included: AquaConserve with no signaling subscription,

Program start date: February 2006

Type of incentive or rebate: Exchange of old controller for new smart controller

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Exchange of the controllers is an added incentive to attend the landscaping classes. Marketing primarily in local newspaper and bill stuffer.

Program description: Customer attends 7 hours of irrigation and landscape design and maintenance classes. They bring in their old controller, and they are given a new smart controller, which they receive help programming during the last portion of the irrigation class.

Program or marketing & recruitment challenges: Limited number of controllers available required very careful approach to how "loud" advertise was. The exchange is a big incentive, class size went from about 35-40 to over 100. About 10% of the customers were clearly not capable of installing the new controller, so the agency had to do the install for them.

Long Beach Water Department: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	170 *units, but contracted to install 49 more with school district.*	*about*
At about how many **sites** have WBIC units been installed through your program?	140 *sites plus 26 more school sites*	*about*
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	2 *commercial sites* 138 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	350 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	300 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	75 *units*	*This number was before the April re-allocation of funds.*
At about how many sites were repairs or other interventions performed on the irrigation systems?	0 *sites*	*Require the customer have a well-working irrigation system before smart controller installed Recommendations for improving irrigation system done frequently but informally by knowledgeble installer.*
For about what percent of installations do you receive customer maintenance calls and questions?	5 *%*	*The questions usually involve programming of the controller.*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	800 *person-hours*	*Scheduler's hours*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	1100 *person-hours*	*Installer's hours*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	0 *person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	40 *person-hours*	*Includes call-backs, reprogram controller, etc.*
About how much money has your agency invested in the program thus far?	$180,000	*This includes cost of controller, of installation, scheduling installer, invoicing for rebate from MWD, etc.*
Through what date is this information current?	6/20/2006	

Agency: Pasadena Water and Power

Program #1: Large Landscapes

Type of customers targeted: Customers with large lots and/or high water use.

Controller technologies included: AquaConserve and HydroPoint

Program start date: September 2004

Type of incentive or rebate: Free controller and free installation.

Who else is involved in addition to agency: The manufacturers.

Marketing and recruitment strategies: Targeted customers were included in the program.

Program description: The controllers were provided by agency and installed by the manufacturer. Weekly visits are made to the customers, and issues responded to as they arise.

Program or marketing & recruitment challenges: Many customers are not familiar with the technology and do not understand how the controllers work or are installed.

Program #2: Controller Exchange Program

Type of customers targeted: Residential customers attending "Protector del Agua" training program.

Controller technologies included: Accurate WeatherSet and WeatherMatic Smartline SL1600

Program start date: March 2006

Type of incentive or rebate: Free controller and training.

Who else is involved in addition to agency: Consultant for training.

Marketing and recruitment strategies: Marketed as part of "Protector del Agua" class.

Program description: The controllers were provided through the "Protector del Agua" class and were free to participants with the exchange of their old controller.

Program or marketing & recruitment challenges: Many customers are not familiar with the technology.

Pasadena Water and Power (PWP): Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	35 *units*	*24 done in landscape classes with MWD*
At about how many **sites** have WBIC units been installed through your program?	29 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	2 *commercial sites* 27 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	13 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	7 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	5 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	5 *sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	60 *%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	85 *person-hours*	*2 people at 42.5 hours each –* *Started program in August 2004. Spend 45 minutes on marketing a week*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	70 *person-hours*	*2- 35 hours each. 2 personnel were out there at all of installations. Total installation time was 35 hrs, one full week.*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	35 *person-hours*	*2- 17.5 hrs each. 5 installations. Installations them self are 2 hrs each controller, but the set-up, meetings before hand, etc. are an addition 2 hrs each. Commercial Total= 20 hrs, Residential total= 15 hrs. Total of 1 installer at 35 hours*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	567 *person-hours*	*2 people- at 283.5 hours each 2 personnel spend at least 3 hours a week on WBIC issues. We visit sites, prepare reports for customer and address customer concerns. At 21 months (thus far), at about 3 hrs each week, at 4.5 weeks a month.*
About how much money has your agency invested in the program thus far?	$77,467	*For the 21 months thus far: Cost of controllers= $48,918.68 . We were reimbursed a certain amount from MWD. (AquCon=24,919.68 Hydroearth=23,999)* *Cost of misc. expenses (hiring landscapers to help modify, plumbers to address concerns, etc.) = $200.00. Cost of staff time= 2 staff at an average of 50/hr.=283.5 hrs total*2 people*50$hr=$28,350*
Through what date is this information current?	6/1/2006	

Agency: Western Municipal Water District

Type of customers targeted: Customers within each customer class that were above 200% of average

Controller technologies included:

AquaConserve
HydroPoint WeatherTRAK
Toro IntelliSense

Program start date: December 2004

Type of incentive or rebate: Free controller and free installation

Who else is involved in addition to agency: Rancho California Water District – program was implemented by Rancho staff within their service area. Contractor performing audits and installations

Marketing and recruitment strategies: 2,800 total properties (2,500 commercial, 300 residential) were identified. The contractor was given the list and began making direct contacts with the selected customers.

Program description: Once contacted, if the customer agrees to receive a new smart controller, an appointment is made and the contractor visits the property to perform a water audit and install the controller. During the audit an estimate of the irrigated area is made. The type of controller is chosen by the customer, from the three offered. The contractor is not supposed to make a recommendation. As a part of the water audit, the contractor may make recommendations or inform the property owner or manager of any problems, but does not make any adjustments.

Program or marketing & recruitment challenges: Anecdotally the agency has heard from the contractor that some customers decline in first few seconds because they think it's a sales call; the contractor feels it would help to have a letter in advance from the agency.

Western Municipal Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	*575 units*	
At about how many **sites** have WBIC units been installed through your program?	*277 sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	*74 commercial sites* *203 residential sites*	*HOAs and multi family dwellings are considered commercial sites*
What is the total number of WBIC units expected to be installed through your program?	*575 units*	*Grant funding has been exhausted*
What is the total number of WBIC **sites** expected to be installed through your program?	*277 sites*	*Grant funding has been exhausted*
What was the total number of WBIC units **originally** expected to be installed through your program?	*units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*0 sites*	*Although repair recommendations were made during the evaluation, the WBIC installation contractor was not allowed to make repairs beyond the controller. Some HOAs made efficiency improvements following WBIC installation.*
For about what percent of installations do you receive customer maintenance calls and questions?	*20-25 %*	*These numbers are skewed because of issues with one HOA with 71 controllers that needed firmware upgrades.*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	*person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*person-hours*	
About how much money has your agency invested in the program thus far?	$	
Through what date is this information current?		

Agency: San Diego County Water Authority

Program #1: Smart Landscape (Residential Voucher)

Type of customers targeted: Residential customers with a minimum of 2,000 square feet of irrigated landscape and with an existing irrigation controller and in-ground irrigation system.

Controller technologies included:

Residential:

Accurate WeatherSet - all models

Aqua Conserve - all ET Series

ET Water Systems - all models

HydroPoint Data Systems - all models (WeatherTRAK)

Irrisoft - all models (WeatherReach)

Irritrol - Smart Dial

Rain Master - Eagle

Toro IntelliSense

Weathermatic - Smartline, SL1600 with SLW10 or with SLW20

Program start date: March 2005

Type of incentive or rebate: Residential voucher for up to $65 off an approved controller. Increased incentive to $80 in February of 2006. Discontinued voucher in March.

Who else is involved in addition to agency: All the member agencies, a marketing company, and a contractor (Honeywell DMC) to administer the program. Program administration includes: processing the vouchers, acting as the call-in center, auditing compliance, and conducting site surveys.

Marketing and recruitment strategies: A marketing company produced promotional materials. Member agencies distribute materials via newsletters, bill stuffers, public events, web sites, etc. An occasional public service announcement plays on local radio, but mostly print media has been used.

Program description: Under the initial program SDCWA offered a voucher of $65 and the subsequent program offered a voucher of $80 per controller. Homeowners could receive a voucher for an approved smart irrigation controller by calling the designated 800 number. An on-site inspection verification visit was performed to ensure installation. In October of 2005 the Water Authority began testing the exchange distribution methodology for controllers. In January it redirected efforts to the distribution process. We allowed the voucher program to stay on-line through March for purposes of continuity.

Program or marketing & recruitment challenges: SDCWA realized they need to do a lot of marketing as it takes an intensive effort to recruit participants. It's a new technology for a lot of people, including the landscapers.

Program #2: Commercial, Industrial, Institutional Voucher Program

Type of customers targeted: Commercial customers with 2,000 square feet of irrigated land and an existing controller..

Controller technologies included:

Commercial:

Accurate WeatherSet - all models

AccuWater - all models

Aqua Conserve - all ET Series

Calsense - All ET1 and ET2000 models

ET Water Systems - all models

HydroEarth - all models (HydroSaver)

HydroPoint Data Systems - all models (WeatherTRAK)

Irrisoft - all models (WeatherReach)

Irritrol - Smart Dial

Rain Bird - All IM Series Models (must have ET option built-in)

Rain Bird - Maxicom

Rain Master - Eagle

Rain Master - Evolution DX2

Toro - IntelliSense, Sentinel, Site Pro

Water2Save - all models

Weathermatic - Smartline, SL1600 with SLW20, SL4800 with SLW20

Program start date: March 2005

Type of incentive or rebate: Up to $13.33 per active station. Increased to $15 per station (based on capacity) in February and then to $25 per station on July 5th.

Who else is involved in addition to agency: All the member agencies, a marketing company, and a contractor (Honeywell DMC) to administer the program (e.g., process the vouchers, act as the call-in center, audit compliance, etc. They also do the site surveys.) SDCWA's initial program required inspections at 100% of sites. Twenty five percent of the sites receiving the $25 per station incentive will be inspected.

Marketing and recruitment strategies: The marketing company produced the materials. Member agencies distribute materials via newsletters, bill stuffers, public events, web sites, etc. An occasional public service announcement is offered, but mostly print media is used.

Due to lack of participation SDCWA and MWD began meeting with manufacturers. After numerous discussions SDCWA determined a higher incentive was needed. It also became clear that manufacturers needed to be involved more heavily in training/certifying installers. Previous site inspections showed that installations/programming was less than desirable across the board. This new program places the onus on the manufacturers to train installers and provide us with a list of installers for their product. Only those products, for which SDCWA receives a manufacturer's list of installers, will be deemed eligible products. Manufacturers will be held responsible for programming/installation. If SDCWA observes a pattern of bad installations for any one particular product we will notify the manufacturer of the problem. If it persists, the product will be taken off the eligible products list.

Program description: Commercial customers can receive a voucher for up to $13.33 per active station for an approved, new weather based irrigation controller. In February it was bumped up to $15 per station.

New program details listed above. Only those sites using a licensed contractor on the list of certified trainers will be allowed to obtain a voucher.

Program or marketing & recruitment challenges: SDCWA realized they need to do a lot of marketing as it takes an intensive effort. It's a new technology for a lot of people, including the landscapers.

Program #3: Residential Distribution Program

Type of customers targeted: Residential customers

Controller technologies included:

Accurate WeatherSet (12 station controller)

WeatherMatic SmartLine SL1600 with the weather monitor

Program start date: October 2005

Type of incentive or rebate: Refocused efforts on distribution of free controllers via exchanges. Distribution of free controllers began in October 2005. Participants must turn in old controller to receive a new controller.

Who else is involved in addition to agency: Metropolitan Water District

Marketing and recruitment strategies: MWD, SDCWA and member agencies produced marketing materials. Member agencies distribute materials via newsletters, bill stuffers, public events, web sites, etc. An occasional public service announcement is offered, but mostly print media is used. Customers are recruited to the landscape classes. Customers can also opt to attend a 1 hour instruction session on "how to" install/program the controller. DVDs (how to install/program) are now being offered.

Program description: As part of the landscape class, participants turn in their old controller and receive a new smart controller. They are given training on how to program it. The old controller is labeled with the customer's name and phone number; they have 30 days to decide whether they want the old controller back. Customers can opt to attend a 1 hour instruction session on "how to" install and program the controller.

Program or marketing & recruitment challenges: These classes are popular, and becoming more so. Some agencies have done limited marketing and it is shown in the numbers. Those agencies with active conservation staff have seen the most participants.

San Diego County Water Authority: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	490 *units*	18 voucher 122 commercial 350 residential
At about how many **sites** have WBIC units been installed through your program?	385 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	25 *commercial sites* 360 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	1,390 *units*	*with distributions*
What is the total number of WBIC **sites** expected to be installed through your program?	1,098 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	650 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*sites*	*not applicable*
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	*not applicable*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	5,720 *person-hours*	*Guesstimate: marketing consultant, SDCWA staff, program consultant.*
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*0 person-hours*	*Not applicable*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*0 person-hours*	*Not applicable*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*0 person-hours*	*Not applicable*
About how much money has your agency invested in the program thus far?	$ 43,000	*Marketing consultant, program administration consultant. Staff time not included.*
Through what date is this information current?	6/30/2006	

Agency: City of Santa Monica / Environmental Programs Division (SM/EPD)

Program #1: Free, direct install

Type of customers targeted: Residential customers in a high water use per parcel zip code

Controller technologies included: AquaConserve ET Scheduler

Program start date: October 2005

Type of incentive or rebate: Free controller and installation

Who else is involved in addition to agency: SustainableWorks

Marketing and recruitment strategies: Direct mailing

Program description: A region (zip code) within the city that consumes more water per parcel than other areas was targeted. Within that area, SM/EPD identified four "meter books" of customers, who were selected route by route until 100 customers were identified.

SustainableWorks sends the initial mailings and then follows up with a contact. They schedule an appointment with the customer and provide the installation. The technology is unique in that this device is not a stand-alone device: it's an add-on to an existing controller. It's an historical based device, which learns the existing program, and then modifies it based on the historic information. One of the reasons SM/EPD chose this device was it was an easy installation process requiring only a three-wire connection. A rudimentary audit is performed to see if location fits criteria; if it does, the device is installed. They will flag any problems observed, but don't require changes to be made to the irrigation system. The irrigated area is also measured for the savings evaluation.

Program or marketing & recruitment challenges: No major problems; people have been fairly receptive

Program #2: Free, direct install

Type of customers targeted: Appropriate test properties

Controller technologies included: ET Water, Weathermatic, Aqua-Conserve, and three variants of the WeatherTRAK controller (HydroPoint, Irritrol, and Toro).

Program start date: January 2004

Type of incentive or rebate: Free smart controller

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Direct contact

Program description: This program is implemented more casually. As the primary staff member goes about his business (i.e., as people question their water use, and call for questions and information, or as he performs audits from other grants) properties are identified as appropriate for testing the smart controller technology. Controllers are installed by SM/EPD staff or a hired contractor. SM/EPD is particularly interested to observe whether these relatively complex devices can be handed to someone and successfully installed, and whether once installed it will actually save water. They've provided them to professional landscapers and property owners. In these cases training is provided. Irrigated area is sometimes measures, sometimes not.

Program or marketing & recruitment challenges: No major problems; people have been fairly receptive

Program #3: Free, direct install

Type of customers targeted: Landscape professionals

Controller technologies included: Any form of WeatherTRAK or ET Water (both of which have signal fee)

Program start date: October 2005

Type of incentive or rebate: Free smart controller

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Part of a landscaping certification process

Program description: Participants are offered a free controller, with the hope they will use these devices and begin specifying them and requiring them in their landscape designs. They are required to complete a form specifying where the free controller they received will be installed. Irrigated area is measured for the water savings evaluation.

Program or marketing & recruitment challenges: No major problems; people have been fairly receptive

Santa Monica: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	64 *units*	
At about how many **sites** have WBIC units been installed through your program?	61_*sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	*0 commercial sites* 61 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	100 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	95 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	100 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	4 *sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	10 *%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	20 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	10 *person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	1,260 *person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	3 *person-hours*	
About how much money has your agency invested in the program thus far?	$30,400	
Through what date is this information current?	5/06/2006	

Agency: West Basin Municipal Water District

Type of customers targeted: Large landscapes; large water users. Primarily cities, water agencies and HOAs.

WBIC technologies included: HydroEarth.

Program start date: October 2004

Type of incentive or rebate: The end user receives equipment, programming and installation, and pays $1 per valve for management services.

Who else is involved in addition to agency: At this point, only HydroEarth. However, any manufacturer could contact WBMWD to participate.

Marketing and recruitment strategies: A direct, targeted approach, whereby the manufacturer directly contacts potential customers

Program description: The end user receives a server, the controllers and the communication system. They also receive installation of the controllers by the manufacturer. The customer is charged $1 per valve.

Partnership Opportunities: In partnership with a local water retailer, West Basin provided incentives that covered the entire cost of the controllers and installations.

Program or marketing & recruitment challenges: WBMWD has had difficulty dedicating sufficient internal resources to the program. WBMWD expects to hire a vendor in the future to market the program more intensively and work with additional qualified vendors.

West Basin Municipal Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	16 *units*	
At about how many **sites** have WBIC units been installed through your program?	3 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	3 *commercial sites* 0 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	30 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	6 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	50 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	10 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	0 *person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*person-hours*	
About how much money has your agency invested in the program thus far?	$2,000	
Through what date is this information current?	May 2006	

Summary of Northern California Agency Programs (2006)

Agency: Contra Costa Water District

Program #1: Residential landscape rebate program, self install, with pre and post inspections

Type of customers targeted: Residential customers with at least 5,000 square feet of turf with a minimum of four active irrigation stations on a well-maintained system. Participants must have a winter/summer difference in water use of at least 800 gpd and have participated in the residential survey (a pre-inspection of the property) to ensure the irrigation system is well-maintained.

Controller technologies included: All smart, self-adjusting controller technologies are included.

Program start date: September 2005

Type of incentive or rebate: Rebate of $25 per active irrigation station up to 100% of material cost of smart controller technology system installed

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Direct contact

Program description: Contra Costa first offered the rebate to customers who have taken part in their residential survey program since 2000. Since then the rebate program has been opened to all customers that are eligible. Non-surveyed customers must first participate in the residential survey program to verify that site conditions meet program requirements. Once the residential survey is complete, the customer selects, buys, and installs the clocks. The agency performs a post inspection, at which time additional data are collected to ensure accurate scheduling of the installed controllers. All residential controllers are scheduled during the post inspection to match the site information collected by the surveyor. Water use is monitored over time, and if the agency does not observe enough savings, they will re-contact the customer and try to get more savings.

Program or marketing & recruitment challenges for both programs: Contra Costa started marketing the program in December 2005 once data collection fields for state analysis were finalized. One issue that arises frequently for customers is selecting the appropriate smart controller, especially for residential customers where there is a wide range of product options. These decisions need to be talked through so customers can decide which technology is best for them. On the commercial side, property managers rely on their landscapers to help make the choice. Landscape companies have been sticking with better-known controllers or manufacturers.

Additionally, on the residential side, there is an issue of installation of accompanying soil and weather sensors. There are two categories of people: 1) handy people who don't think anything of installation, and then 2) those that will have to hire someone. For those that need to hire an installer not knowing what skill level is needed for the installer and a reasonable cost for that installation has been a deterrent to getting involved in the program.

Program #2: Commercial landscape rebate self install with pre and post inspections

Type of customers targeted: Commercial properties at 150% or higher of water budget and with either a dedicated irrigation meter or a submeter for irrigation. It must be confirmed that consumption is high enough to meet eligibility criteria. The properties must also have a well-maintained automatic irrigation system.

Controller technologies included: All smart, self-adjusting controller technologies are included. List of technologies was not limited based on limited evaluation of in-field data available. District wants first hand experience with as many systems as possible. CCWD needs to understand whether issues are technology or manufacture based.

Program start date: December 2004

Type of incentive or rebate: Rebate of $40 per active irrigation station up to 100% of material cost of smart controller technology system installed

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Direct contact

Program description: Appointments are made with targeted property owners or managers for a pre-inspection. At that time, they are informed of the amount of rebate for which they will qualify, based on number of active stations. They are then sent an approval notification letter with an application for the rebate. The customer then selects, purchases, and installs the smart irrigation controller. Contra Costa staff provides assistance to customer in selecting the technology type.

Contra Costa maintains a web site that contains program and controller information. Program qualifications, steps to complete the program and the different types of technologies available are described on the site. Along with links to the manufacturers' web sites, a two page flyer that contains controller information including: system features, controller costs, contact/purchase information and availability of installers is available for each manufacture in the program. The flyer template was developed by Municipal Water District of Orange County.

Customers are encouraged to call the agency with questions about the various technologies. Contra Costa has classified the technologies into 6 categories; they work with the customer to identify the best category, and then help them choose a controller within that category.

Once a smart controller is installed, the agency conducts a post-installation inspection, including an audit of the irrigation system. It includes: verification of the number of active stations, testing of representative stations to determine application rates and collecting other data needed to program the technology installed. Property managers and landscape maintenance companies are then give the data so they can program the device. If problems are found during this inspection, the customer is informed. The agency then monitors water use for the site, and if water savings are not observed, the Contra Costa will contact the customer. The schedule will be reviewed, if settings are the issue the water district will reprogram the clock once customer ok is given.

Contra Costa Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	42 *units*	*6 residential,* *36 commercial*
At about how many **sites** have WBIC units been installed through your program?	12 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	*7 commercial sites* 5 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	149 *units*	*< 40 residential,* *109+ commercial*
What is the total number of WBIC **sites** expected to be installed through your program?	75 *sites*	*residential about 30* *commercial between 30 and 60*
What was the total number of WBIC units **originally** expected to be installed through your program?	149 *units*	*40 residential* *109 commercial*
At about how many sites were repairs or other interventions performed on the irrigation systems?	2 *sites*	*agency does not do repairs or other interventions*
For about what percent of installations do you receive customer maintenance calls and questions?	17 *%*	*residential (2 of 5);* *Commercial (1 of 7)*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	*72 person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	66 *person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*0 person-hours*	*not applicable*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	16 *person-hours*	
About how much money has your agency invested in the program thus far?	$26,471	*This is the amount of rebate funds provided during the period. This does not include labor costs.*
Through what date is this information current?	6/8/2006	

Agency: East Bay Municipal Utility District

Program #1: Large Landscape Irrigation Rebate Program (Irrigation hardware rebates)

Type of customers targeted: Large commercial and institutional landscape irrigators including city street medians, parks, gardens, sports facilities, and home owner association (HOA) managed common area landscaping in residential development.

Controller technologies included: The program includes a variety of irrigation hardware including any WBIC or soil-moisture controller. Eighty-five controllers have been installed as follows:

8 Station 8 installations

12 Station 14 installations

16 Station 12 installations

18 Station 7 installations

24 Station 38 installations

32 Station 3 installations

36 Station 2 installations

40 Station 1 installation

Manufacturer's represented include:

6 RainMaster Eagle with iCentral

1 Cal Sense ET 2040

77 AquaConserve

1 ET Water Systems

Program start date: Smart controllers have been rebated through this program since 2004. As of the July 1, 2006 launch of the new WaterSmart irrigation controller program (described below), smart controllers will no longer be eligible under this program.

Type of incentive or rebate: The following table shows the percentage of hardware costs rebated under the program; smart controllers qualify for 50% of the hardware cost.

50% EBMUD Rebate	75% EBMUD Rebate	100% EBMUD Rebate
Irrigation controllers	Drip Irrigation Equipment	Moisture Sensors
Matched Precipitation Rate Sprinkler Heads	Pressure Regulation Devices	Rain Shut-off Devices
Sub-meters		Check Valves
		Nozzles

For rebates over $1,000, the rebate program pays 50% of a customer's total rebate at the time of project final inspection. The remaining half is paid after one year if the customer demonstrates twelve months of water use efficiency.

Marketing and recruitment strategies: As one of the longest standing EBMUD programs, the Irrigation Rebate Program is known among landscape contractors and managers within the EBMUD service area and much of the program activity is initiated by customers seeking assistance with landscape upgrades. The program is promoted through free landscape consulting services (water audits). Staff also contacts customers who have had their metered consumption data flagged due to abnormally high use. Cold calling campaigns, newsletters, Web-site information, landscape conferences, and other presentations are also used to generate program activity.

Program description:

EBMUD's Irrigation Rebate Program is designed to help large landscape irrigators improve the efficiency of existing irrigation systems. Customers who participate in a landscape irrigation audit may qualify for rebates of 50 to 100 percent of the materials cost of installing water-efficient irrigation equipment. To qualify for an irrigation rebate, customers must have an irrigation audit, dedicated irrigation meter, or install a submeter to measure irrigation water use.

Program or marketing & recruitment challenges: The target audience for the program, landscape contractors and property managers, typically has higher priorities than improving landscape water efficiency. Unseasonably cool and wet weather can suppress participation.

Program # 2: WaterSmart Irrigation Controller Program (Residential and Commercial Voucher Program)

Type of customers targeted: Residential, commercial, and institutional customers with a minimum of 750 GPD of irrigation use. (For mixed use accounts there must be a minimum of 750 gpd difference between the billing period that includes the month of July and the billing period that includes the month of January. Outreach is also targeted to product manufacturers and distributors, landscape professionals and property managers.

Controller technologies included: The program is open to any WBIC or soil-moisture controller that meets the following requirements:

1. Controller has completed the Irrigation Association's 5th Draft testing protocol for Climatologically Based Controllers or later edition or, if soil moisture based, must complete the 4th Draft Testing Protocol for Soil Moisture Based Controllers or later edition.

2. The results of the testing protocol must be posted on the Irrigation Association website on the Smart Water Application Technology (SWAT) page under performance reports.

3. EBMUD reserves the right to evaluate eligibility of a manufacturer for the EBMUD WaterSmart Irrigation Controller program based on customer and technical support provided by the manufacturer and/or their distribution network.

4. Manufacturer's must also train and make available a minimum of three professional installers willing to install controllers in the EBMUD service area for customers who choose to hire an installer to complete the controller swap-out and controller set-up and programming.

EBMUD facilitated third-party verification of controller effectiveness which has had a positive effect of improving the technology before it is offered to the customer. Several manufacturers have run their equipment through the SWAT protocol and chose to withhold posting results on the IA web site until they could improve their product to be as good as other products that had previously posted results. Thus far, five different manufacturers have posted results on the web site. As soon as a product performance report is posted on the web site, it can be added to the EBMUD approved list if it also meets other requirements.

Program start date: July 1, 2006

Type of incentive or rebate: A voucher, for up to 50% of the cost of the hardware, not including any signaling fee, up to a maximum amount based on summer irrigation use in three tiers. If the billing database shows that the difference in use between the billing period that includes the month of August and the billing period that includes the month of January is:

1) 750 to 3,000 gpd – the rebate would be up to 50% of the purchase price not to exceed $300

2) 3,001 – 6,000 gpd – the rebate would be up to 50% of the purchase price not to exceed $600

3) 6,000+ gpd – the rebate would be up to 50% of the purchase price not to exceed $1,200

Customers may be eligible for one voucher for each existing controller but will require higher summer irrigation consumption. For example, if a customer requests three controllers the customer must have a minimum consumption of 2,250 GPD (3 times 750 GPD)

Marketing and recruitment strategies: EBMUD conducted market research that served as a basis for developing a tactical marketing plan and have now identified approximately 22,000 potential residential sites and over 6,200 potential commercial sites.

A professional marketing firm conducted two focus groups with large residential water users and in-depth telephone interviews of commercial property managers. Market research findings informed all aspects of program design including the administrative process, eligibility requirements, program and product positioning, and outreach tactics.

Once commercial property managers interviewed understood what the smart controllers do they were ready to buy one on the spot. The challenge is to get to the right person to make the decision. Many homeowners and commercial sites rely on their landscapers to make the decision, which is an additional reason why EBMUD would like to educate landscapers.

The recruitment will take a two-pronged approach. For residential, a direct mail (DM) packet will be sent to the high water users. The DM will explain the program and the potential water savings. The packet includes a customized cover letter, brochure, lift note (explanation of offer), application form, qualifying product list and return envelope. A referral to an informational web site is also included and website development is on-going.

The Second recruitment targeted commercial customers and was cold calling to property managers.. The goal was to set up a site meeting offering a free irrigation audit and include the landscape maintenance contractor. The contractor was identified as key influencer of property manager in the market study.

EBMUD piloted the use of SWAT marketing materials. The SWAT marketing materials were successful in generating significant interest in the program. Marketing materials were mailed out three times to 23,000 (7% of 320K EBMUD residential customers) qualified residential customers (customers using 750 GPD or more irrigation in July). The 23,000 customers received the SWAT materials September 2006, January 2007 and March 2007 and EBMUD received over a thousand voucher requests from customers that filled out a two page application. EBMUD issued approximately 1,200 vouchers (5.2% of the 23,000) that resulted from the direct mailing but only 20% of the vouchers were redeemed for controllers.

Program description: Customers submit an application and their minimum consumption is verified and customer and site information is entered into a database. The maximum voucher amount is determined based on the three tiers and the voucher is sent to the customer. The customer uses the voucher to purchase the WaterSmart controller from a list of distributors or manufacturers. The customer may install the controller themselves or hire their gardener or other professional installer to do the installation. Manufacturers will post a minimum of three professional installers on their web site (not EBMUD's web site). Customers may call one of these professionals if they choose. EBMUD may in the future (not currently) offer an additional incentive in the form of a credit on their water bill if they use an installer trained by the manufacturer of the controller they choose. Once a customer has installed a smart controller, EBMUD will set up an appointment to review the installation and programming. On the same visit EBMUD representatives will measure the irrigated area. This information will be used to determine a water budget. EBMUD will continue to monitor water use. If no water savings are observed, they will attempt to provide telephone assistance and if needed, may make a second site visit to trouble-shoot the installation and programming.

Program or marketing & recruitment challenges: EBMUD anticipates that the biggest challenge will be getting the customer to program the controller correctly. This will require that the proper plant, irrigation, soil type, sun exposure is collected and entered into the controller correctly. Another issue anticipated is that customers will have lots of choices and it may be difficult for them to choose which controller to buy. User friendly marketing materials have been developed to address this. To verify correct product installation and programming staff will be trained in each technology. Other challenges include accurately measuring the irrigated area with a subtotal for the turf area so that potential water savings can be determined. CIT testing was to be completed two years ago but, some protocol challenges have been raised which has delayed some manufacturers from submitting their products for testing at CIT for certification as a smart controllers so they can be listed as a qualified products. In developing individual WBIC programs rather than developing a single regional program, required significantly more work for each agency. Assuming the role as lead agency turned out to be much more time consuming than anticipated and delayed the development of EBMUD's program.

East Bay Municipal Utility District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	(Program 1) *85 units*	*(Program 2) Over 50 commercial controllers pre approved and a waiting list of 100 potential residential customers*
At about how many **sites** have WBIC units been installed through your program?	(Program 1) 19 *sites*	*(Program 2) We estimate 80 % of the sites will be one controller per site. About 205 of sites will have multiple controllers*
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	(Program 1) 19 *commercial sites* 0 *residential sites*	*See above*
What is the total number of WBIC units expected to be installed through your program?	1,300 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	*Sites 1,100*	
What was the total number of WBIC units **originally** expected to be installed through your program?	*Units 1,300*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*We do not anticipate many irrigation upgrades*	*Commercial customers will be introduced to our large irrigation upgrade program which offers 50% to 100% of the cost of water conservation hardware.*
For about what percent of installations do you receive customer maintenance calls and questions?	*% TBD*	*Initial installation and programming questions will be directed to the manufacturer. After installation EBMUD staff will monitor potential savings and assist customers not meeting water saving goals*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	*2,500*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*0person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*person-hours N/A*	*Future Estimate ½ hour per station*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*0 person-hours*	*Future Estimate 5 hours per controller*
About how much money has your agency invested in the program thus far?	$ 60,000	*Marketing study and program materials*
Through what date is this information current?	June 2006	

Agency: Santa Clara Valley Water District

Type of customers targeted: Large commercial and residential high water users who have already participated in a residential surveying program

Controller technologies included:

AquaConserve (modified historic)
HydroPoint WeatherTRAK (real time)
Chosen through bid process to manufacturers

Program start date: December 2005

Type of incentive or rebate: Customers must pay 50% of the cost of the controller.

Who else is involved in addition to agency: Contracted with WaterWise to administer the program

Marketing and recruitment strategies: Starting with direct mail, targeting those who had wanted to be in a previous pilot study but had not been able to be included. Will expand to include public outreach events, other survey programs, web site, and presentations.

Program description: Every customer receives a pre-installation survey conducted by WaterWise Consulting (SCVWD consultant), after which the participant decides which type of controller they would prefer, either real time (WeatherTRAK) or modified historic (AquaConserve). The participant also decides if they would prefer to participate in the "direct install" (which is performed by WaterWise staff) or "self install". Self install customers must attend a workshop where a representative from the manufacturer explains the concepts of evapotranspiration and how to program the controller using the results of their pre-installation site survey. The manufacturer then reviews how to install the controller and provides information regarding trouble shooting common issues associated with the controller. The participants then take the controllers with them to install on their site.

Program or marketing & recruitment challenges: Too early to tell, but not so far.

Santa Clara Valley Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	45 *units*	
At about how many **sites** have WBIC units been installed through your program?	10 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	5 *commercial sites* 5 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	657 *units*	*residential direct install -- 64* *residential self-install-- 96* *direct, small commercial -- 64* *self, small commercial -- 64* *large, direct -- 96* *large, self -- 273* *TOTAL - 657*
What is the total number of WBIC **sites** expected to be installed through your program?	*275 sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	*657 units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*1 sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	*10%*	
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	*120 person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*160 person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*10 person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*person-hours*	
About how much money has your agency invested in the program thus far?	$35,000	
Through what date is this information current?	July 2006	

Agency: Alameda County Water District

Type of customers targeted: A wide variety: residential, commercial, municipal and other; targeted for high water use and/or large lot size. Properties must have a well-maintained automatic irrigation system.

Controller technologies included: Any smart, self-adjusting controller or add-on to an existing controller with schedule adjustment capabilities are eligible. ACWD did not want to limit the choice of technologies to just a few because the District felt it was important to have the ability to evaluate as many technologies as possible through this program. ACWD requested detailed information from manufacturers about their product(s) and this information will be made available to its customers to assist them in making their decisions. The information requested included how their product(s) work, warranty information, customer service and technical support, and any special requirements or maintenance needs.

Program start date: Started June 1st, no installations yet. ACWD is currently conducting pre-qualification screenings (surveys) for interested customers. These survey have the potential to result in approximately 17 small and large controller installations.

Type of incentive or rebate: Rebate on the purchase of the smart controller, free installation

Who else is involved in addition to agency: A contractor hired by ACWD through an RFP process to conduct the installations.

Marketing and recruitment strategies: ACWD is recruiting participants through existing programs that target higher water users such as our large landscape water budget program and our single family resident high water use notification program. ACWD and is also advertising the program through its newsletter and web site.

Program description: Customer applies to participate in the program. ACWD conducts a pre-qualification site assessment to verify eligibility which will include verifying irrigated area measurements. If approved to participate in the program, the customer chooses a smart controller, purchases it, and submits the receipt for the rebate (usually equivalent to the average cost, or for large customers, about 60% of the average cost). The controller is then installed by the ACWD contractor. ACWD will then conduct a post-installation inspection and will monitor water use.

Program or marketing & recruitment challenges: No marketing or recruitment challenges so far. Program development challenges were related to simplifying the program to maximize participation and water savings, while keeping the costs down. This was the rationale behind both hiring a contractor to conduct all of the installations and going with a rebate program. Special legal considerations surfaced frequently during the planning process (e.g. Whether or not prevailing wages applied to ACWD's installation contractor - ACWD legal counsel determined that they did apply, responsibility for the disposal of the old controller – left to the customer, and various liability concerns related to the installation work.) As ACWD moves forward with the program they will likely fine tune the program to adapt to situations they have not yet considered. ACWD is already noticing that customers require a lot of guidance in selecting the appropriate WBIC for their current system. Most of the commercial customers will rely on advice from their landscape professional for this decision, while the residential customers will be assisted by ACWD staff in selecting the best type of technology for their current system.

Alameda County Water District: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	0 *units*	
At about how many **sites** have WBIC units been installed through your program?	0 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	0 *commercial sites* 0 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	124 *units*	*36 – Residential, 88 – Commercial*
What is the total number of WBIC **sites** expected to be installed through your program?	*50-60 sites*	*Estimate 1 controller per residential site and 5 controllers per commercial site.*
What was the total number of WBIC units **originally** expected to be installed through your program?	124 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*sites*	*A well-maintained irrigation system is required to qualify for the program.*
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	*No installations so far*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	40 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	0 *person-hours*	*All installation hours will be through a contractor*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	0 *person-hours*	*No installations so far.*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	0 *person-hours*	*No installations so far.*
About how much money has your agency invested in the program thus far?	$0	*Only staff time so far.*
Through what date is this information current?	June 2006	

Agency: Sonoma County Water Agency

Program #1: Residential, pre installation audit, self install

Type of customers targeted: Targeting highest water users first; site must include at least 1,500 square feet of irrigated area, with at least 500 square feet of well-maintained turf.

Controller technologies included: SCWD has a list of four manufacturers they have "qualified" Controller products based on SWAT testing and published results.

Program start date: January 2006

Type of incentive or rebate: A combined maximum of $450 rebate; $300 maximum for up to 50% of the price of a qualified smart controller, plus up to $150 at 100% of the cost for the signaling fees for the rebate program required 5 years of pre-paid service.

Who else is involved in addition to agency: The member agencies

Marketing and recruitment strategies: The first effort is a direct mailing to the targeted customers. May be expanded in the future.

Program description: Interested customers make a pre-installation appointment. At this visit, a full indoor and outdoor water audit is conducted. The eligibility criteria are verified from site data collected during the audit. The customer then purchases a qualified controller and either installs it or hires someone to install it. After the controller is installed, a post-installation inspection is performed and the rebate is issued.

Program #2: Commercial pre-installation, audit self-install

Type of customers targeted: Any commercial site that is interested

Controller technologies included: SCWA has a list of four manufacturers they have "qualified." These are the ones that received the highest signal and also the ones that are SWAT tested, or use the same technology that has been tested. They are only including controllers with a signaling fee.

Program start date: March 2006

Type of incentive or rebate: For 13-24 active stations, up to 50% of the purchase price for up to $700; for 25+ active stations, 50% of purchase price up to $1,100. There is no rebate for signal fees in the commercial program.

Who else is involved in addition to agency: The member agencies

Marketing and recruitment strategies: The manufacturers have the information, and they are marketing it on their own. Many municipalities would like to obtain the smart controllers for the large landscapes (e.g., parks, etc.).

Program description: Interested customers make a pre-installation appointment. At this visit, a full outdoor water audit is conducted. The customer then purchases a qualified controller and either installs it or hires someone to install it. No training or technical assistance is provided. It is up to the customer to seek this information from the manufacturer who is ultimately responsible for the success of their product. Irrigated area is collected during the pre-installation audit.

Program or marketing & recruitment challenges for both programs: SCWA has four customers signed up so far. This year, there has been lots of rain and flooding. There is not a perception of need for these controllers right now.

Sonoma County Water Agency: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	4 *units*	*through April 2006*
At about how many **sites** have WBIC units been installed through your program?	4 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program?	*commercial sites*	
At about how many **residential sites** have WBIC units been installed through your program?	*residential sites*	
What is the total number of WBIC units expected to be installed through your program?	219 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	219 *sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	219 *units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	0 *sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	0 *%*	*so far*
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	20 *person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	4 *person-hours*	*For the audits, but not for installations*
About how much time (person-hours) have contracted installers invested thus far in the installation process?	0 *person-hours*	*Not applicable*
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	0 *person-hours*	*Not applicable*
About how much money has your agency invested in the program thus far?	$	
Through what date is this information current?	4/26/2006	

Agency: Davis Water

Program #1: Residential & schools self install

Type of customers targeted: High water users with use per square foot of lot size that is more than 25% above average.

Controller technologies included: Hunter and Weathermatic (35 of each). Each of these technologies features an on-site weather station that measures the main variables of the ET equation. In addition, there are no fees, and no signing up for service.

Program start date: Will start this summer (2006).

Type of incentive or rebate: Rebate amount of $169 (residential).

Who else is involved in addition to agency: No one

Marketing and recruitment strategies: Davis will take a targeted approach that will directly contact potential participants rather than have a self-selection of the "do-gooders." Davis hopes to maximize the water savings.

Program description: They are using a voluntary self-install approach. A letter will be sent to the target group of SF residential customers, with the goal of installing 69 controllers. Some kind of on-site audit will be performed, although this is still being finalized. Davis plans to have all the residential installations completed by the end of the summer.

On the non-residential side, Davis is working with the school district where they have a long history of working together on a number of different programs. In June Davis will work with them to install 10 controllers. The exact incentive has not yet been determined, but will likely be a rebate of some kind.

Program or marketing & recruitment challenges: None encountered yet, as they have not yet started installations.

Davis Water: Agency Progress and Cost Reporting

Item	Amount	Notes
Installation Process		
How many WBIC units have been installed through your program?	0 *units*	
At about how many **sites** have WBIC units been installed through your program?	0 *sites*	
At about how many **commercial sites** have WBIC units been installed through your program? At about how many **residential sites** have WBIC units been installed through your program?	0 *commercial sites* 0 *residential sites*	
What is the total number of WBIC units expected to be installed through your program?	79 *units*	
What is the total number of WBIC **sites** expected to be installed through your program?	*Sites*	
What was the total number of WBIC units **originally** expected to be installed through your program?	*units*	
At about how many sites were repairs or other interventions performed on the irrigation systems?	*sites*	
For about what percent of installations do you receive customer maintenance calls and questions?	*%*	
Agency Investment in the WBIC Program		
About how much time (person-hours) has your agency invested thus far in marketing the program, including handling for requests additional information, recruitment, etc.?	*person-hours*	
About how much time (person-hours) in total has your agency invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) have contracted installers invested thus far in the installation process?	*person-hours*	
About how much time (person-hours) has your agency invested in customer service after installation (e.g., customer complaints, resolving problems, etc.) thus far?	*person-hours*	
About how much money has your agency invested in the program thus far?	$	
Through what date is this information current?	May 2006	

APPENDIX H – WATER SAVINGS DETAILED RESULTS BY AGENCY

The following tables present detailed water savings results by agency and various factors including customer category, climate zone, and controller installation method.

Table H.1: Weather-normalized change in water use volume (kgal) by agency and customer category

Agency	Customer Category	Weather-Normalized Change in Water Use Volume (kgal) Descriptive and Validatory Statistics							
		N	Mean	Median	Std. Deviation	Confidence Interval	Lower Confidence Bound	Upper Confidence Bound	Statistically Significant Reduction?
ACWD	Non-Residential	1	-59.8	-59.8	.				
	Residential	4	-89.6	-71.6	92.5	90.7	-180.2	1.1	No
Burbank	Residential	76	-19.0	-10.7	49.1	11.0	-30.0	-7.9	Yes
CCWD	Non-Residential	5	121.9	492.4	632.9	554.7	-432.8	676.6	No
	Residential	27	-40.5	-34.6	141.2	53.2	-93.7	12.7	No
Eastern	Non-Residential	87	-110.6	-47.8	284.5	59.8	-170.4	-50.8	Yes
EBMUD	Non-Residential	79	-112.5	-28.0	596.1	131.4	-244.0	18.9	No
	Irrigation	11	108.3	39.7	231.1	136.6	-28.3	244.8	No
	Residential	243	-64.2	-23.1	472.1	59.4	-123.6	-4.9	Yes
Foothill	Residential	245	-7.8	-3.3	34.6	4.3	-12.1	-3.4	Yes
Glendale	Residential	109	-5.3	-2.6	12.9	2.4	-7.7	-2.9	Yes
Goleta	Non-Residential	8	-132.7	-152.4	354.6	245.7	-378.4	113.0	No
	Residential	18	11.9	-30.5	139.2	64.3	-52.4	76.2	No
Inland Empire	Residential	186	-61.6	-52.9	93.7	13.5	-75.1	-48.2	Yes
LADWP	Non-Residential	16	-1119.8	109.6	3142.9	1540.0	-2659.8	420.2	No
	Residential	461	12.6	.3	92.1	8.4	4.2	21.0	Increase
Pasadena	Non-Residential	17	-353.6	-234.2	956.2	454.6	-808.1	101.0	No
Santa Barbara	Non-Residential	15	-167.0	-104.8	401.1	203.0	-370.0	35.9	No
	Residential	58	-70.3	-52.4	208.3	53.6	-123.9	-16.7	Yes
Santa Monica	Non-Residential	2	-12.0	-12.0	8.1	11.2	-23.2	-0.9	Yes

Agency	Customer Category	Weather-Normalized Change in Water Use Volume (kgal) Descriptive and Validatory Statistics							
		N	Mean	Median	Std. Deviation	Confidence Interval	Lower Confidence Bound	Upper Confidence Bound	Statistically Significant Reduction?
	Residential	68	6.4	2.6	42.1	10.0	-3.6	16.4	No
SCV	Non-Residential	17	-1390.8	6.9	6023.7	2863.4	-4254.3	1472.6	No
	Residential	17	1.0	7.5	137.8	65.5	-64.5	66.5	No
SCWA	Non-Residential	3	-780.3	-258.1	1092.4	1236.1	-2016.4	455.8	No
	Residential	4	-11.3	-8.7	57.4	56.3	-67.6	45.0	No
SDCWA	Non-Residential	10	-7.5	-127.1	489.8	303.6	-311.1	296.1	No
	Residential	391	-7.4	2.4	93.1	9.2	-16.6	1.8	No
Western	Non-Residential	36	105.3	-231.1	1747.5	570.8	-465.5	676.1	No
	Residential	79	-112.3	-67.7	312.9	69.0	-181.3	-43.3	Yes

Table H.2: Summed weather-normalized change in water use by agency and customer category

Agency	Customer Category	Weather-Normalized Total Change in Water Use			
		N	kgal	hcf	acre-feet
ACWD	Non-Residential	1	-59.8	-79.9	-0.2
	Residential	4	-358.3	-479.0	-1.1
Burbank	Residential	76	-1442.5	-1928.5	-4.5
CCWD	Non-Residential	5	609.4	814.8	1.9
	Residential	27	-1093.6	-1462.1	-3.4
Eastern	Non-Residential	87	-9625.3	-12868.1	-29.8
EBMUD	Non-Residential	79	-8888.8	-11883.5	-27.6
	Irrigation	11	1191.2	1592.5	3.7
	Residential	243	-15603.9	-20860.8	-48.4
Foothill	Residential	245	-1899.5	-2539.5	-5.9
Glendale	Residential	109	-579.2	-774.4	-1.8
Goleta	Non-Residential	8	-1061.6	-1419.2	-3.3
	Residential	18	215.0	287.4	0.7
Inland Empire	Residential	186	-11463.3	-15325.2	-35.5
LADWP	Non-Residential	16	-17916.4	-23952.5	-55.5
	Residential	461	5816.3	7775.9	18.0
Pasadena	Non-Residential	17	-6010.6	-8035.6	-18.6
Santa Barbara	Non-Residential	15	-2505.4	-3349.4	-7.8
	Residential	58	-4079.1	-5453.4	-12.6
Santa Monica	Non-Residential	2	-24.0	-32.1	-0.1
	Residential	68	437.6	585.0	1.4
SCV	Non-Residential	17	-23644.3	-31610.0	-73.3
	Residential	17	16.6	22.2	0.1
SCWA	Non-Residential	3	-2341.0	-3129.7	-7.3
	Residential	4	-45.1	-60.3	-0.1
SDCWA	Non-Residential	10	-75.0	-100.3	-0.2
	Residential	391	-2899.9	-3876.9	-9.0
Western	Non-Residential	36	3791.0	5068.1	11.8
	Residential	79	-8869.5	-11857.6	-27.5

Table H.3: Weather-normalized change in water use volume (kgal) by agency and climate zone

Agency	Climate Zone	Weather-Normalized Change in Water Use Volume (kgal) Descriptive and Validatory Statistics							
		N	Mean	Median	Std. Deviation	Confidence Interval	Lower Confidence Bound	Upper Confidence Bound	Statistically Significant Reduction?
ACWD	intermediate	5	-83.6	-59.8	81.2	71.2	-154.8	-12.4	Yes
Burbank	intermediate	76	-19.0	-10.7	49.1	11.0	-30.0	-7.9	Yes
CCWD	inland	31	-36.0	-34.6	244.9	86.2	-122.2	50.2	No
	intermediate	1	631.7	631.7	.				
Eastern	intermediate	87	-110.6	-47.8	284.5	59.8	-170.4	-50.8	Yes
EBMUD	coastal	66	-211.1	-25.4	587.6	141.8	-352.8	-69.3	Yes
	inland	254	-37.1	-17.6	480.6	59.1	-96.2	22.0	No
	intermediate	13	4.8	9.0	104.0	56.5	-51.7	61.3	No
Foothill	intermediate	245	-7.8	-3.3	34.6	4.3	-12.1	-3.4	Yes
Glendale	intermediate	109	-5.3	-2.6	12.9	2.4	-7.7	-2.9	Yes
Goleta	coastal	26	-32.6	-40.0	230.2	88.5	-121.1	55.9	No
Inland Empire	intermediate	186	-61.6	-52.9	93.7	13.5	-75.1	-48.2	Yes
LADWP	coastal	233	-37.6	-4.4	558.1	71.7	-109.2	34.1	No
	inland	63	39.1	.2	212.8	52.6	-13.5	91.7	No
	intermediate	181	-32.1	17.9	732.2	106.7	-138.8	74.6	No
Pasadena	intermediate	17	-353.6	-234.2	956.2	454.6	-808.1	101.0	No
Santa Barbara	coastal	72	-90.5	-60.6	261.0	60.3	-150.8	-30.2	Yes
	intermediate	1	-68.1	-68.1	.				
Santa Monica	coastal	71	5.7	1.1	41.3	9.6	-4.0	15.3	No
SCV	coastal	1	6.4	6.4	.				
	intermediate	33	-716.2	7.5	4318.6	1473.5	-2189.6	757.3	No
SCWA	intermediate	7	-340.9	-47.1	753.9	558.5	-899.4	217.6	No
SDCWA	coastal	186	9.6	5.9	54.9	7.9	1.7	17.4	Increase
	intermediate	215	-22.1	-4.7	151.1	20.2	-42.3	-1.9	Yes
Western	intermediate	115	-44.2	-90.9	1007.4	184.1	-228.3	140.0	No

Table H.4: Summed weather-normalized change in water use by agency and climate zone

Agency	Climate Zone	Weather-Normalized Total Change in Water Use			
		N	kgal	hcf	acre-feet
ACWD	intermediate	5	-418.1	-558.9	-1.3
Burbank	intermediate	76	-1442.5	-1928.5	-4.5
CCWD	inland	1	-1115.9	-1491.8	-3.5
	intermediate	31	631.7	844.5	2.0
Eastern	intermediate	87	-9625.3	-12868.1	-29.8
EBMUD	coastal	66	-13930.4	-18623.6	-43.2
	intermediate	13	-9433.5	-12611.6	-29.2
	inland	254	62.5	83.5	0.2
Foothill	intermediate	245	-1899.5	-2539.5	-5.9
Glendale	intermediate	109	-579.2	-774.4	-1.8
Goleta	coastal	26	-846.6	-1131.9	-2.6
Inland Empire	intermediate	186	-11463.3	-15325.2	-35.5
LADWP	coastal	233	-8756.0	-11705.9	-27.1
	intermediate	181	2462.9	3292.6	7.6
	inland	63	-5807.0	-7763.4	-18.0
Pasadena	intermediate	17	-6010.6	-8035.6	-18.6
Santa Barbara	coastal	72	-6516.4	-8711.7	-20.2
	intermediate	1	-68.1	-91.1	-0.2
Santa Monica	coastal	71	401.8	537.1	1.2
SCV	coastal	1	6.4	8.6	0.0
	intermediate	33	-23634.1	-31596.4	-73.3
SCWA	intermediate	7	-2386.1	-3190.0	-7.4
SDCWA	coastal	186	1776.5	2374.9	5.5
	intermediate	215	-4751.4	-6352.1	-14.7
Western	intermediate	115	-5078.5	-6789.5	-15.7

Table H.5: Weather-normalized change in water use volume (kgal) by agency and installation method

Agency	Installation Method	Weather-Normalized Change in Water Use Volume (kgal) Descriptive and Validatory Statistics							
		N	Mean	Median	Std. Deviation	Confidence Interval	Lower Confidence Bound	Upper Confidence Bound	Statistically Significant Reduction?
ACWD	Professional	2	-133.6	-133.6	104.4	144.6	-278.2	11.1	No
	Self	3	-50.3	-24.3	59.9	67.8	-118.1	17.5	No
Burbank	Self	76	-19.0	-10.7	49.1	11.0	-30.0	-7.9	Yes
CCWD	Professional	32	-15.1	-32.3	268.3	93.0	-108.1	77.8	No
Eastern	Professional	48	-160.6	-52.5	297.0	84.0	-244.6	-76.6	Yes
	Self	39	-49.1	-38.8	259.1	81.3	-130.4	32.2	No
EBMUD	Professional	160	-42.5	-7.7	381.2	59.1	-101.5	16.6	No
	Self	173	-95.4	-25.1	587.4	87.5	-182.9	-7.9	Yes
Foothill	Self	245	-7.8	-3.3	34.6	4.3	-12.1	-3.4	Yes
Glendale	Self	109	-5.3	-2.6	12.9	2.4	-7.7	-2.9	Yes
Goleta	Professional	26	-32.6	-40.0	230.2	88.5	-121.1	55.9	No
Inland Empire	Self	186	-61.6	-52.9	93.7	13.5	-75.1	-48.2	Yes
LADWP	Professional	382	-20.1	22.4	670.5	67.2	-87.3	47.2	No
	Self	95	-46.6	-27.5	78.7	15.8	-62.4	-30.8	Yes
Pasadena	Self	17	-353.6	-234.2	956.2	454.6	-808.1	101.0	No
Santa Barbara	Professional	73	-90.2	-65.0	259.2	59.4	-149.6	-30.7	Yes
Santa Monica	Professional	46	12.2	5.4	46.1	13.3	-1.1	25.5	No
	Self	24	-6.2	-4.8	28.2	11.3	-17.5	5.1	No
SCV	Professional	29	71.8	18.6	199.2	72.5	-0.7	144.3	No
	Self	5	-5141.7	-51.7	10957.9	9604.8	-14746.6	4463.1	No
SCWA	Professional	6	-406.8	-64.8	803.5	642.9	-1049.7	236.1	No
	Self	1	54.7	54.7	.				
SDCWA	Self	401	-7.4	2.0	117.7	11.5	-18.9	4.1	No
Western	Professional	115	-44.2	-90.9	1007.4	184.1	-228.3	140.0	No

Table H.6: Summed weather-normalized change in water use by agency and installation method

Agency	Installation Method	Weather-Normalized Total Change in Water Use			
		N	kgal	hcf	acre-feet
ACWD	Professional	2	-267.2	-357.2	-0.8
	Self	3	-150.9	-201.7	-0.5
Burbank	Self	76	-1442.5	-1928.5	-4.5
CCWD	Professional	32	-484.2	-647.3	-1.5
Eastern	Professional	48	-7709.2	-10306.5	-23.9
	Self	39	-1916.1	-2561.7	-5.9
EBMUD	Professional	160	-6794.8	-9084.0	-21.1
	Self	173	-16506.6	-22067.7	-51.2
Foothill	Self	245	-1899.5	-2539.5	-5.9
Glendale	Self	109	-579.2	-774.4	-1.8
Goleta	Professional	26	-846.6	-1131.9	-2.6
Inland Empire	Self	186	-11463.3	-15325.2	-35.5
LADWP	Professional	382	-7670.5	-10254.6	-23.8
	Self	95	-4429.7	-5922.0	-13.7
Pasadena	Self	17	-6010.6	-8035.6	-18.6
Santa Barbara	Professional	73	-6584.5	-8802.8	-20.4
Santa Monica	Professional	46	562.4	751.9	1.7
	Self	24	-148.9	-199.1	-0.5
SCV	Professional	29	2080.9	2781.9	6.5
	Self	5	-25708.6	-34369.8	-79.7
SCWA	Professional	6	-2440.8	-3263.1	-7.6
	Self	1	54.7	73.1	0.2
SDCWA	Self	401	-2974.9	-3977.2	-9.2
Western	Professional	115	-5078.5	-6789.5	-15.7

APPENDIX I – REGIONAL MULTIPLE REGRESSION MODELS

Separate multiple regression analysis was used to determine the factors that did and did not influence changes in water use in northern and southern California. Multiple regression analysis was also used to compare the performance of different smart controller technologies on a level playing field because factors that were shown to influence water use could be controlled for as much as possible. All analyses that involved a comparison of one or more factors or groups were completed through the multiple regression effort.

Multiple regression analysis allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and water savings estimates after adjusting for factors known to influence savings such as the application rate prior to installation of the smart controller.

Multiple regression models were developed using two approaches. First, bivariate relationships between water use and factors that might be associated were carefully examined. Where a significant relationship was observed, the factor was deemed appropriate for inclusion in a multiple linear regression model. Next multiple regression models on theoretical grounds using factors the researchers hypothesized could be influential on water savings. Ultimately, the model with the best fit was selected. Separate models were also developed for northern and southern California.

A multiple linear regression model allows the simultaneous examination of the association of multiple factors with a single outcome measure of interest, often referred to as the dependent variable. In this instance, the estimated annual percent water savings per site was the dependent variable. The factors examined for an association with the dependent variable are referred to as independent or predictor variables. This simultaneous examination allowed researchers to look at a particular association of interest, for example the association of smart controller technology, simultaneously adjusted for all the other variables in the model.

Factors with p-values less than 0.05 were considered statistically significant, at the 95% confidence level.

The results of the analyses in this study are based on mathematical models and other statistical tools that seek to find the center point of a large group of data, or a line that represents the best fit between two variables. Thus, by definition, there will always be data points above and below the values predicted by even the best models. Statistical models often give the impression of great precision, however in reality these models seldom predict water savings for any specific site very well, but if the fit is good they will usually predict water savings for a large group much better. From the perspective of any planning or policy study that deals with large groups, the ability to understand group dynamics (as opposed to individual dynamics) is the key to good decision making.

Northern California Best Fit Multiple Regression Model

The independent variables in the model include the installation method (professional vs. self), participating water agency (EBMUD used as referent), pre-smart controller application efficiency, climate zone (coastal used as referent), controller brand (Weathermatic used as referent). The dependent variable was the delta application ratio.

Table Appendix I.1: Northern California Multiple Regression Model Summary

	R	R Square	Adjusted R Square	Std. Error of the Estimate
Model N Cal	.493a	.243	.200	.7693

a. Predictors: (Constant), Toro, Professional, Calsense, Nelson, LawnLogic, Acclima, RainMaster, AccurateWeatherSet, SCWA, Irrigation, Irritrol, Hunter, Commercial, SCV, inland, CCWD, AquaConserve, PreAR, intermediate, ETWater, ACWD, HydroPoint

Table Appendix I.2: Northern California coefficients and significance of independent variables

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	.183	.141		1.294	.197
PreAR	-.306	.042	-.400	-7.249	.000
ACWD	.003	.463	.000	.007	.995
CCWD	-.019	.163	-.006	-.119	.906
SCV	1.026	.207	.329	4.958	.000
SCWA	.071	.313	.011	.225	.822
Professional	.121	.096	.070	1.253	.211
Irrigation	-.060	.241	-.011	-.250	.803
Commercial	-.122	.097	-.062	-1.261	.208
intermediate	-.077	.122	-.036	-.631	.528
inland	-.074	.255	-.016	-.292	.771
Acclima	-.029	.901	-.002	-.032	.974
AccurateWeatherSet	-.298	.472	-.029	-.631	.529
AquaConserve	.487	.157	.189	3.099	.002
Calsense	-.158	.776	-.009	-.204	.838
ETWater	.076	.125	.037	.605	.546
Hunter	-.029	.146	-.011	-.203	.840
HydroPoint	-.056	.186	-.022	-.300	.764
Irritrol	.081	.158	.026	.509	.611
LawnLogic	-3.572	.928	-.205	-3.849	.000
Nelson	-.194	.786	-.011	-.247	.805
RainMaster	.410	.364	.052	1.126	.261
Toro	-.036	.156	-.013	-.231	.817

a. Dependent Variable: DeltaAR

Only a few factors achieved statistical significance in this model: Pre-Application Ratio, Santa Clara Valley, AquaConserve, and LawnLogic. The overall fit of the model indicates that this model explains about 24.3% of the variability in the northern California changes in water use.

Southern California Best Fit Multiple Regression Model

The independent variables in the model include the installation method (professional vs. self), participating water agency (LADWP used as referent), pre-smart controller application efficiency, climate zone (coastal used as referent), controller brand (Weathermatic used as referent). The dependent variable was the application ratio change score.

Table Appendix I.3: Southern California Multiple Regression Model Summary

	R	R Square	Adjusted R Square	Std. Error of the Estimate
Model N Cal	.519a	.269	.260	.8173

a. Predictors: (Constant), Toro, PreAR, HydroEarth, Calsense, ETWater, Goleta, Nelson, Irritrol, SantaBarbara, RainMaster, Foothill, Burbank, Eastern, Glendale, SantaMonica, inland, InlandEmpire, Western, SDCWA, AccurateWeatherSet, intermediate, Commercial, AquaConserve, Professional, HydroPoint

A number of factors achieved statistical significance in this model: Pre-Application Ratio, Foothill, SDCWA (San Diego County), Santa Barbara, Santa Monica intermediate climate zone, and Rain Master. The overall fit of the model indicates that this model explains about 26.9% of the variability in the southern California changes in water use.

Table Appendix I.4: Southern California coefficients and significance of independent variables

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	.018	.129		.143	.887
PreAR	-.275	.015	-.402	-17.797	.000
Burbank	.275	.181	.057	1.516	.130
Eastern	-.119	.250	-.026	-.475	.635
Foothill	.445	.156	.158	2.842	.005
Glendale	.231	.168	.057	1.379	.168
Goleta	-.096	.173	-.012	-.556	.578
Inland Empire	-.065	.116	-.020	-.555	.579
Santa Barbara	-.240	.112	-.049	-2.140	.033
Santa Monica	.508	.165	.102	3.083	.002
SDCWA	.586	.128	.253	4.568	.000
Western	-.023	.186	-.006	-.125	.901
Professional	.242	.136	.123	1.777	.076
Commercial	-.007	.125	-.002	-.059	.953
intermediate	-.167	.068	-.086	-2.436	.015
inland	.051	.079	.016	.652	.514
AccurateWeatherSet	-.084	.109	-.034	-.778	.437
AquaConserve	.193	.141	.067	1.365	.173
Calsense	.071	.305	.007	.232	.817
ETWater	.956	.831	.023	1.150	.250
HydroEarth	.659	.598	.023	1.103	.270
HydroPoint	.149	.165	.069	.902	.367
Irritrol	.097	.476	.004	.205	.838
Nelson	-.945	.595	-.032	-1.589	.112
RainMaster	.678	.287	.068	2.362	.018
Toro	.176	.234	.022	.754	.451

a. Dependent Variable: DeltaAR

REFERENCES

Accurate WeatherSet WeatherSet [online] [accessed November 20, 2008] <http://www.weatherset.com/>

Addink, John and Sylvan Addink. 2005. *Irrigation Controller Using Regression Model* United States. Patent 6,892,113 B1, May 10, 2005

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. *Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements*. Irrigation and Drainage Paper 56. UN-FAO, Rome.

Aqua Conserve, Inc. 2004. ET-6, ET- 9 and ET-14 Station Indoor Irrigation Controller User's Guide Aqua Conserve. Riverside, CA

Aqua Conserve, Inc. *AquaCons Setup: Denver, Colorado* Aqua Conserve. Riverside, CA

Aqua Conserve, Inc. 2008. Aqua Conserve [online] [accessed November 20, 2008] <https://www.aquaconserve.com/?CFID=5998996&CFTOKEN=57523461>

Aquacraft, Inc. 1997. *Project Report: Evaluation of Reliability and Cost Effectiveness of Soil Moisture Sensors in Extended Field Use*. Boulder, Colo. Aquacraft, Inc.

Aquacraft, Inc. et. al. 2004, *National Multiple Family Submetering and Allocation billing Program Study*. Aquacraft, Inc., Boulder, CO

Bamezai, Anil 2004. *LADWP Weather-Based Irrigation Controller Pilot Study*. LADWP, Los Angeles, CA

California Ordinance 1992, *Model Water Efficient Landscape Ordinance.* California Code of Regulations: Division 2, Title 23, Chapter 2.7, section 491, part (n).

California Ordinance 2004 "Updated Model Water Efficient Landscape Ordinance"

Calsense 2006. *ET Gauge and Enclosure Installation* Calsense. Carlsbad, CA

Calsense 2006. *ET Gauge and Enclosure Information* Calsense. Carlsbad, CA

Calsense 2001. *Moisture Sensor Installation Calsense.* Carlsbad, CA

Calsense 2007. *Wind Gauge Installation* Calsense. Carlsbad, CA

Calsense 2007 *Quick Set Up Guide* Calsense. Carlsbad, CA

Calsense 2008. Calsense [online] [accessed November 20, 2008] < http://www.calsense.com/>

Cooley, H., Christian-Smith, J. & H., P.G., 2008. More With Less: Agricultural Water Conservation and Efficiency in California.

Cochran, W. G. and G.W. Snedecor. 1982. *Statistical Methods. Seventh Edition.* Iowa State University Press. Ames, Iowa.

Costello, L. R. and N. P. Matheny, J. R. Clark 1991. *Estimating the Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method* University of California ANR Leaflet No. 212493

DeOreo, W.B. et. al. 2008. California Residential Baseline Water Use Study. Aquacraft, Inc., Boulder, CO.

DeOreo, W.B. et. al. 2003. Weather-Based Irrigation Controller Research and Support. Aquacraft, Inc., Boulder, CO.

Draper, N.R. et. al. 1980. *Applied Regression Analysis.* J. Wiley and Sons. New York, NY.

Ervin, E. H. and A. J. Koski 1998. *Drought Avoidance Aspects and crop Coefficients of Kentucky Bluegrass and Tall Fescue Turfs in the Semiarid West* Crop Sciences 38:78-795

ETWater Systems 2008. ET Water [online] [accessed November 20, 2008] http://www.etwater.com/public/index.html

Griffin, Ronald C. 2006. *Water Resource Economics: The Analysis of Scarcity, Policies and Projects.* MIT Press. Cambridge, MA

Hanak, E. & Davis, M., 2006. Lawns and Water Demand in California.

HydroPoint Data Systems, Inc. 2008. WeatherTRAK [online] [accessed November 20,2008] <http://www.weathertrak.com/>

Hunter Industries, Inc. 2007. Untitled brochure Hunter Industries, Inc. San Marcos, CA

Hunter Industries, Inc. 2008. *Evapotranspiration Sensor and Module for Hunter Controllers with SmartPort: Owner's Manual and Programming Instructions* Hunter Industries, Inc. San Marcos, CA

Hunter Industries, Inc. 2008. Hunter Industries: The Irrigation Innovators [online] [accessed November 20, 2008] <http://www.hunterindustries.com/>

Irmak, Suat Jose O. Payero, and Derrel L. Martin 2005. *Using Modified Atmometers (ET_{gauge}) for Irrigation Management* University of Nebraska, Lincoln. Lincoln, NB.

Irrigation Association 2006. *Smart Water Application Technology Performance Summary Report: ETWater* Irrigation Association. Falls Church, VA.

Irrigation Association 2007. *Smart Water Application Technology Performance Summary Report: Aqua Conserve Irrigation* Association. Falls Church, VA.

Irrigation Association 2007. *Smart Water Application Technology Performance Summary Report: Weathermatic* Irrigation Association. Falls Church, VA.

Irrigation Association 2006. *Smart Water Application Technology Performance Summary Report: WeatherTRAK* Irrigation Association. Falls Church, VA.

Irrigation Association 2006. *Smart Water Application Technology Performance Summary Report: Toro* Irrigation Association. Falls Church, VA.

Irrigation Association 2006. *Smart Water Application Technology Performance Summary Report: Irritrol* Irrigation Association. Falls Church, VA.

Irrigation Association 2007. *Smart Water Application Technology Performance Summary Report: Hunter* Irrigation Association. Falls Church, VA.

Irrigation Association 2008. *Smart Water Application Technology Performance Summary Report: Rain Master* Irrigation Association. Falls Church, VA.

Irrigation Association 2007. *Smart Water Application Technology Performance Summary Report: Calsense* Irrigation Association. Falls Church, VA.

Irrigation Association 2008. *Smart Water Application Technology Calibration Report: Acclima* Irrigation Association. Falls Church, VA.

Irrigation Association Water Management Committee. 2005. Landscape Irrigation Scheduling and Water Management. Irrigation Association. Falls Church, VA.

Irritrol Systems 2006. *Smart Dial Series: ET-Based Controllers* Irritrol Systems. Riverside, CA

Irritrol Systems 2008. Irritrol Controllers [online] [accessed November 20, 2008] <http://www.irritrolsystems.com/controllers/controllers.html>

Jensen, M. E. et al. 1990. *Evapotranspiration and Irrigation Water Requirements.* American Society of Civil Engineers, New York, NY

Jakubowski, Scott D. 2008. Weather-Effectiveness of Runoff Reducing Weather Based Irrigation Controllers (Smart Timers) WaterSmart Innovations Conference Las Vegas, Nevada October 8, 2008

Kennedy/Jenks Consultants 2008. *Pilot Implementation of Smart Timers: Water conservation, Urban Runoff reduction, and Water Quality* Municipal Water District of Orange County, Fountain Valley, CA

Mayer, P. et. al. 2008. The California Water Smart Irrigation Controller Project: Results and Perspective on a Large Field Study of an Important Emerging Technology. WaterSmart Innovations Conference Proceedings. Las Vegas, NV.

Mayer, P. et. al. 1999. *Residential End Uses of Water.* American Water Works Association. Denver, CO.

Meyer, J. L. and V. A Gibeault, 1986. "Turfgrass Performance Under Reduced Irrigation" California Agriculture, 40 (7, 8): 19-20

Municipal Water District of Orange County, Irvine Ranch Water District 2004. *The Residential Runoff Reduction Study.*

Planned Marketing Solutions International 2005. *Weather-Based Irrigation Controller Program Research and Marketing Strategy.* East Bay Municipal Utility District, Oakland, CA

Rain Master Irrigation Systems undated *Weather Center II User Manual, Revision D* Rain Master Irrigation Systems. Simi Valley, CA

Rain Master Irrigation Systems 2008. Eagle [online] [accessed November 20, 2008] <http://www.rainmaster.com/eagle.htm>

Shedd, Mary, Michael D. Dukes and Grady L. Miller. 2007. *Evaluation of Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass* Proceedings ASCE EWRI World Environmental & Water Resources Congress May 15-19, 2007, Tampa, FL

Solano County Water Agency. 2005. *Annual Report Grant E-67020 Evapotranspiration Controller System Project* Solano County Water Agency. Elmira, CA

Sovocool, K.A., M. Morgan, and D. Bennett. 2006. An in-depth investigation of xeriscape as a water conservation measure, *Journal AWWA*, **98**: 82-93.

Snow, Steve. Personal interview October 24, 2008

Starr, Robert. Personal interview. October 24, 2008

The Toro Company. 2006. *Intelli-Sense™ TIS-612 and TIS-240 Controllers* The Toro Company. Riverside, CA

The Toro Company. 2008. Toro [online] [accessed November 20, 2008] <http://www.toro.com/irrigation/com/index.html>

U.S. Department of Agriculture, Soil Conservation Service. 1970. *Irrigation Water Requirements: Technical Release No. 21* Engineering Division. Washington, D.C.

U.S. Department of the Interior. 2007. *Weather and Soil Moisture Based Landscape Irrigation Scheduling Devices: Technical Review Report* U.S. Department of the Interior Bureau or Reclamation, Southern California Area Office, Temecula, CA and Technical Service Center, Water Resources Planning and Operations Support Group, Denver, CO.

U.S. Department of the Interior. 2008. *Final Technical Memorandum No. 86-68210-SCAO-01: Summary of Smart Controller Water Savings Studies Literature Review of Water Savings Studies for Weather and Soil Moisture Based Landscape Irrigation Control Devices* U.S. Department of the Interior Bureau or Reclamation, Southern California Area Office, Temecula, CA and Technical Service Center, Water Resources Planning and Operations Support Group, Denver, CO.

Weathermatic Corp. 2008. Weathermatic [online] [accessed November 20, 2008] <http://www.weathermatic.com/>

Weathermatic Corp. undated *Smartline* Weathermatic, Dallas, TX

White, R., D. Chalmers, and J. McAffee. 2007. How Much Water is Enough? Using PET to develop water budgets and promote voluntary water conservation in Texas lawns and landscapes. TNLA Green. April 2007. Texas Nursery and Landscape Association.