

# EVALUATION OF WATER SAVINGS FROM WEATHER BASED IRRIGATION CONTROLLERS IN SANTA CLARITA VALLEY

Submitted to:  
Stephanie Anagnoson  
Castaic Lake Water Agency  
27234 Bouquet Canyon Road  
Santa Clarita, CA

January 23, 2015



Submitted by:  
Aquacraft, Inc.  
Water Engineering and Management  
2709 Pine Street  
Boulder, CO 80302  
303-786-9691  
[www.aquacraft.com](http://www.aquacraft.com)



*Intentional blank page*

## TABLE OF CONTENTS

<b>LIST OF TABLES .....</b>	<b>4</b>
<b>LIST OF FIGURES.....</b>	<b>5</b>
<b>EXECUTIVE SUMMARY .....</b>	<b>8</b>
<b>INTRODUCTION .....</b>	<b>10</b>
The Suppliers.....	10
Demographics .....	11
Water Deliveries.....	12
Groundwater.....	12
Imported Water and Water Banking .....	12
Recycled Water .....	12
Water Rates.....	12
Weather Based Irrigation Controller Program Evaluation.....	13
Project Goals .....	14
<b>ANALYSIS OF CHANGES IN WATER USE .....</b>	<b>14</b>
Task 1: Data Collection.....	16
Water Billing Data .....	17
GIS Imagery .....	18
Task 2: Tabulation of Billing and Weather Data .....	18
Weather Data Tabulation .....	19
CIMIS .....	21
Task 3: Weather Normalization .....	22
Task 4: Determination of the Application Ratios.....	26
GIS Analysis .....	27
Landscape Analysis of the GIS Group .....	28
Analysis of the Test Group .....	32
Task 5: Data Assembly .....	33
Task 6: Statistical Analysis.....	35
Paired Comparisons .....	36
Other Comparisons.....	46
Bias Test .....	50
Saving Projections for Population.....	51
<b>CONCLUSIONS AND RECOMMENDATIONS .....</b>	<b>52</b>

## LIST OF TABLES

Table 1: Table of terms and abbreviations .....	6
Table 2: Water rates and average cost of water at 25 CCF of consumption .....	13
Table 3: The water billing data provided for the four participating agencies .....	17
Table 4: Time periods for pre-post analysis.....	18
Table 5: Comparison of seasonal versus outdoor water use in the Test and Control groups .....	19
Table 6: OWU and ET <sub>o</sub> data.....	24
Table 7: Weather normalization factors .....	26
Table 8: Number of WBIC homes and GIS sites for each agency .....	27
Table 9: Landscape characteristics used for calculating the theoretical irrigation requirement.	30
Table 10: Logic for determination of application ratios in Test group .....	33
Table 11: Variables contained in the analysis dataset.....	33
Table 12: Change in application ratios.....	40
Table 13: Analysis of actual and potential water savings .....	45
Table 14: Comparison by method of installation .....	48
Table 15: Comparison by method of instruction .....	49
Table 16: Projected savings based on Valencia Application Ratio distributions .....	52

## LIST OF FIGURES

Figure 1: Water service providers in the Santa Clarita Valley .....	10
Figure 2: Service areas of Castaic Lake Water Agency and Purveyors .....	11
Figure 3: Analysis flowchart of the WBIC study for CLWA.....	15
Figure 4: Location of NCDC weather stations are represented by the green flags. Saugus Power Plant and Woodland Hills Pierce College do not appear on the map. ....	20
Figure 5: NCDC weather stations for the Santa Clarita and San Fernando Valleys and the period of record.....	21
Figure 6: Net ET <sub>o</sub> for Santa Clarita CIMIS Station (#204) .....	22
Figure 7: Impact of exponent value on normalization .....	23
Figure 8: Weather normalization curve .....	24
Figure 9: Irrigated area versus lot size .....	28
Figure 10: Landscape ratio versus irrigated areas .....	32
Figure 11: Changes in raw outdoor water use for Test and Control groups over study period...	38
Figure 12: Mean changes in weather-corrected outdoor water use for Test and Control groups .....	39
Figure 13: Change in outdoor water use versus antecedent application ratio .....	40
Figure 14: Relationship between pre and post application ratios for Test group.....	41
Figure 15: Change in outdoor water use versus antecedent application ratio .....	42
Figure 16: Average change in use as a percentage of outdoor water use .....	43
Figure 17: Percent of group falling into application ratio bins .....	44
Figure 18: Comparison of mean changes by agency .....	47
Figure 19: Comparison of median changes by agency .....	47
Figure 20: Comparison of changes by method of installation (-1=contractor, 0=homeowner) ..	48
Figure 21: Comparison of changes by method of instruction .....	49
Figure 22: Comparison of application ratios of Test group to the Valencia population .....	50
Figure 23: Application ratio for the year of WBIC installation .....	51

**Table 1: Table of terms and abbreviations**

<b>Terms and Abbreviations</b>	<b>Definition</b>
<b>AFY</b>	<i>Acre feet per year</i>
<b>Antecedent Irrigation Application Ratio</b>	<i>The application ratio of the landscapes prior to the installation of a WBIC.</i>
<b>Application Ratio (AR)</b>	<i>The ratio of the water applied to the landscape versus the theoretical irrigation requirement.</i>
<b>BU</b>	<i>A billing unit which is equivalent to one CCF.</i>
<b>CCF</b>	<i>One hundred cubic feet of water. One CCF is equal to one billing unit (BU).</i>
<b>CIMIS</b>	<i>California Irrigation Management Information System</i>
<b>Control Group</b>	<i>The combined set of single family homes from the utility databases that did not receive a WBIC and were located within 500 feet of a home that did receive a WBIC, and whose outdoor water use in 2007 matched that of the Test group.</i>
<b>ET<sub>o</sub></b>	<i>A measure of how much water is lost from the landscape due to temperature, wind, solar radiation, and other factors. ET<sub>o</sub> not adjusted for rainfall.</i>
<b>Effective Precipitation</b>	<i>The percentage of measurable precipitation that is available for use by the plants and is not lost to deep percolation or run-off.</i>
<b>GIS group</b>	<i>A random sample of homes from each of the utility databases that received WBICs between 2010-2012 for which GIS analysis could be performed for direct analysis of their landscapes</i>
<b>HH</b>	<i>Household</i>
<b>Irrigated Area</b>	<i>The planted area of the landscape, measured in GIS, supplied by the utility or calculated using a regression model</i>
<b>Irrigation Efficiency (IE)</b>	<i>A measure of how well the irrigation system supplies water to each sub-area in the landscape analysis. It is the ratio of water reaching the plant root zones to the applied water.</i>
<b>Landscape Ratio (LR)</b>	<i>The ratio of the TIR to the Reference Requirement</i>
<b>Lot Area</b>	<i>The area on which the house and landscape are sited</i>
<b>NCDC</b>	<i>NOAA's National Climate Data Center</i>
<b>Net ET<sub>o</sub></b>	<i>ET<sub>o</sub> minus estimated effective rainfall</i>
<b>Non-Seasonal Use</b>	<i>Non-seasonal use often serves as a proxy for indoor use and is estimated from the billing period of minimum consumption, pro-rated to the entire year, with the assumption that the minimum month use did not include any outdoor use.</i>
<b>Reference Requirement (Ref Req)</b>	<i>The amount of water that would be applied to the landscape if the entire landscape were planted in the reference species – typically cool season turf, 6" in height, fully watered, full sun.</i>
<b>Outdoor Water Use (OWU)</b>	<i>The amount of water applied to the landscape during the irrigation season.</i>
<b>SB X 7-7</b>	<i>Home Water Use Efficiency Senate Bill 7</i>
<b>SCV WUE SP</b>	<i>Santa Clarita Valley Water Use Efficiency Strategic Plan</i>
<b>Seasonal Use</b>	<i>The difference between total annual use and non-seasonal use.</i>
<b>Species Coefficient (SC)</b>	<i>The amount of irrigation required to maintain the health of a</i>

	<i>species in relation to the amount of water required by the reference species, it ranges from (0.3 to 0.8)</i>
<b>Test Group</b>	<i>The combined set of single family homes from the utility databases that received a WBIC between 2010-2012 and for which billing data and landscape area were available</i>
<b>Theoretical Irrigation Requirement (TIR)</b>	<i>The irrigation requirement of the landscape based on the irrigated area, types of plants in the landscape and with allowances for irrigation efficiencies in well designed and installed systems.</i>
<b>WBIC</b>	<i>Weather based irrigation controller</i>

## EXECUTIVE SUMMARY

Weather based irrigation controllers, also known as smart controllers or WBICs, represent a major achievement in irrigation technology. These controllers have the ability, when properly programmed and installed, to match the actual irrigation applications of the landscape to the amount required to meet the water requirements of the plants, or the theoretical irrigation requirements (TIR) of the landscape.

There are many opinions about how this technology should work in the real world and about its potential to effect a reduction in water used for landscape irrigation. In the minds of many, WBICs should be able to achieve tremendous reductions in landscape water use, and their use should be encouraged throughout the service areas of every water provider. Many agencies are paying substantial amounts for rebates and giveaways to encourage adoption of WBICs. The use of smart controllers is mandated in the California Model Efficient Landscape Ordinance.

This report seeks to provide empirical information about the performance of WBICs for water conservation through an examination of actual water use for over 1000 WBIC sites in the Santa Clarita Valley of California. The report started from the monthly billed consumption provided by the agencies for the entire single family populations of the four major water providers in the area (Santa Clarita Water Division, Valencia Water Company, Newhall County Water District, and Los Angeles County Waterworks District #36). From this, the WBIC homes were identified from the billing data, and tables of weather-corrected outdoor water use for each of the WBIC sites and for a Control group were assembled. This allowed a pre-post and a side-by-side comparison of weather-corrected outdoor water use to be performed.

Initially, the study was done using seasonal water use, as estimated from the minimum month billing for each customer. Seasonal water use is often used as a proxy for outdoor use, but an examination of the results with the Agency staff suggested that this approach was under-estimating outdoor use, since the warm climate in the service area leads to year round irrigation. In order to avoid this, the study data was recalculated using outdoor use instead of seasonal, where outdoor use was calculated as the difference between annual use and indoor use as measured by data logging results, which avoided counting winter irrigation as indoor use.

Considerable effort was expended to get the best possible estimates of the TIRs for each of the Test homes. This was done to allow the analysis to take into effect the ratios of the actual irrigation applications to the TIR values (the application ratios) for the homes prior to receiving WBICs, which were referred to as the antecedent application ratios (AR). Homes with higher application ratios would be expected to show the greatest decrease in landscape water use, and homes with the lower application ratios would be expected to show an increase in water use, given how WBICs are intended to work.

The results of the analysis were striking: the WBICs performed generally as expected and brought the application ratios of the group closer to 1.0, which is what they are designed to do.

However, because more than half of the lots were under-irrigating prior to receiving the devices, the program resulted in an overall *increase* in outdoor water use. On the other hand, when the performance of just the lots that were over-irrigating was investigated, a significant reduction in outdoor use was observed. Overall, however, there was a slight net increase in the weather-adjusted outdoor water use of the Test group compared to the Control group.

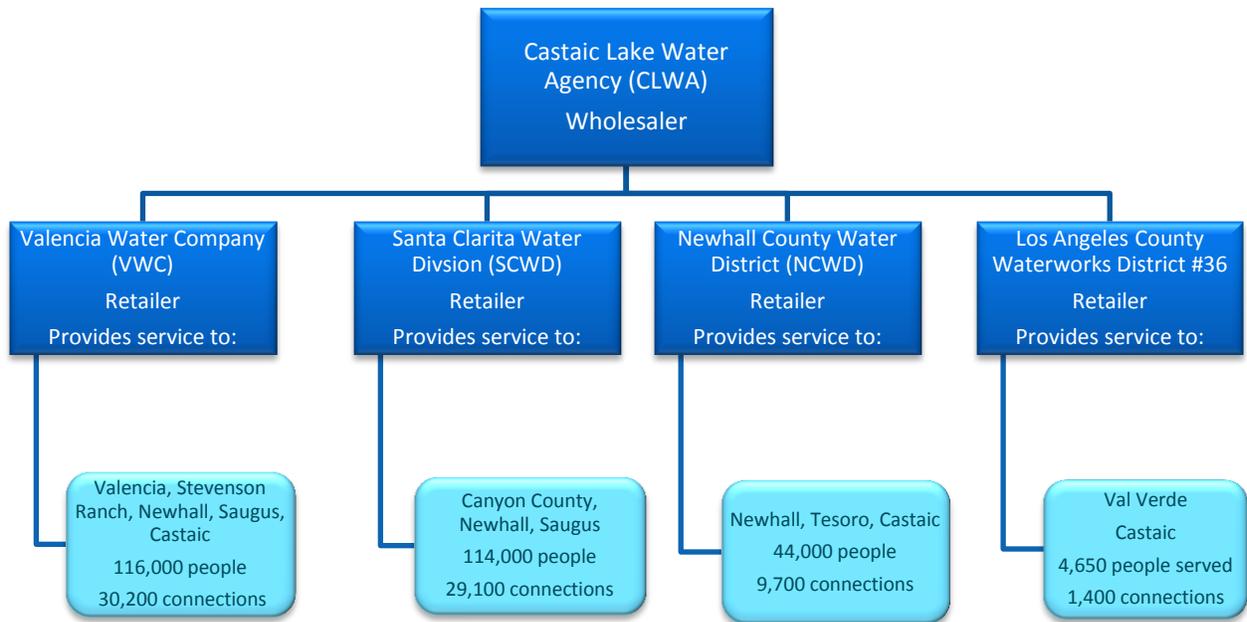
The conclusion of the study is that, when considering retrofits, WBIC programs must be directed only at customers that are known to be over-irrigating, and that general rebate or give-away programs are likely to have the unintended consequence of increasing the landscape water use of the population. When used for new homes, however, with landscapes designed for low water application from the start, WBICs should be a useful tool. The danger comes when they are installed on existing landscapes that have been historically under irrigated. It is this situation in which they can lead to an increase in water use.

## INTRODUCTION

The Santa Clarita Valley Family of Water Suppliers (the Suppliers) developed the Santa Clarita Valley Water Use Efficiency Strategic Plan (SCV WUE SP) that was finalized in 2008 as a way of promoting water efficiency in the Santa Clarita Valley. The Residential Landscape Program is one of several programs designed to help the Suppliers reduce per capita water use at least 10% by 2030. Per capita use equals the total water supplied to all customers divided by the estimated population of the service area. Current updates are being made to the Santa Clarita Valley Water Use Efficiency Strategic Plan (SCV WUE SP) to meet the more aggressive Home Water Use Efficiency Senate Bill 7 (SB X7-7) conservation goal of 20% reduction in water use by 2020.

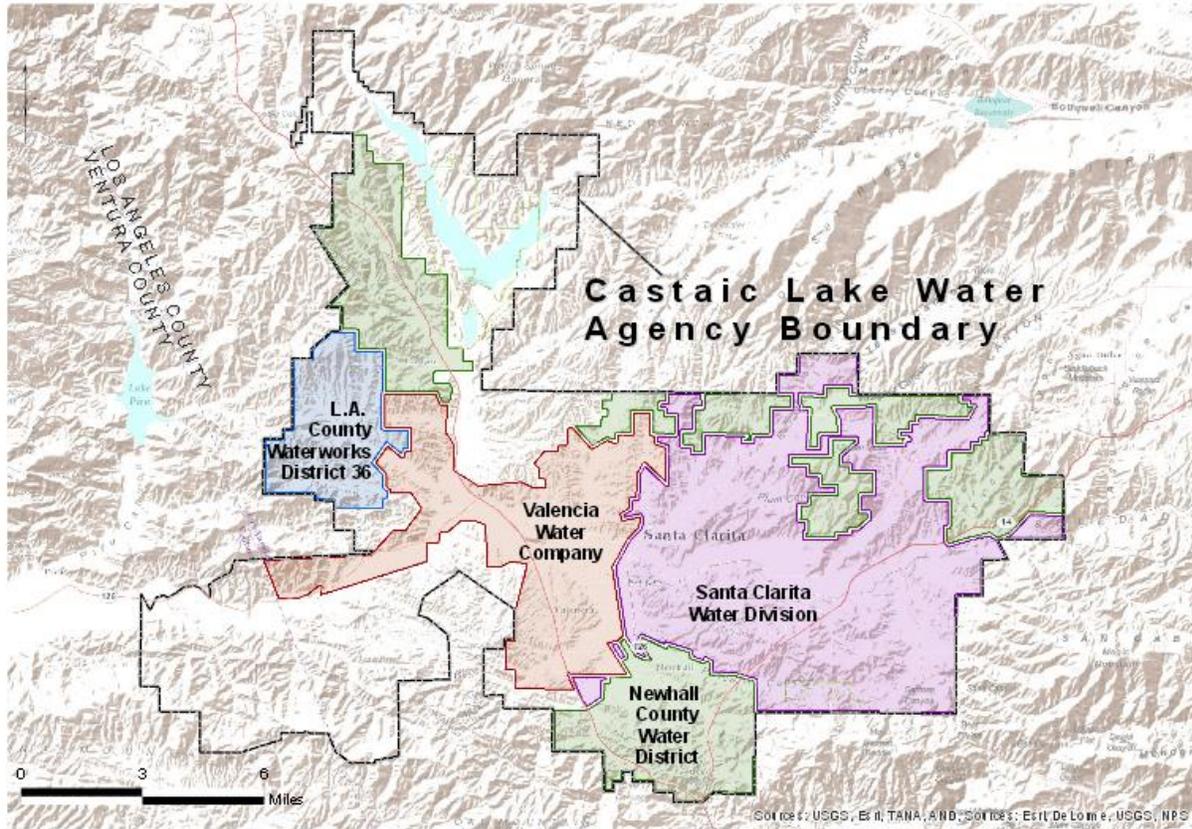
### The Suppliers

The Suppliers, shown in Figure 1, comprise one wholesale and four retail water suppliers: Castaic Lake Water Agency (public water wholesaler), Valencia Water Company, Santa Clarita Water Division, Newhall County Water District, and Los Angeles County Waterworks District #36. The four retail purveyors provide water to approximately 70,400 service connections<sup>1</sup>. The service area covered by the Suppliers is shown in Figure 2.



**Figure 1: Water service providers in the Santa Clarita Valley**

<sup>1</sup> Ludorff & Scalmanini, Consulting Engineers. 2011 Santa Clarita Valley Water Report. June 2012.



**Figure 1-1**  
CLWA and Purveyor Service Areas

**Figure 2: Service areas of Castaic Lake Water Agency and Purveyors<sup>2</sup>**

## Demographics

The City of Santa Clarita is a bedroom community, located in the Santa Clarita Valley northwest of Los Angeles and formed by the merger of the communities of Newhall, Saugus, Valencia and Canyon Country in 1987. The unincorporated communities, adjacent to the City of Santa Clarita, include Val Verde, Stephenson Ranch, Castaic, and Westridge.

The population of the valley is over 230,000 and the median income in 2010 was \$87,927. Eighty-six percent of the population has at least a high school degree and over 40% has a bachelor’s degree or higher. Thirty percent of the population is employed in educational, professional and scientific services, health care, or construction.

<sup>2</sup> Ludorff & Scalmanini, Consulting Engineers. 2012 Santa Clarita Valley Water Report. June 2013.

## Water Deliveries

The total water deliveries for Santa Clarita Valley in 2012 were approximately 85,200 af of which 18% was for agriculture, other miscellaneous uses, and individual domestic uses. The remaining 82% was for municipal use. Water sources include local groundwater, imported water, and recycled water<sup>3</sup>.

## Groundwater

Groundwater is supplied by two main sources: the alluvial aquifer and the Saugus Formation. Based on the 2010 Santa Clarita Valley Urban Water Management Plan, pumping from the alluvial aquifer ranged from a low of 30–35,000 AFY following dry years to a high of 40,000 AFY in normal/wet years. Alluvial groundwater is supplemented by pumping from the Saugus Formation which provides 7,500 to 15,000 AFY in normal years and as much as 35,000 AFY in dry years. These ranges are believed to be sustainable over the long term.

## Imported Water and Water Banking

Castaic Lake Water Agency (CLWA) imports water from the State Water Plan (SWP) and the Buena Vista/Rosedale-Rio Bravo water purchase from sources located in Kern County. Water is delivered to CLWA through the West Branch of the California Aqueduct. CLWA's contractual amount from the SWP is 95,200 AFY with an additional 11,000 AFY available for additional purchase. Additionally dry-year supplies are accessed through water banking and exchange programs such as the Rosedale-Rio Bravo Water Banking and Exchange Program where 96,000 af is stored and the Semitropic Water Storage District banking program where 35,000 af is stored.

## Recycled Water

Over the past nine years recycled water deliveries have ranged between 300 and 500 AFY, which have been used for golf course and roadway landscaping. The multi-phase Recycled Water Master Plan is ultimately expected to produce over 17,000 AFY for non-potable purposes. An additional 5,000 AFY will be recycled from the proposed Newhall Ranch Water Reclamation Plant.

## Water Rates

The following table shows the water rates charged within the four retail providers in the Agency. As shown in Table 2, the water rates within the Agency are very low. None of the top rates exceed \$3/CCF and the average cost for water at the 25 CCF level of consumption, which includes fixed charges, is also less than \$3/CCF.

---

<sup>3</sup> Ludorff & Scalmanini, Consulting Engineers. 2012 Santa Clarita Valley Water Report. ES.1 2012 Water Requirements and Supplies. June 2013.

**Table 2: Water rates and average cost of water at 25 CCF of consumption**

Utility	Fixed Charge/Mo	# of Blocks	Base Rate (\$/CCF)	Top Rate (\$/CCF)	Avg Cost/CCF at 25 CCF <sup>4</sup> Monthly Consumption
LA#36 <sup>1,2</sup>	\$17.23	2	\$0.00	\$2.2670	\$2.22
Newhall <sup>3</sup>	\$15.27	1	\$2.3026	\$2.3026 <sup>5</sup>	\$2.91
Santa Clarita	\$17.41	3	\$1.5699	\$2.3020 <sup>6</sup>	\$2.35
Valencia <sup>7</sup>	\$13.55	5	\$1.471	\$2.958 <sup>8</sup>	\$1.86

<sup>1</sup>LA#36 bills bi-monthly. The charges in the table have been changed to monthly for the purpose of comparison with the other utilities.

<sup>2</sup>LA#36 has a Quantity Facilities Surcharge of \$0.1740/BU. For example, if a customer uses 15,000 BU in their billing cycle a charge of \$2.61 is added to the bill.

<sup>3</sup><http://www.ncwd.org/customer-service/ratesandfees.htm>

<sup>4</sup><http://dpw.lacounty.gov/wwd/web/Documents/WaterRates/WWD36Non-Tiered2014-01.pdf> and from sample bill provided by LA#36.

<sup>5</sup>This includes a CLWA pass through charge of \$0.5764 per billing unit which is subject to change.

<sup>6</sup>There are three tiers in Santa Clarita: Tier 1 is for 0-14 CCF, Tier 2 is 15-49 CCF and Tier 3 is 50 CCF and above.

<sup>7</sup> Sample water bill: <http://www.valenciawater.com/service/YourWaterBill.asp>. There are five tiers from Super Efficient to Wasteful.

<sup>8</sup>Valencia provides an allotment on 9 CCF for indoor use and an allocation for outdoor use based on landscaped area, weather conditions, and days in the billing cycle. Bill was calculated based on customer staying within water budget.

## **Weather Based Irrigation Controller Program Evaluation**

The Suppliers began their Residential Landscape Program in 2010. The program provided landscapers, gardeners and homeowners with Weathermatic Smartline 1600 controllers<sup>4</sup> at no cost to the customer following completion of a training course either in the classroom or online. The course was designed to explain proper use, installation, and programming of the controllers. Installation of the controllers was done either by the owner or by a contractor, and installation was inspected by a consultant in ensure the unit was properly installed and programmed. Records were kept on whether the controller was homeowner or contractor-installed so that the impact of the method of installation on water use could be determined. Under the SCU WUE SP, the Residential Landscape Program was to include provision of high-efficiency sprinkler nozzles; this part of the program was not implemented in order to avoid complicating the analysis.

Aquacraft was asked to evaluate the efficacy of the WBIC program in order to determine the extent to which it has changed outdoor water use. These changes were to be determined in both customers who received the WBICs and in a Control group. In addition, the study was to investigate the factors that appear to impact these changes, including whether instruction was

---

<sup>4</sup> The controllers included a wireless weather station.

offered face-to-face or online and whether the controller was homeowner-installed or contractor-installed.

## Project Goals

The following five goals were identified for the study:

1. Determine the overall *change* in water use (in acre-feet), for the system as a whole, from the distribution of 1,365 Weathermatic 1600 irrigation controllers.
2. Determine the overall *change* in the average household outdoor water use from the distribution of 1,365 Weathermatic 1600 irrigation controllers.
3. Examine and compare the factors that effect *changes* in water use including but not limited to:
  - a. Online classes
  - b. Face-to-face classes
  - c. Contractor installed
  - d. Resident installed
  - e. Intensity of irrigation application of customer prior to receiving WBIC
4. Examine any differences, if differences exist, in water use between the participating retail agencies.
5. Provide recommendations for improvements to the existing Residential Landscape Program that will increase water savings in order to assist the Suppliers in meeting the conservation goals.

## ANALYSIS OF CHANGES IN WATER USE

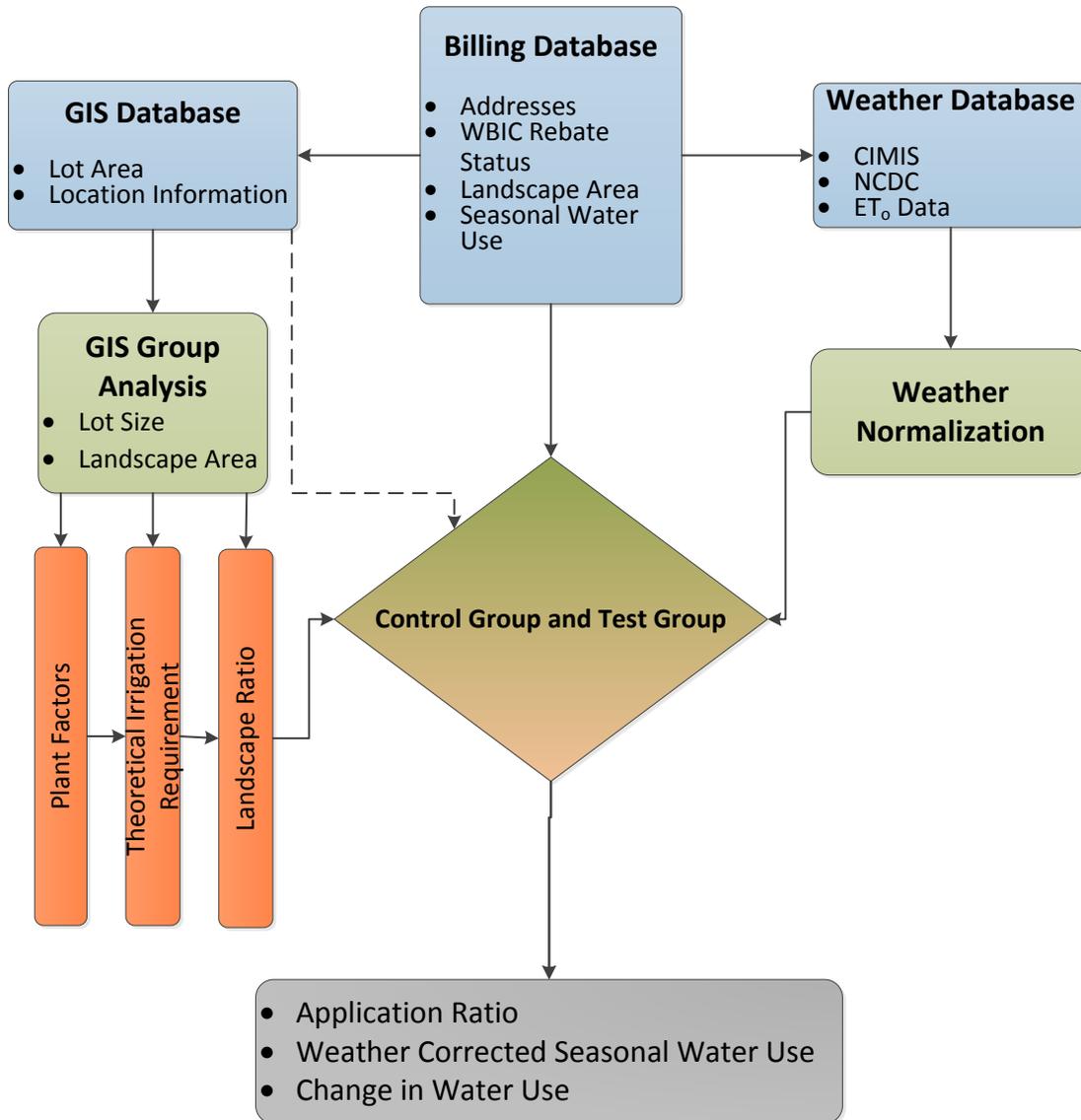
The overall strategy for the project was to conduct analyses of the changes in weather normalized outdoor water use for the sites that were provided with a WBIC (the Test group) prior to and following the WBIC installations. These changes were then compared to changes over the same period for a random group of customers with similar water use who did not receive a WBIC (the Control group). The difference in the change between the Test group and the Control group could then be attributed to the WBIC program. This was based on the assumption that all of the other factors that might affect water use, such as the economy, the perception of drought and cost for water, would affect both groups to approximately the same degree. This is a standard pre-post and side-by-side statistical analysis.

Figure 3 is a flowchart of the steps taken to perform the analysis on the impact of the WBIC installations for the Castaic Lake Water Agency. Aquacraft created billing, GIS, and weather databases in order to select GIS, Test and Control groups<sup>5</sup>. A variety of analyses were

---

<sup>5</sup> The Test Group consisted of the homes that installed WBIC's, the GIS group was a sub-set of approximately 100 of the WBIC homes on which aerial landscape analysis was performed and the Control group was comprised of the single family homes from the Agency's billing database and excluded the Test homes and the GIS homes.

performed on these groups from which models were developed and further analyses were performed. These models allowed Aquacraft to calculate an application ratio, determine the outdoor water use and demonstrate changes in water use.



**Figure 3: Analysis flowchart of the WBIC study for CLWA**

Following the initial statistical analysis, which was intended to show the overall impacts of the WBIC program on water use, just the Test group was studied in order to see what factors affected the change in water use. This step of the analysis allowed projections to be made of how water use might have change if elements of the program were to be modified.

One of the key parameters for impacts analysis was the extent to which the irrigation on the lots differed from that of the theoretical irrigation requirement (TIR) prior to the installation of the WBIC. Since WBICs are designed to match irrigation applications to the TIR, the change in

water use for a specific site should depend strongly on whether the owners were over or under-irrigating. The degree of over or under-irrigation is captured by the irrigation AR, which is the ratio of the water applied to the landscape (applied water) versus the theoretical irrigation requirement. The applied water can be estimated from billing and logging data, but the only way to estimate the TIR is to know the landscape area, the local  $ET_0$  and the types of plants the landscape contains. In order to generate this information, the best available aerial photo information and parcel information was used from the local GIS system, while the  $ET_0$  data was obtained from the weather station located on the Agency property.

Since the budget did not allow for a complete analysis of the individual landscapes on each of the WBIC test group homes, the following approach was used. First a sample of homes from the Test group was selected (the GIS group), and a detailed landscape analysis was performed on them using the best available aerial photos and GIS area analyses. From this information models were generated that could be used to estimate the necessary parameters for the other WBIC homes for which landscape areas were not available.<sup>6</sup>

The two key parameters needed for estimating the TIRs for the Test group were the landscape areas and the landscape ratios. The landscape areas were estimated from the relationship between landscape areas and lot sizes that was developed from the GIS group. The landscape ratios were determined from the relationship between landscape ratio and the landscape area observed in the GIS group. Having estimates of landscape areas and landscape ratios made it possible to calculate the TIRs for the entire Test group. In this manner, the antecedent irrigation application ratios of each of the test homes were estimated for each of the WBIC homes without having to perform detailed analyses on each of the lots.

There were seven tasks specified in the work plan:

1. Data collection
2. Assembly of billing data into tables
3. Perform weather normalization of outdoor water use
4. Determine irrigation application rates for Test group
5. Create an analytical database
6. Perform statistical analyses
7. Draw conclusions about system performance and recommendations

Detailed discussion of each task is provided in the following sections.

### ***Task 1: Data Collection***

A major component of the work was the collection of water billing data and GIS information for the four retail water providers in the service area. Each provider maintains its own billing records so it was necessary to deal with four separate data formats. In addition to billing data,

---

<sup>6</sup> The only agency that reported landscape areas for most homes was Valencia. The data was used as provided. The process of estimation was needed for the other homes.

GIS information in the form of aerial photos, parcel shape files and address information was obtained so that all of the Test homes could be identified and the landscapes on approximately 100 homes could be analyzed as to their areas, plant types and theoretical irrigation requirements. This information was then used to estimate the irrigation AR for the entire Test group, which was thought to be an important factor for explaining changes in post WBIC water use.

### Water Billing Data

The water billing data from each agency was taken in whatever form it was provided, and separate billing databases for each agency were created. From these databases queries were written to summarize water use in a consistent format for the analysis. The number of records provided, the frequency of billing, the billing units, and the years for which billing data was provided, are shown in Table 3.

**Table 3: The water billing data provided for the four participating agencies**

Agency	Number of Records Provided	Years in record	Billing Units	Bills/year
LA #36	1,333	2007-2013	CCF	6
Newhall	8,533	2007-2013	CCF	12
Santa Clarita	23,573	2007-2013	CCF	12
Valencia	26,249	2007-2013	CCF	12
Total	59,688			

The water billing database contained a field that identified the homes that had been provided with a WBIC and the year of the WBIC installation. Installations as part of this program occurred over a four year period: from May 2010 to June 2013. At the commencement of the study some WBICs had been in place for less than a year while others had been in place for over three years. Once all of the data was assembled it was possible to extract water use data for the WBIC sites (referred to as the Test group) and for the remaining, non-WBIC sites, from which a Control group was selected.

To deal with the variability in when WBIC installations occurred, a period of billing data was collected that was long enough to allow customized test periods to be tailored for each home based on the installation year. This allowed a pre-post test period for each home in which the pre-installation period was the same length as the post-installation period, insuring that each home included in the analysis had at least one full year of post-installation operation. The year in which the installation took place was not included in the pre-post analysis since the installation year was only a partial year of data. The year of installation also includes the start-up period for the system, which is likely to be non-representative of the true operation of the WBIC. The pre and post-installation periods, based on the year of installation, are shown in Table 4.

**Table 4: Time periods for pre-post analysis**

<b>Pre-Installation Period</b>	<b>Year of Installation</b>	<b>Post-Installation Period</b>
2007, 2008, 2009	2010	2011, 2012, 2012
2009, 2010	2011	2012, 2012
2011	2012	2013
2012	2013 (addendum)	2014

### **GIS Imagery**

The budget of the project did not allow for GIS analysis of all of the WBIC homes so a random sample of homes was selected for analysis. This sample was used to estimate the irrigation requirements of the landscape. GIS analysis allowed Aquacraft to determine the parcel size, the amount of landscaped area in each parcel, and the type of plant material used in a typical landscape such as turf, xeriscape, or trees and shrubs. The data obtained from the GIS imagery allowed direct determination of the TIR in order to develop landscape models which could be applied to the remainder of the Test group<sup>7</sup>. These models included the irrigated area versus parcel size and the landscape ratio versus irrigated area.

Aquacraft was unable to obtain high resolution imagery from Los Angeles County so the best available imagery from Castaic Lake Water Agency was used for landscape analysis. This standard GIS imagery, from 2011, had one-foot resolution, which proved adequate for performing landscape analysis.

### **Task 2: Tabulation of Billing and Weather Data**

Aquacraft requested single family billing data from each of the four participating water agencies which was initially aggregated into annual, seasonal, and non-seasonal use for each customer. All data was provided in CCF so no unit conversion was necessary before performing landscape analysis on the sites. Billing data was supplied in different formats by each agency however, so considerable cleaning of the data was required in order to get it into the format needed for analysis.

The initial analysis of the billing data looked at the impact of the WBICs on seasonal water use, which required disaggregation of the seasonal and non-seasonal use from the total use. Typically seasonal use is defined as the difference between total annual use and non-seasonal use. Non-seasonal use, which often serves as a proxy for indoor use, was estimated from the billing period of minimum consumption, pro-rated to the entire year, with the assumption that the minimum month use did not include any outdoor use. Therefore non-seasonal use was

---

<sup>7</sup> It was not necessary to determine TIR for the Control group because the group did not have a WBIC, and hence had no period prior to a WBIC installation to investigate.

determined by using the month with the lowest water use, typically either December or January.

Due to the warm climate in the Santa Clarita Valley, it is known that substantial irrigation occurs during all months of most years. The Agency staff raised the concern that the use of non-seasonal use as a proxy for indoor use resulted in an over-estimation of the indoor use, which had the effect of under-estimating the outdoor use. In order to address this concern, an additional analysis was performed where indoor use was based on the value measured in the 2011 California Single Family Water Use Efficiency Study for the Southern California study sites of 7.7 CCF per month.<sup>8</sup> Multiplying the monthly indoor allotment of 7.7 CCF by 12 months results in annual indoor use allowance of 92.4 CCF; subtracting this estimate of indoor use from the annual billed consumption gave the annual outdoor use for each site which was used for the landscape analysis.

A comparison of these two methods of analysis is shown in Table 5. The second column of the table shows the average seasonal water use for the Test and Control groups that was calculated using the seasonal/non-seasonal approach. The third column shows the average outdoor use that was calculated using the observed indoor use as described from the above referenced study. This shows that the outdoor water use was 27% greater than the seasonal use<sup>9</sup>. This shows that the use of seasonal use determined from billing data will tend to underestimate outdoor use and should be used as a proxy for outdoor use with caution, especially in warm climates.

**Table 5: Comparison of seasonal versus outdoor water use in the Test and Control groups**

Group	Average Seasonal Use CCF (2007-2009)	Average Outdoor Use CCF (2007-2009)	Median Seasonal Use CCF (2007-2009)	Median Outdoor Use CCF (2007-2009)
<b>Test group</b>	207	263 (+27%)	149	188 (+26%)
<b>Control group</b>	203	257 (+27%)	170	209 (+23%)

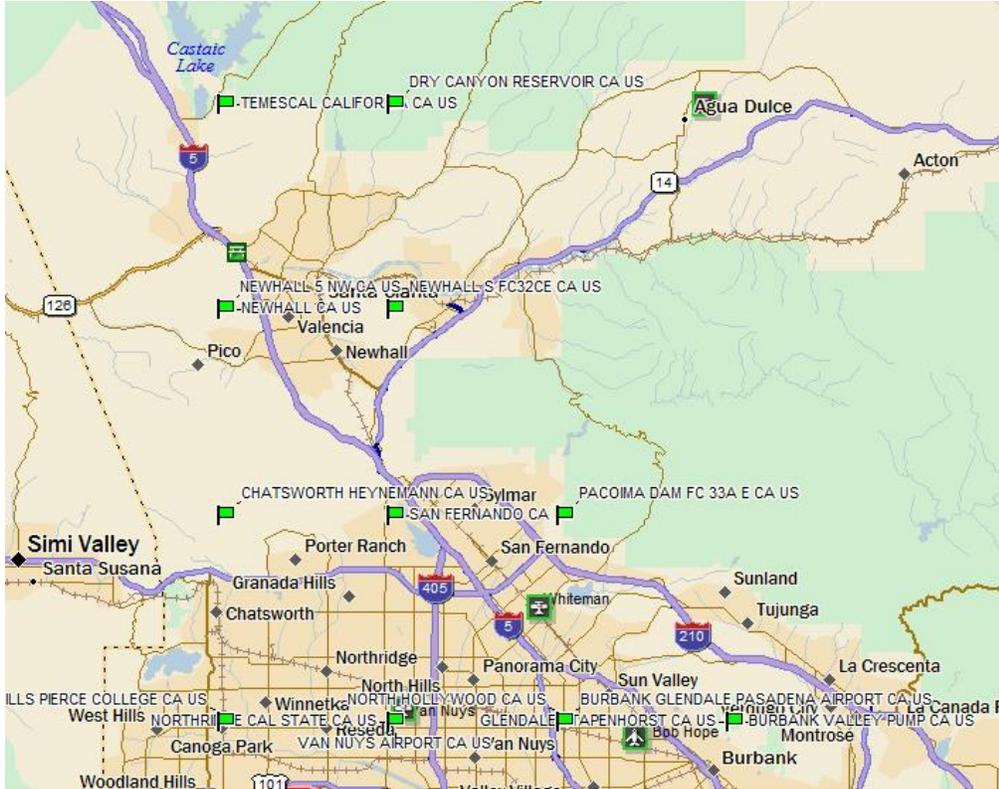
### Weather Data Tabulation

Weather data, in the form of mean monthly temperature and total rainfall, was acquired from NOAA's National Climate Data Center (NCDC)<sup>10</sup>. There are 16 stations located throughout the Santa Clarita and San Fernando Valleys, as shown in Figure 4, but only 11 of those stations had sufficient data to be included in the analysis. Some stations had data dating as far back as 1950 while other stations were much newer and data collection didn't begin until 1989.

<sup>8</sup> California Single-Family Water Use Efficiency Study. Aquacraft, Inc., California Department of Water Resources. 2012.

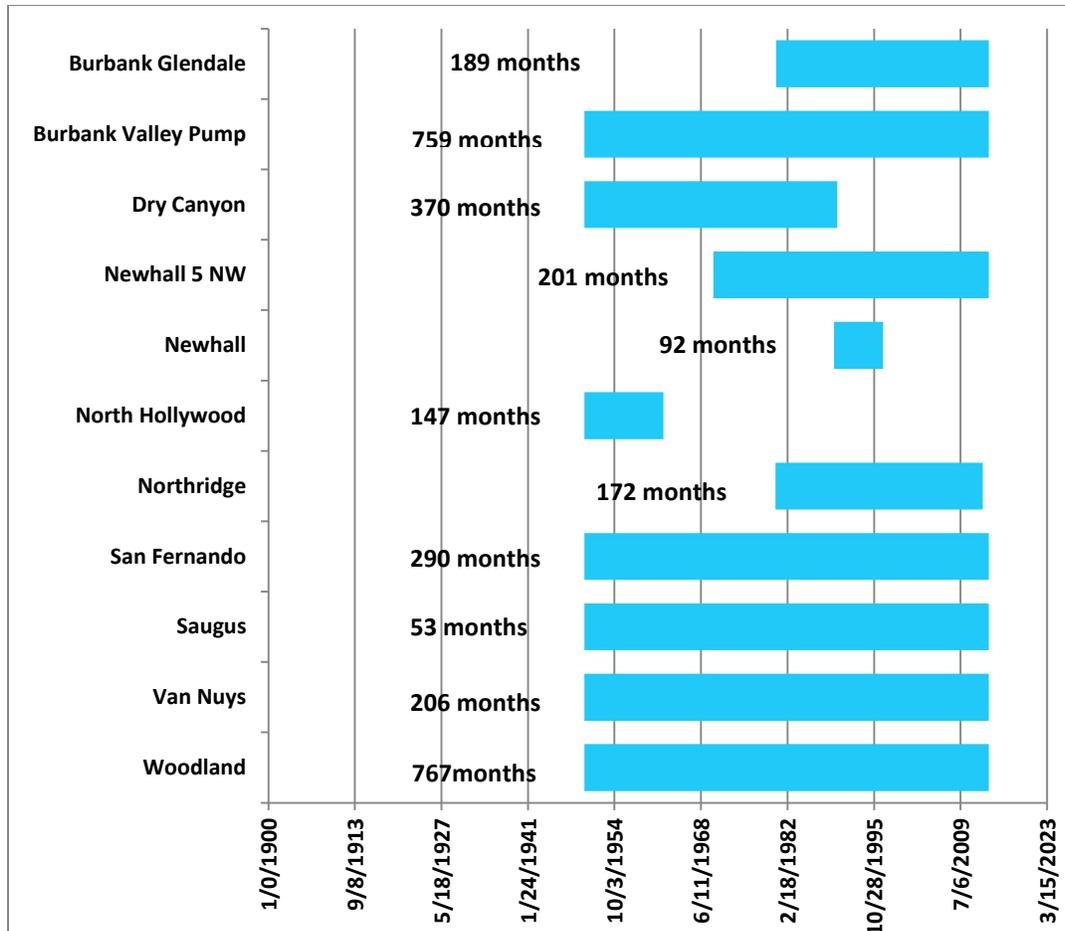
<sup>9</sup>  $1 + (257 - 203) / 203 = 1.27$

<sup>10</sup> <http://www.ncdc.noaa.gov/>. National Oceanographic and Atmospheric Administration. Accessed April 3, 2014.



**Figure 4: Location of NCDC weather stations are represented by the green flags. Saugus Power Plant and Woodland Hills Pierce College do not appear on the map.**

None of the stations had a complete set of data but Burbank Valley Pump and Woodland Hills Pierce College had the greatest number of valid months of weather data with 759 and 767 months, respectively. Newhall and Saugus Power Plant had fewer than 100 months of data. The 11 stations and the period of record are shown in Figure 5.



**Figure 5: NCDC weather stations for the Santa Clarita and San Fernando Valleys and the period of record**

In an effort to address gaps in the weather data records relationships were developed to extend the records for missing data at one station on the basis of complete data at another station. In this way, a complete record of temperature and rainfall could be prepared going back to 1997. The plan was to then examine the relationship between outdoor water use and variations in weather conditions as a possible basis for weather-normalizing outdoor water use. The amount of billing data that the four agencies were able to provide for the period from 1997 to 2006 was too limited to allow this approach to be implemented, so an alternative approach was used based on ET data from CIMIS (California Irrigation Management Information System) for the period from 2007 to 2013. Using this approach yielded good results.

### CIMIS

Rainfall and evapotranspiration (ET<sub>o</sub>) data were available from the CIMIS for the same period for which good water use data was available from the utilities (2007-2013). The CIMIS station that provided the best data was Station 204, which is in the Los Angeles Basin region of Los Angeles County located on CLWA property and maintained by CLWA staff. The station is currently active and weather data has been available from this site since December 4, 2006.

The gross ET<sub>o</sub> data and rainfall data were obtained for Station 204. The net ET<sub>o</sub> was estimated by subtracting 10% of the total rainfall (effective precipitation) from the gross ET<sub>o</sub>. The annual net ET<sub>o</sub> data for the period is shown in Figure 6.

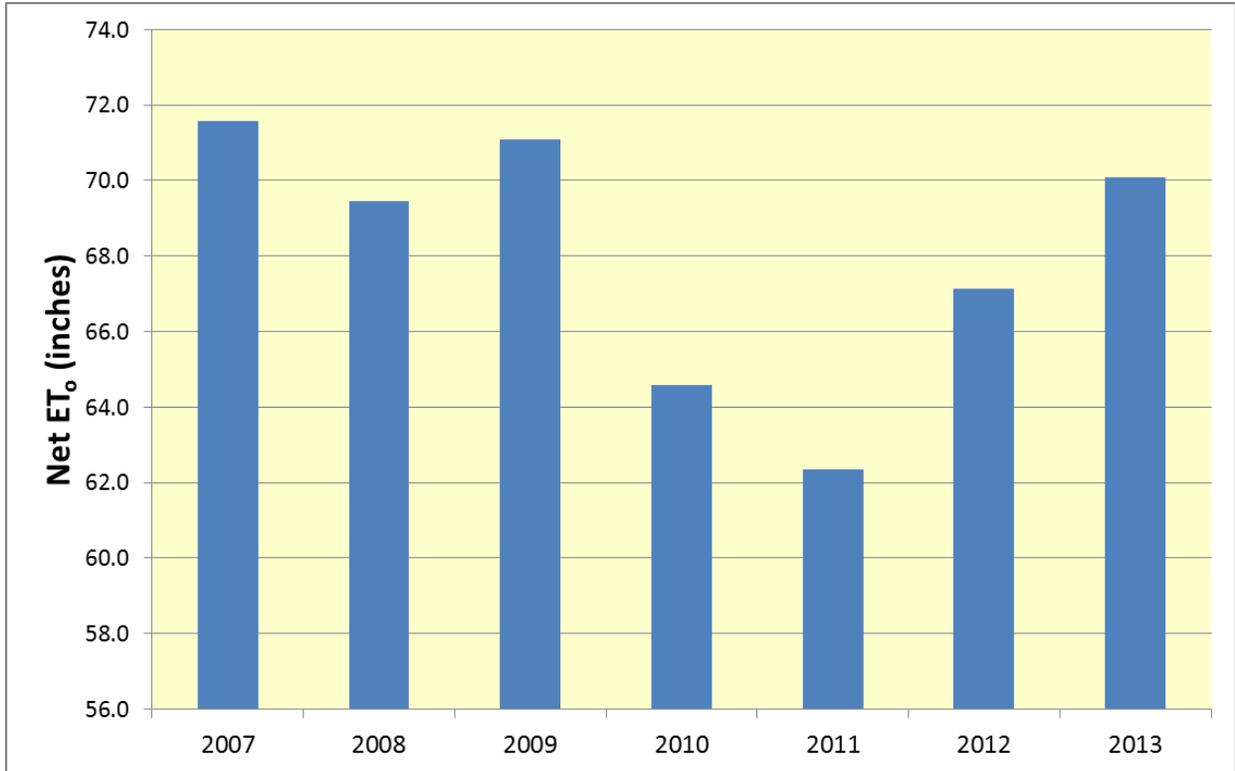


Figure 6: Net ET<sub>o</sub> for Santa Clarita CIMIS Station (#204)

### Task 3: Weather Normalization

The weather normalization process follows a power curve relationship where the normalized water use equals the observed water use in the study year times the ratio of the weather parameter in each year to the normal value for that parameter, raised to a power, that captures the elasticity of the water use to changes in the weather parameter.

$$OWU_{ni} = OWU_i \left( \frac{WP_i}{WP_n} \right)^\gamma$$

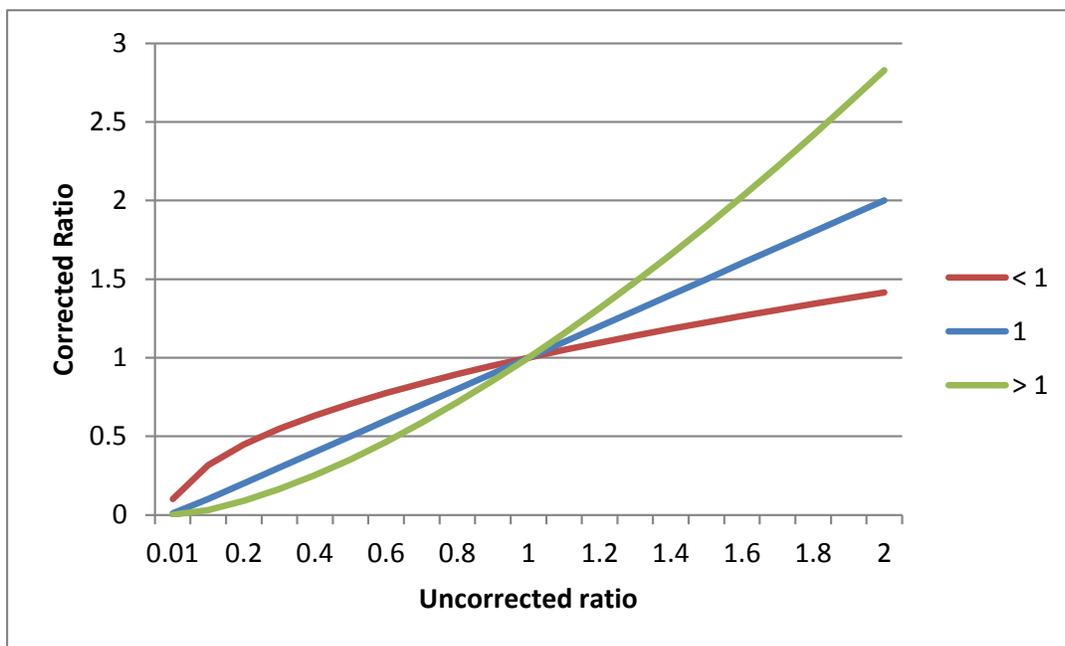
Where:

- OWU<sub>ni</sub> = normalized outdoor water use in study year i
- OWU<sub>i</sub> = observed outdoor water use in study year i
- WP<sub>i</sub> = value of weather parameter (e.g. temp, rainfall, ET) in year i
- WP<sub>n</sub> = average value of weather parameter over the study period
- γ = elasticity exponent

Analysis showed that a single normalization curve, based on the behavior of the Control group, was the best approach to capturing the effects of weather on landscape water use. The reason

for including just the Control group is that the data came from the period in which the WBICs had been installed, and the water use of the Test group would presumably have been impacted by the operation of the WBICs. The Control group, which consisted of more than 33,000 accounts, none of whom were participants in the WBIC program, would have been free from the impacts of the WBICs and would allow estimation of the weather effects free from the impacts of WBICs.

The value of the elasticity exponent can be a negative number, can equal 0, or can be a positive number (including 1). A value of zero means that there is no exponential relationship between the outdoor water use and the weather parameter. Since any number raised to the zero power equals 1 then the ratio of  $(WP_i/WP_n)^0 = 1$ . This means the normalized outdoor use will be the same as the observed outdoor use, or will be a linear function, which can have a coefficient. If the exponent is less than one, then the effect of the parameter will diminish as the ratio increases. If the exponent is greater than 1, then the effect of the parameter will increase as the ratio gets larger. If the exponent equals 1, then the relationship is linear. The three non-zero possible relationships are demonstrated in Figure 7.



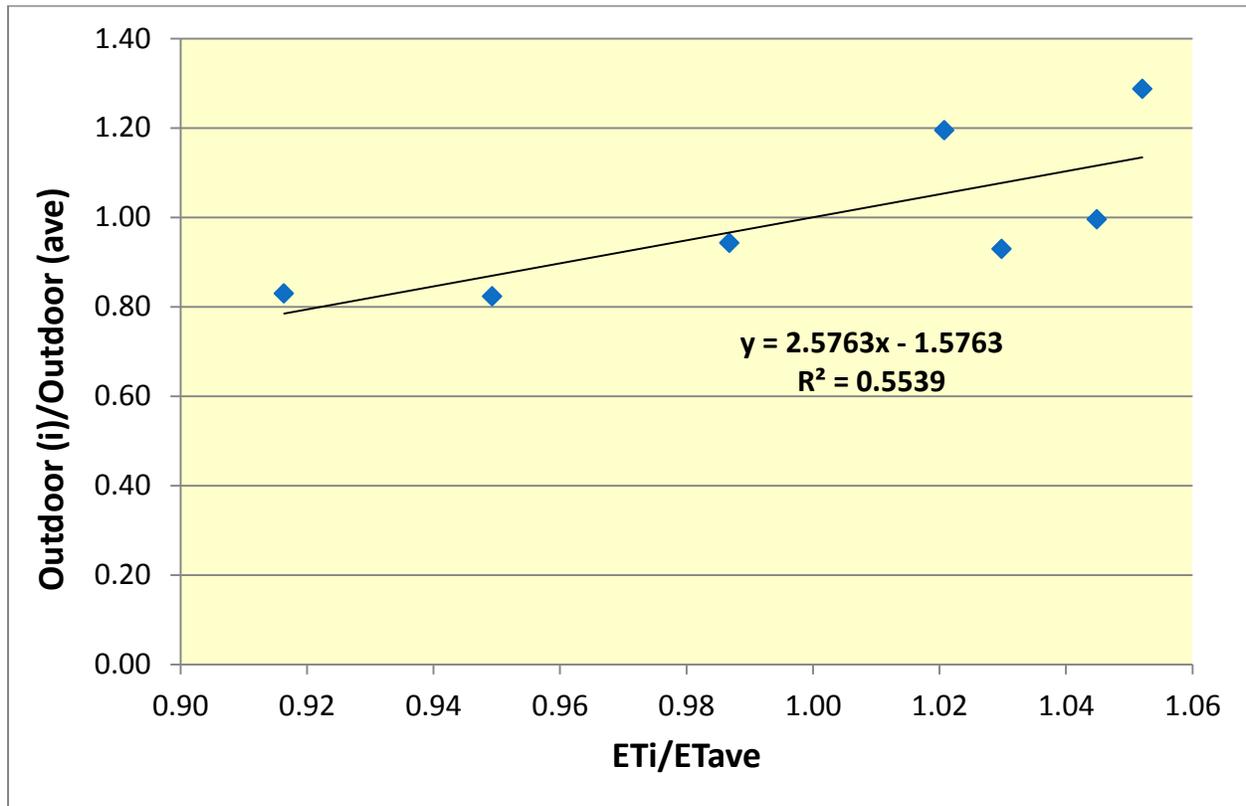
**Figure 7: Impact of exponent value on normalization**

The weather normalization process requires comparing the ratios of water use to  $ET_0$  to their average values and fitting a curve to the data in order to see whether a statistically significant relationship can be observed. Table 6 shows the ratios of outdoor water use for the Control group for the years from 2007 to 2013 and the ratios for  $ET_0$  for the same period. The outdoor water use ratio (OWU ratio) is the ratio of the weather corrected outdoor water use in each year to the average outdoor use for the period from 2007 to 2013. The  $ET$  ratio is the ratio of the  $ET_0$  for the year to the average of the  $ET_0$  for the period. The data is plotted as a scatter

diagram in Figure 8. A linear relationship with a good correlation coefficient emerges from the data as shown in the figure. This relationship was used to normalize all of the outdoor water use to average conditions of ET = 68.0 inches.

**Table 6: OWU and ET<sub>o</sub> data**

	2007	2008	2009	2010	2011	2012	2013	Ave
<b>Ave outdoor water use for control group (CCF)</b>	194	180	150	124	125	142	140	151
<b>OWU ratio</b>	1.29	1.19	1.00	0.82	0.83	0.94	0.93	–
<b>ET<sub>o</sub> (in)</b>	71.6	69.5	71.1	64.6	62.4	67.1	70.1	68.0
<b>ET ratio</b>	1.05	1.02	1.04	0.95	0.92	0.99	1.03	–



**Figure 8: Weather normalization curve**

The following formulas show how the relationship, shown in Figure 8, was used to generate factors for normalizing the outdoor water use in each of the study years to the expected use based on an average ET<sub>o</sub> of 68.0 inches, which is the objective of the normalization procedure. Equation 1 and Equation 2 show that the values on the x and y axes of Figure 8 represent the

ratios of outdoor water use and  $ET_o$ , shown simply as ET, to avoid confusion with multiple subscripts, in the individual study years to their average values over the study period.

$y = \frac{OWU_i}{OWU_{ave}}$	<b>Equation 1</b>
-------------------------------	-------------------

$x = \frac{ET_i}{ET_{ave}}$	<b>Equation 2</b>
-----------------------------	-------------------

Equation 3 shows the observed linear relationship between these ratios.

$y = 2.5763 x - 1.5763$	<b>Equation 3</b>
-------------------------	-------------------

Equation 4 substitutes the values for  $y$  and rearranges to get the average outdoor water use ( $OWU_{ave}$ ) value on one side and the outdoor water use (OWU) in the individual year on the other side of the equation.

$OWU_i = OWU_{ave} (2.5763x - 1.5763)$	<b>Equation 4</b>
--	-------------------

Equation 4 rearranges once again to solve for normal (average) outdoor water use as a function of the yearly outdoor use and observed relationship, called the Normalization Factor in Equation 6, which is the inverse of the value of the relationship.

$\frac{OWU_i}{2.5763 x - 1.5763} = OWU_{ave}$	<b>Equation 5</b>
---	-------------------

$Normalization\ Factor = \frac{1}{2.5763x - 1.5763}$	<b>Equation 6</b>
--	-------------------

In Equation 7 the normalized outdoor water use is shown to be the product of the yearly outdoor water use times the Normalization Factor.

$OWU_{ave} = Normalization\ Factor \times OWU_i$	<b>Equation 7</b>
--	-------------------

Table 7 shows the calculated normalization factors for each of the study years. Notice that in years with greater than average  $ET_o$  the factor is less than one and in years with less than average  $ET_o$  it is greater than one. This is what the process should do, and has the effect of showing the expected outdoor use for average conditions of  $ET_o$ .

**Table 7: Weather normalization factors**

Year	2007	2008	2009	2010	2011	2012	2013
ET ratio	1.05	1.02	1.04	0.95	0.92	0.99	1.03
Normalization Factor	0.87	0.95	0.89	1.16	1.30	1.04	0.92

#### **Task 4: Determination of the Application Ratios**

The AR is the ratio of the amount of water that is actually applied to the landscape to the amount that is theoretically required based on standard engineering calculations. Determination of the application ratios was an important element of the analysis, and considerable effort went into generating the necessary data for the entire Test group, so that the effect of the antecedent application ratio on the change in water use could be examined. Overall, the determination was a two-step process, with direct calculations performed on a sample of homes (the GIS group), and estimations based on the results of the GIS analysis being done on the remainder of the Test group.

When properly installed and programmed, WBICs are designed to apply the precise amount of irrigation water needed to satisfy the TIR of the landscape. The TIR is a function of the irrigated area, the types of plants used in the landscape, the efficiency of the irrigation system and the local, net ET<sub>o</sub>. The ratio of the actual amount of water applied to the landscape versus the TIR is the application ratio. Ideally, a properly operating WBIC will apply the TIR to the landscape and will have an application ratio (AR) of 1.0.

The implication of the AR factor is that homes in the Test group, which had AR values less than 1.0 prior to the installation of a WBIC, should tend to *increase* their irrigation application when using a WBIC and homes in the Test group with an AR greater than 1.0 should tend to *decrease* their application. One of the key findings of the statewide study of WBICs in California in 2009 (Aquacraft 2009), was that the antecedent application ratio was one of the strongest determinants of changes in water use after installing a WBIC<sup>11</sup>. This is why it was considered important to estimate the pre-post application ratios of the entire Test group, in order to examine the relationship between antecedent application ratios and the changes in water use affected by WBICs.

There are two key parameters needed for determining the application ratio for the Test group: irrigated area and the landscape ratio (LR). From these two parameters the theoretical irrigation requirement and application ratios can be developed. The irrigated area is the area of the lot on which some type of formal landscape has been installed, as opposed to areas covered by non-irrigated native vegetation. The landscape ratio is the ratio between the

<sup>11</sup> Evaluation of California Weather-based “Smart” Irrigation Controller Programs. Aquacraft, Inc. Presented to the California Department of Water Resources and facilitated by California Urban Water Conservation Council. July 1, 2009.

theoretical irrigation requirement of the actual landscape on the lot and the reference landscape, which is composed of a total cool season turf landscape with allowance for irrigation efficiency.

It was not feasible to do a complete landscape analysis for the entire WBIC Test group, but models were developed using GIS analysis on a random sample of homes, which were applied to the Test group to determine the irrigated area, TIR and landscape ratio. Using these models and outdoor use data, antecedent irrigation application ratios were estimated for each of the WBIC Test group homes. This was also possible for many of the homes in the Valencia group since the agency provided the irrigated areas. This made it possible to check for a bias in the Test group by comparing the mix of application ratios to that from the much larger Valencia group. This analysis was done and discussed in the section of the report on Bias Tests.

### GIS Analysis

An analysis of 115 lots from the WBIC homes was conducted using aerial photography in order to directly determine the irrigated areas, theoretical irrigation requirements and application ratios of the sample. Addresses for the GIS group were obtained from the billing databases. The number of homes selected from each agency for GIS analysis was proportional to the number of WBICs installed in that agency relative to the total number of WBICs installed by that agency during the study period from 2010-2012. The homes selected for analysis in GIS were selected using the process of systematic random sampling<sup>12</sup>. Sites selected in this manner should be fairly representative of the WBIC population as a whole for each agency. Table 8 shows the number of homes in the Test group for each of the agencies as well as the number of sites included in the final GIS analysis.

**Table 8: Number of WBIC homes and GIS sites for each agency**

Agency	Test Group 2010-2012 WBIC Homes	Number of GIS Sites	Percentage of Utility Total <sup>2</sup>
Valencia	505	59	12
Santa Clarita	425	41	10
Newhall	120	14	12
LA#36	8	1	12
<b>Total</b>	<b>1061</b>	<b>115</b>	<b>11</b>

<sup>2</sup>A proportional number of sites was initially selected for Valencia, Santa Clarita, and Newhall but during GIS analysis certain sites had to be eliminated due to the fact that the parcel area was not well-defined in GIS.

<sup>12</sup> <https://explorable.com/systematic-sampling>

## Landscape Analysis of the GIS Group

ArcGIS provided the ability to determine the lot size and irrigated areas of the 115 homes selected from the billing database. It was from the analysis of this GIS group that other parameters could be estimated for the remainder of the Test group.

### Lot size and irrigated area

The lot size and the irrigated area were first measured for each of the 115 GIS sites. Valencia provided irrigated area for most of its WBIC participants so it was not necessary to measure these, but irrigated area information was not available for the other agencies. One of the key objectives of the GIS analysis was to develop a relationship between the total lot size and the irrigated area, which could be used to estimate the landscape areas for the homes for which only lot size was available.

The analysis provided a reasonably good relationship between irrigated area and parcel size. Figure 9 shows this relationship developed from the analysis. This model shows that the irrigated area is typically approximately 30% of the lot plus 1,410 square feet and has an  $R^2$  value of 0.44. While the majority of the lots are under 20,000 ft<sup>2</sup> with less than 10,000 ft<sup>2</sup> of irrigated area, the graph shows that the data is affected by several very large lots which have a wide range of irrigated area. Consequently, the relationship was expected to be more accurate for the majority of smaller lots in the Test group. This relationship allowed an estimate of the irrigated area for the remaining homes in the Test group, from which their TIRs could be estimated.

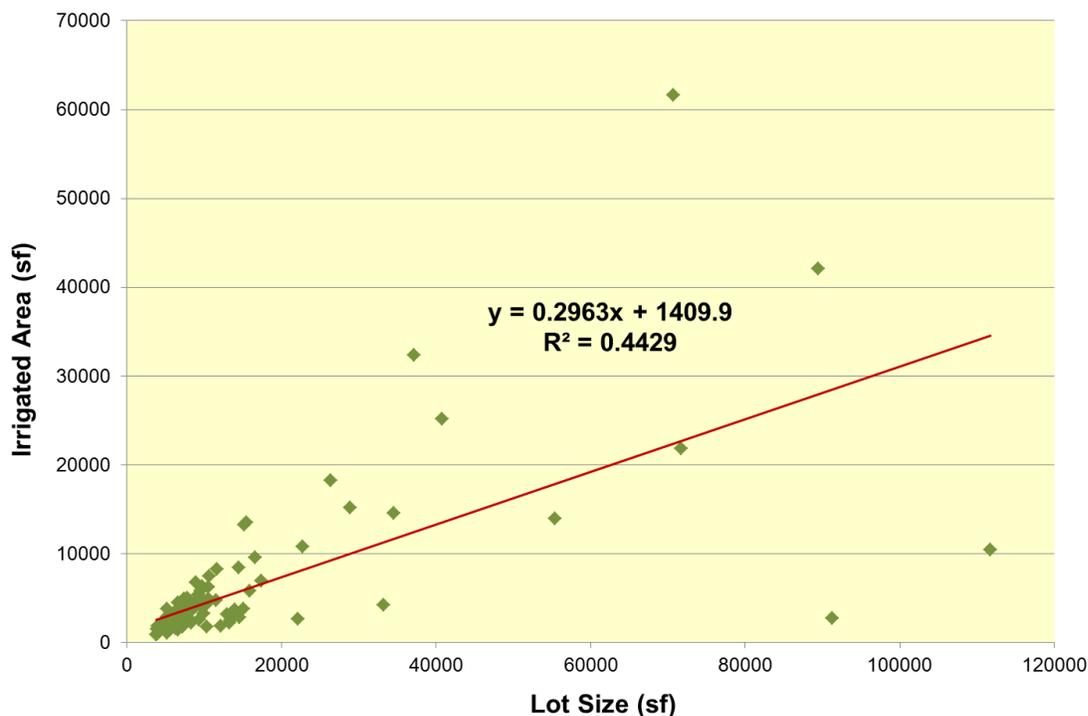


Figure 9: Irrigated area versus lot size

### *Theoretical Irrigation Requirement*

The amount of water needed to maintain a landscape at a fairly high level is classified as the TIR. This is an estimate of the amount of water that should be applied to the landscape to fully meet its water requirements. TIR is based on the area of the landscape being irrigated, the types of plants in the landscape, the efficiency of the irrigation system and the local, net  $ET_o$ . TIR is a horticultural parameter that is aimed at optimizing plant growth.

The landscape characteristics for the GIS group were determined through aerial photo analysis. Typically each landscape is composed of several smaller sub-areas, each with its own characteristic plant types which have different water requirements known as the species coefficient. The efficiency of the irrigation system also factors into the calculation of TIR. Each plant type was assigned an irrigation type based on the plant material in the landscape and the type of irrigation commonly used with that plant material. Turf is usually irrigated with overhead spray irrigation while xeriscape is more commonly irrigated with drip irrigation. Table 9 shows the landscape characteristics used to calculate the landscape ratio for each site. Once the water requirements of each sub-area have been calculated it is a simple matter to determine the water requirement of the landscape.

### *Reference Requirement*

The reference requirement is the volume of water that the reference species requires. For landscape purposes the reference species is fully watered, cool season turf, growing in full sun, at a height of 6 inches. The reference requirement is higher than what is normally required by any species encountered on residential landscapes, including turf, which is normally not optimally watered, nor is it always in full sun or kept at a height of 6 inches. No allowance is made for irrigation efficiency in estimating the reference requirement because the water requirement has traditionally been determined from lysimeters, which apply the water directly to the root zone.

### *Species Coefficient*

The water requirement of each plant type is given as a coefficient based on the water requirement of the reference species (cool season turf). The species coefficients used in this analysis came from the California Model Efficient Landscape Ordinance and ranged from 0.8 for turf to 0.3 for xeric plants. Swimming pools, while not made up of plants are considered part of landscape and were given an estimated coefficient of 1.25 to account for their open water surface and losses due to splashing.

### *Irrigation Efficiency*

Not all water from the irrigation system reaches the plants it is designed to irrigate. Factors such as evaporation, runoff, poor head spacing, and overspray affect the efficiency of the system. Because landscape irrigation is not 100% efficient it is necessary to *increase* the amount of water applied to the landscape in order to adequately meet the needs of the plant material. Overhead irrigation, such as sprayers and rotors, usually used to irrigate turf and large plantings, are more prone to run-off and evaporative losses. Drip systems, frequently

used to irrigate xeriscape, usually have a higher irrigation efficiency. The species coefficient and the irrigation efficiency for each landscape type are shown in Table 9.

**Table 9: Landscape characteristics used for calculating the theoretical irrigation requirement**

Landscape Type	Species Coefficient	Irrigation Efficiency
Pool	1.25	100%
Cool season turf	0.80	71%
Non-turf plants	0.65	71%
Xeriscape	0.30	90%
Non-irrigated vegetation	0.00	0%

Once the irrigated areas are measured and the species coefficients and irrigation efficiencies for each sub-area are estimated, calculating the TIR for each site is a simple matter. The formula for calculating the TIR is shown in Equation 8.

$TIR = Net\ ET_o \sum_{i=1}^n IA_i \left( \frac{SC_i}{IE_i} \right)$	<b>Equation 8</b>
--	-------------------

Where:

TIR = Theoretical Irrigation Requirement

ET<sub>o</sub> = Net Evapotranspiration

IA<sub>i</sub> = Irrigated Area of the i<sup>th</sup> area

SC<sub>i</sub> = Species coefficient of the i<sup>th</sup> area

IE<sub>i</sub> = Irrigation efficiency of i<sup>th</sup> area

n = number of irrigation zones in landscape

**Calculating the Reference Requirement**

The reference requirement is the amount of water that would be applied to the landscape if the entire irrigated area was planted in fully-watered cool season turf with a 100% efficient irrigation system. The purpose of this value is to allow comparisons of the landscape requirement to a standard reference value, based on ET, to be expressed. The reference requirement can be calculated from GIS analysis by using Equation 9.

$Reference\ Requirement = Net\ ET_o \times IA$	<b>Equation 9</b>
--	-------------------

Where:

Ref Req = Reference Requirement (cf)

Net ET<sub>o</sub> = Net Evapotranspiration (ft)

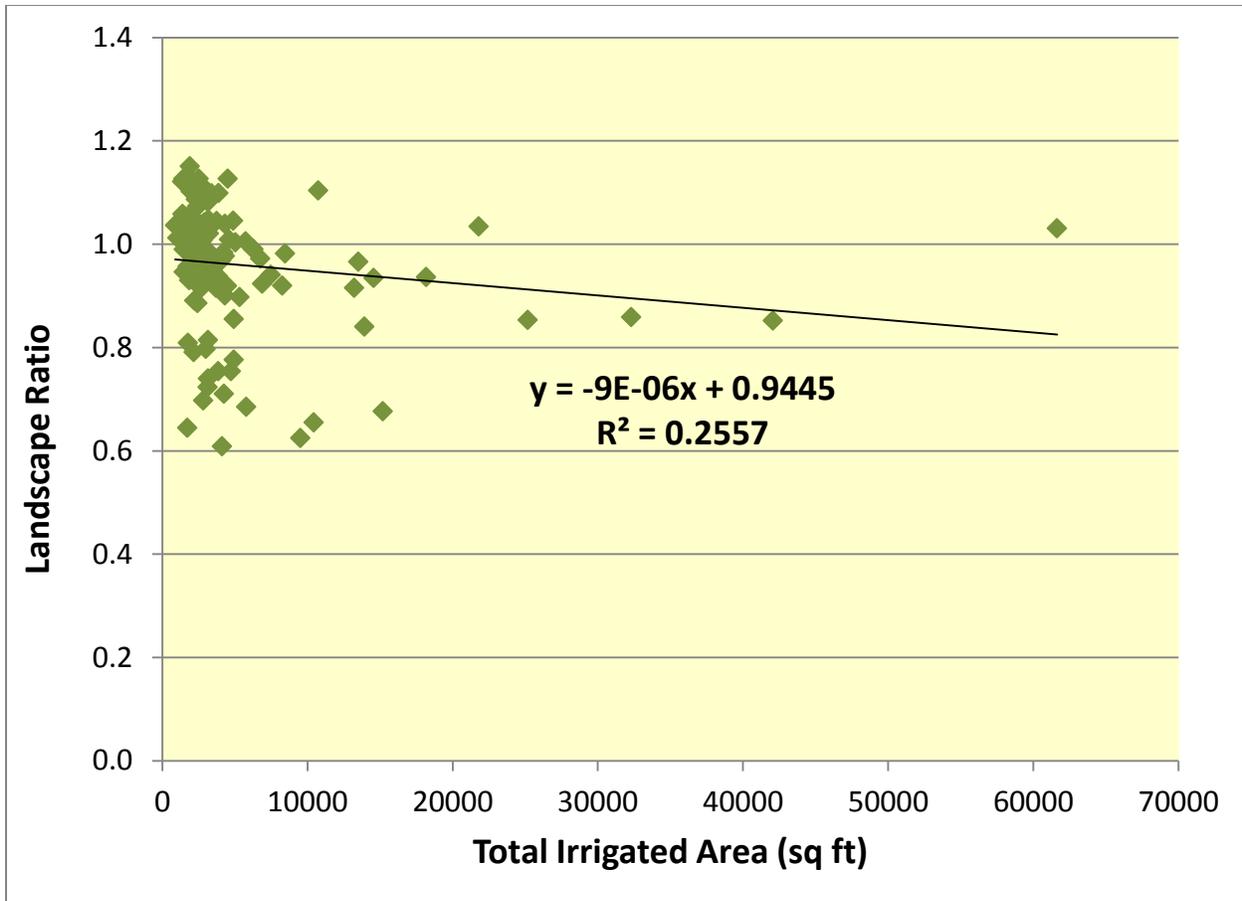
IA<sub>i</sub> = Irrigated Area of the i<sup>th</sup> area (sf)

### Calculating the Landscape Ratio for GIS Group

The landscape ratio for the GIS group was calculated as the ratio of the actual water requirement of the landscape, based on the TIR, to the reference requirement. Following analysis of the landscape in the GIS sample, it was a simple matter to calculate the landscape ratio as shown in Equation 10.

$LR = \frac{TIR}{Reference\ Requirement}$	<b>Equation 10</b>
---	--------------------

In order to estimate the TIR of the Test group, it was first necessary to estimate how the water requirements of the landscapes varied from the reference requirement as a function of the irrigated area. This was to prevent an over-estimation of the requirements that would occur if a constant value had been used. It was suspected that as landscapes increased in size, their water requirements, relative to ET, would decrease. In order to explore this, the relationship between the landscape ratios developed from the GIS analysis and the landscape size was examined. This relationship is shown in Figure 10. While not as good a fit as that developed for irrigated area, the relationship does show a decrease in landscape ratio as the size of the irrigated landscape increases; this relationship was used to estimate the TIR and landscape ratios for the non-GIS members of the Test group.



**Figure 10: Landscape ratio versus irrigated areas**

### Analysis of the Test Group

Landscape analysis in GIS allowed Aquacraft to observe the relationship between the lot size and irrigated area. It also made it possible to observe the relationship between the landscape ratio and irrigated area. These relationships were used to estimate the irrigated areas, the theoretical irrigation requirements, and the application ratios for the Test group. The working assumption was that the same pattern of landscape versus lot size prevailed throughout the area and similar plant types were used in the landscapes. By making these assumptions it was possible to get estimates of the landscape ratio for the entire group.

The analysis of the application ratios for the Test group used the five-step logic shown in Table 10. The table shows the equations that were used to generate the application ratios for the lots in the Test group for which the only information available was their lot size (and the models derived from the GIS sample). From this, the irrigated areas of the lots were determined using the relationship shown in Figure 9. The reference requirement of each lot was calculated using Equation 12 from the local  $ET_0$  and the irrigated areas. The estimated irrigated area was also used to obtain an estimate of the landscape ratio (LR) for the lot using the relationship shown in Figure 10, which was input into Equation 11.

**Table 10: Logic for determination of application ratios in Test group**

$LR = \frac{TIR}{Ref Req}$	<b>Equation 11</b>
$Ref Req = ET_o \times Irr Area$	<b>Equation 12</b>
$LR = \frac{TIR}{ET_o \times Irr Area}$	<b>Equation 13</b>
$TIR = LR \times ET_o \times Irr Area$	<b>Equation 14</b>
$AR = \frac{Actual OWU}{TIR}$	<b>Equation 15</b>

At this point the LR,  $ET_o$  and Irrigated Area were known for Equation 13, which was rearranged to solve for the TIR in Equation 14. The final step was to calculate the application ratio as the ratio of the actual outdoor water use, obtained from the billing data, to the TIR. This process allowed the application ratios for each of the Test group homes to be either determined directly using the irrigated areas supplied by the agency or from the GIS analysis, or estimated using the results of the GIS analysis.

### **Task 5: Data Assembly**

The data generated in the previous steps were assembled into a SPSS<sup>13</sup> data set that contained the key information for the Test group and the Control group. Table 11 shows a list of the variables contained in the data set. Since the application ratio was only needed for the evaluation of the Test group, none of the variables that relate to determination of irrigated area or theoretical irrigation requirement were included for the Control group. Because  $ET_o$  was used for normalizing the outdoor water use it was included in the data for both groups. This data set was used to generate the statistical results contained in the following section.

**Table 11: Variables contained in the analysis dataset**

<b>Variable</b>	<b>Group</b>	<b>Description</b>
<b>Keycode or ID</b>	Both	ID used for lots on which a GIS landscape analysis was done
<b>Address</b>	Both	Customer address from billing database
<b>Folio Number</b>	Both	Account number uses in Valencia to ID customer
<b>Customer Number</b>	Both	ID for customer in other databases
<b>Agency</b>	Both	Name of the water provider: Newhall, LA36, Santa Clarita, Valencia
<b>Group</b>	Both	Test of Control

<sup>13</sup> Statistical Package for Social Sciences

<b>Variable</b>	<b>Group</b>	<b>Description</b>
<b>Area Source</b>	Test	Where got the irrigated area (GIS, Agency, Model)
<b>Lot Size (SF)</b>	Test	Area of lot from GIS, not available for Valencia
<b>Irrigated Area (SF)</b>	Test	Total irrigated area in landscape
<b>Landscape Ratio</b>	Test	Ratio of TIR to Reference Requirement
<b>Year Installed</b>	Test	Year WBIC installed
<b>Install Method</b>	Test	Owner/Contractor
<b>Instruction Methods</b>	Test	Class/Online
<b>SeasUse2006</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2007</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2008</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2009</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2010</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2011</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2012</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2013</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>SeasUse2014</b>	Both	Raw outdoor water use (Not weather-corrected)
<b>ET_2006</b>	Both	ET
<b>ET_2007</b>	Both	ET
<b>ET_2008</b>	Both	ET
<b>ET_2009</b>	Both	ET
<b>ET_2010</b>	Both	ET
<b>ET_2011</b>	Both	ET
<b>ET_2012</b>	Both	ET
<b>ET_2013</b>	Both	ET
<b>ET_2014</b>	Both	ET
<b>TIR_2006</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2007</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2008</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2009</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2010</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2011</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2012</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2013</b>	Test	Irrigated area * Landscape Ratio * ET
<b>TIR_2014</b>	Test	Irrigated area * Landscape Ratio * ET
<b>AR_2006</b>	Test	Outdoor use/TIR
<b>AR_2007</b>	Test	Outdoor use/TIR
<b>AR_2008</b>	Test	Outdoor use/TIR
<b>AR_2009</b>	Test	Outdoor use/TIR
<b>AR_2010</b>	Test	Outdoor use/TIR
<b>AR_2011</b>	Test	Outdoor use/TIR

Variable	Group	Description
AR_2012	Test	Outdoor use/TIR
AR_2013	Test	Outdoor use/TIR
AR_2014	Test	Outdoor use/TIR
Pre WBIC AR	Test	Ave of Application Ratio as a function of Install year prior to WBIC
Pre WBIC TIR	Test	Ave of TIR as function of install year prior to WBIC
Pre WBIC Excess Use	Test	Pre WBIC AR * Pre WBIC TIR (Non-weather corrected excess use)
OutdoorUse2006WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2007WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2008WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2009WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2010WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2011WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2012WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2013WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
OutdoorUse2014WC	Both	Outdoor use in Year $i$ * Weather Normalization Factor $_i$
Pre WBIC Outdoor water Use_Weather Corrected	Both	Ave Weather Corrected outdoor use as function of install year prior to WBIC
Post WBIC Outdoor water Use_Weather Corrected	Both	Ave Weather Corrected outdoor use as function of install year after WBIC
Change in Use_Weather Corrected	Both	Pre-post Weather Corrected outdoor water use

### **Task 6: Statistical Analysis**

The statistical analysis comprised two elements: The first was a paired pre-post analysis on changes in outdoor water use from prior to the WBIC installation to after the WBICs were installed. In the second, the change in water use of the Test group was compared to the change in the Control group. The difference between the change in the Test group and the Control group was then attributed to the WBICs. A number of other factors, such as the method of installation were also investigated as follow-up studies.

Because the dataset contained outdoor water use for each home before and after the WBIC installation period it was possible to calculate the change in water use directly for each home by simple subtraction of the pre-WBIC water use from the post-WBIC water use. By following this approach, after normalizing for  $ET_o$ , a negative change in outdoor water use represented a reduction in use and a positive change represented an increase in use. It was due to the availability of the pre-post data for individual homes that this determination could be made.

Since the homes were studied before and after the intervention it was a safe assumption that the change in outdoor water use represented a real variation rather than two unrelated values that might occur in different groups of homes.

During the study period, the most recent year for which a full year of water data was available was 2013, so it was necessary to tailor the pre-post period for the homes based on the year of the WBIC installation. As described previously and shown in Table 3, homes that had a WBIC installed in 2010 used a three year pre and post period, homes where the WBIC was installed in 2011 used a two year period pre and post period and homes that had a WBIC installed in 2012 used a single year for the pre-post period. In 2015, after the billing data for 2014 is available, the analysis will be updated.

The Control group did not have WBICs installed but to avoid creating a bias in the data, due to changes in the pre-post period, “install” years were assigned to the Control group in the same proportion as occurred in the Test group. So, for example, if a certain percentage of the Test group had an install year of 2010 then the same percentage of the Control group was assigned a date of 2010 for purposes of calculating their pre and post weather-corrected outdoor water use.

Knowing the change in water use for just the Test group cannot, by itself, be a measure of the impact of the WBIC installation. This is because there are a number of other factors that influence outdoor water use. Weather patterns were already accounted for in the normalization process, but other factors like economic conditions, drought perceptions, water restrictions or any other factor that affects the water use of the general population must be accounted for. We know that in 2008 there was a major deflation in housing prices and a general depression of the economy. That certainly had an impact on water use.

In order to account for the impact of these general conditions the water use of the Control group was analyzed. The Control group consisted of a large group of single family residences whose water use patterns were identical to those of the Test group in 2007, and who were within 500 feet from one of the WBIC homes. The changes in the weather-corrected outdoor water use of each of the homes in the Control group were determined. The basic assumption in the analysis is that whatever factors are impacting water use for the general population will have similar influences on both the Test group and the Control group. The only other difference between the groups is the presence of the WBIC in the Test group, and so the difference in the change between the two groups represents the impact of the WBIC given the close proximity of the two groups and their similar water use patterns prior to the installation of the WBIC.

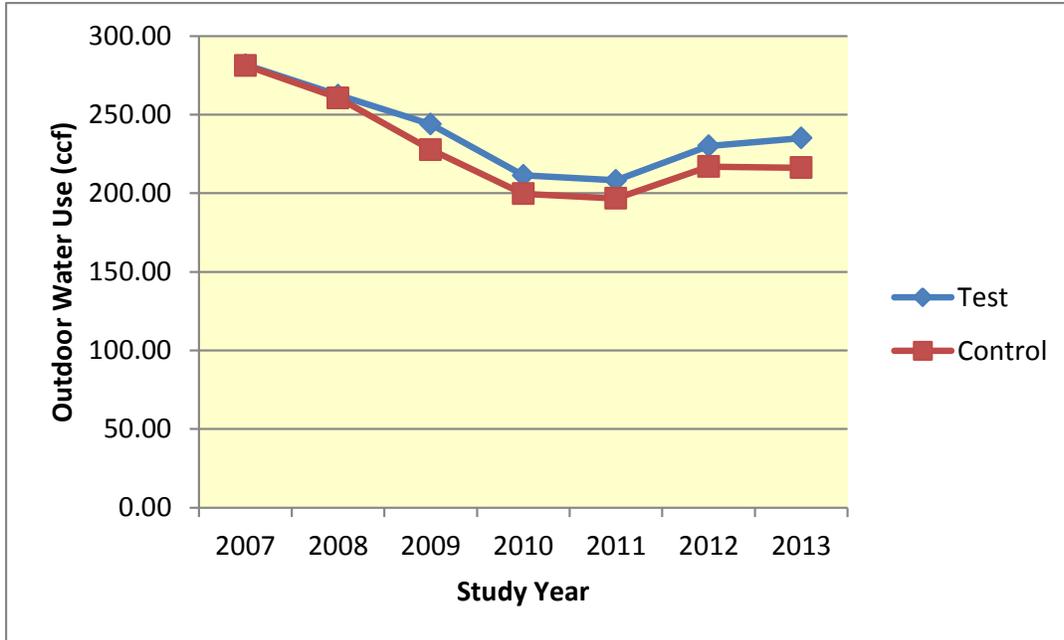
### **Paired Comparisons**

In order to be included in the final, paired analysis, each home from both the Test group and the Control group had to have data for the weather-corrected change in outdoor water use. This meant that the home could not be missing water consumption data for the period required to calculate the average pre and post-installation outdoor water use. In addition, each of the

Test group homes needed to have data for the application ratio prior to the installation of the WBIC, referred to as the antecedent application ratio. This meant that these homes needed to have lot area data. Homes that were missing either of these two critical parameters were excluded from the analysis. In addition to lot area, the homes in the Control group had to be located within 500 feet of a Test home and their overall average outdoor water use had to match that of the Test group for the year 2007. There were a total of 892 homes in the paired analysis Test group, and 33,149 homes in the Control group that met these criteria.

As described in Section 3 on weather normalization, the changes in weather-corrected outdoor water use were determined for each home in the Test group and the Control group. The average change and the 95% confidence interval for each group were determined. Because the water use had been normalized for  $ET_o$ , the observed changes were based on average year weather conditions for the period, and they reflected the factors that affected water use in that period, including the presence of a WBIC. The study assumes that change could be positive or negative, and the statistical significance of the change was measured by the confidence interval. If the intervals overlapped each other, then the change could not be considered statistically significant at the 95% confidence level. If the interval of a change statistic includes zero, then the change, whether an increase or decrease, could not be demonstrated at that level of confidence.

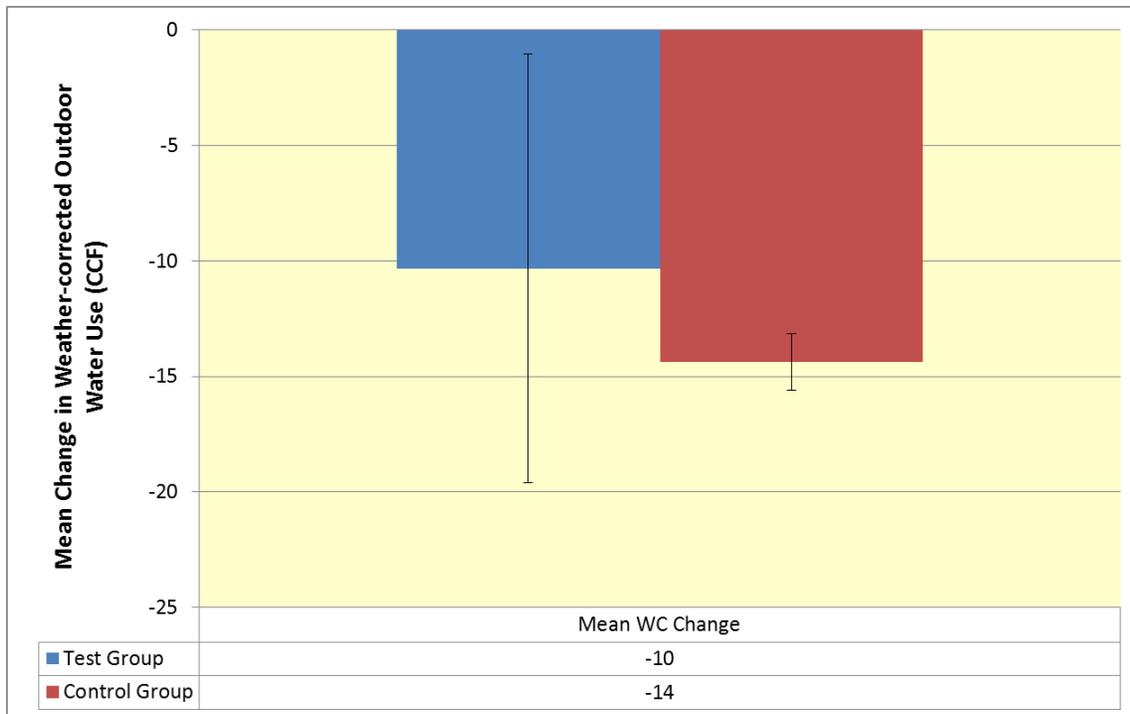
Figure 11 shows the uncorrected outdoor water use for the two groups for each of the study years beginning in 2007. This figure shows that while both groups started out with very similar outdoor water use, the Control group's outdoor water use dropped slightly more than did the Test group's. The figure shows that, in fact, the only year for which the outdoor water use of the two groups was identical was in 2007; each year after that the Control group's use was lower than that of the Test group.



**Figure 11: Changes in raw outdoor water use for Test and Control groups over study period**

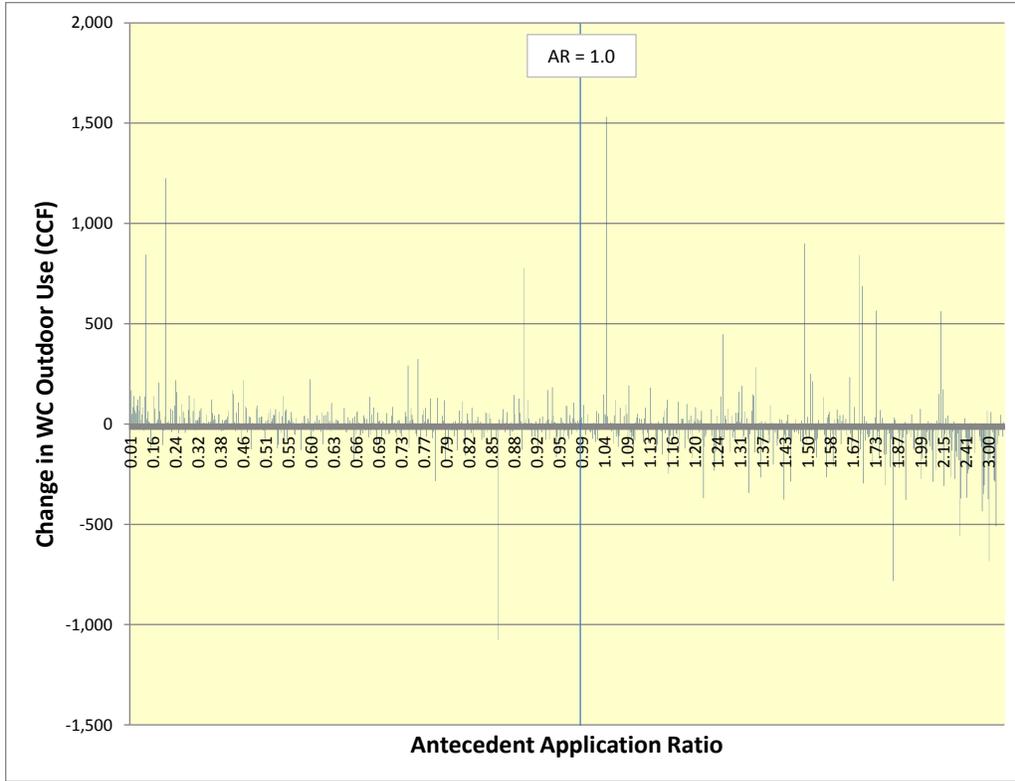
Figure 12 shows the average weather-corrected change in outdoor water use over the study period for the Test and Control groups. This figure shows that after the effect of changes in weather were accounted for the average outdoor water use of the Test group fell by approximately 10 CCF per home, while the outdoor water use of the Control group fell by 14 CCF per home. This is, in effect, an indication that the overall effect of the WBIC program was to *increase* outdoor water use by approximately 4 CCF per home relative to the Control group.

The fact that the overall program resulted in a net increase in outdoor water use was not a surprise since a similar finding has occurred in previous studies. If the WBICs are installed and functioning correctly they adjust the irrigation application not necessarily to reduce overall use, but to bring it into conformance with the theoretical irrigation requirements based on  $ET_0$  and their internally programmed species and application factors. When considering the data from this perspective one would expect to see a relationship between the change in outdoor water use and the antecedent application ratios of the Test group.



**Figure 12: Mean changes in weather-corrected outdoor water use for Test and Control groups**

Figure 13 shows the weather-corrected change in outdoor water use for the Test group according to their antecedent application ratios, which have been arranged from smallest to largest. A dividing line has been inserted at the value of 1.0. This means that the data points to the left of the line represent homes that were under-irrigating prior to the installation of the WBICs and the homes to the right of the line were homes that were over-irrigating. Examination of this graph closely shows that very few of the under-irrigating homes had a reduction in their outdoor water use, while many of the homes that were over-irrigating showed a reduction in their outdoor water use after the installation of the WBICs. All of the largest reductions in outdoor use occurred in homes with application ratios greater than 1. This is the expected result.

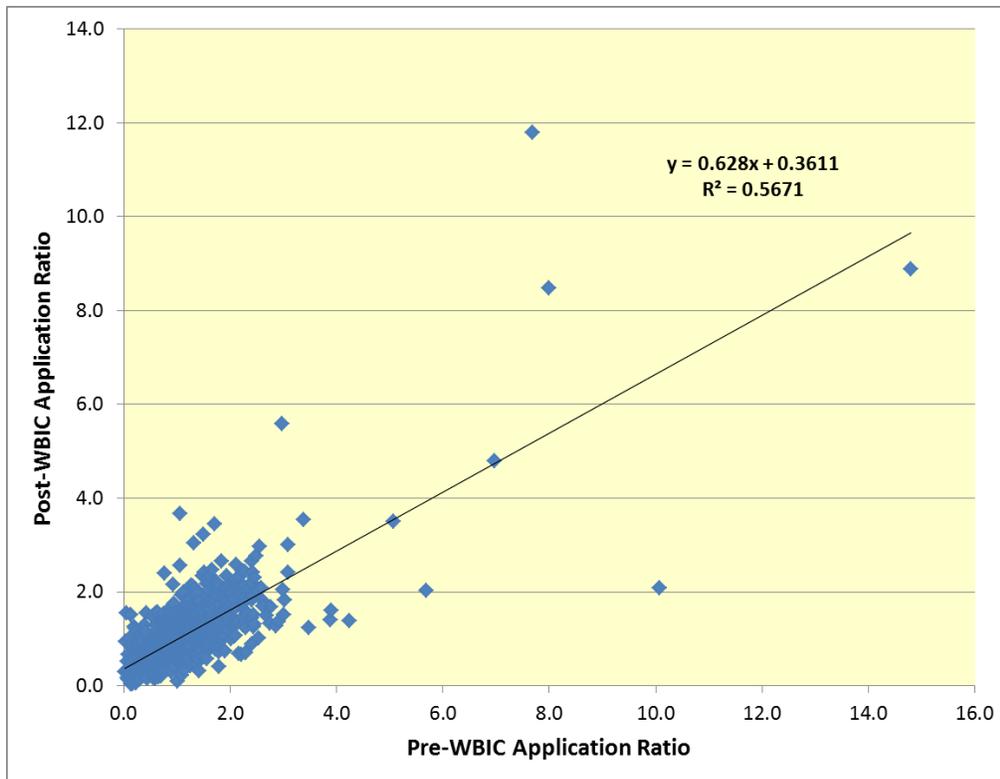


**Figure 13: Change in outdoor water use versus antecedent application ratio**

The data also shows, that overall there was little net reduction in the average application ratios of the Test group as a result of the WBICs. As shown in Table 12, the mean and median change in application ratios for the group was negligible. The best fit line, plotted in Figure 14, shows that at the median application ratio of 0.96 the application ratios of the post WBIC period were 97% of the pre-WBIC application ratios. This is a further indication that the degree of reductions in applications on one group of properties was balanced by a corresponding increase on others.

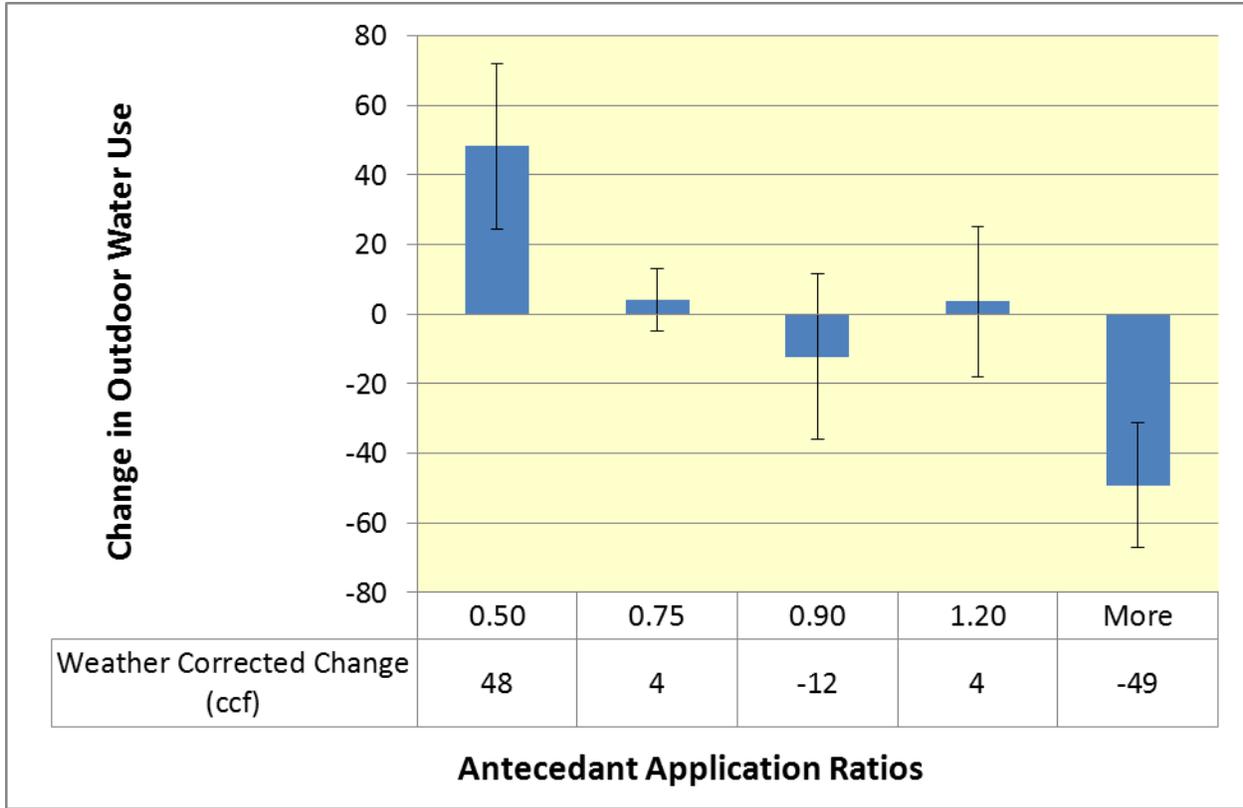
**Table 12: Change in application ratios**

Application Ratios	Pre WBIC	Post WBIC	Change
Average	1.14	1.08	-0.06
Median	0.97	0.95	-0.02



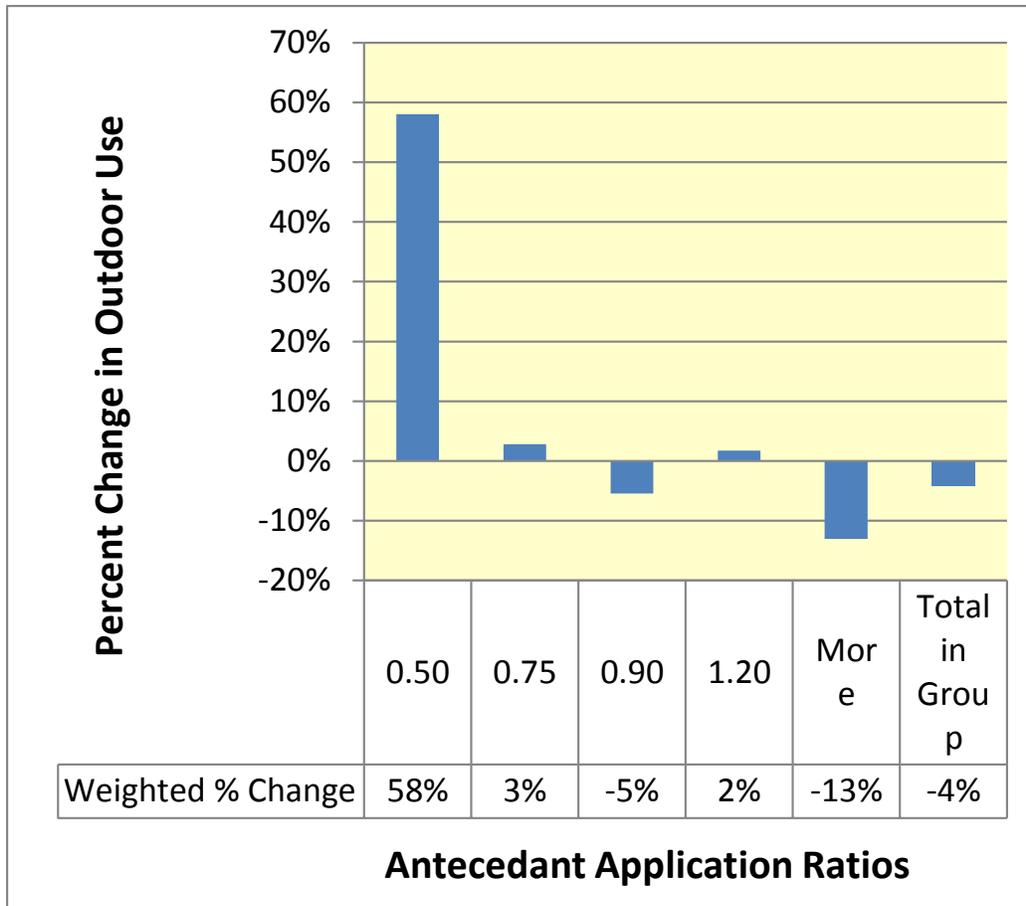
**Figure 14: Relationship between pre and post application ratios for Test group**

The next logical analysis is to examine the changes in water use for the Test group based on the distribution of the antecedent application ratios. This has been done in Figure 15, which shows the average change in the weather-corrected outdoor water use for Test homes falling into bins of 0-0.5, 0.5-0.75, 0.75-0.9, 0.9-1.2, and more than 1.2. This figure shows exactly what one would expect for properly functioning WBICS: the change in outdoor water use is inversely proportional to the antecedent application ratio, where the smaller the antecedent ratio the larger the change in outdoor water use associated with the WBIC. Homes that were applying less than 50% of the TIR prior to receiving a WBIC showed an average increase of 58%, or 48 CCF in their outdoor water use, while homes that were applying more than 120% of TIR prior to receiving their WBIC showed an average decrease of 14% or 49 CCF in their outdoor water use.



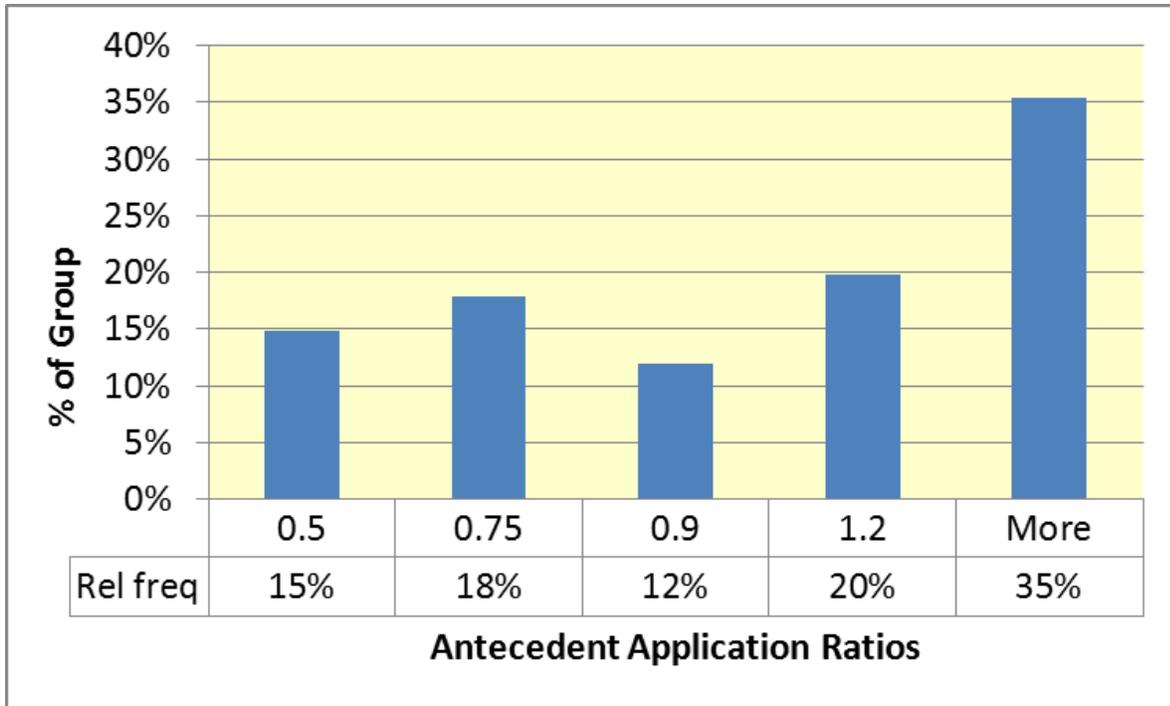
**Figure 15: Change in outdoor water use versus antecedent application ratio**

Figure 16 shows the average change in weather corrected water use as a percentage of their outdoor water use in each of the bins. Customers with application ratios of 0.5 or less had a 48% increase in their outdoor water use while customers with an application ratio greater than 1.2 had a 49% decrease in their outdoor water use. These changes are not corrected for the changes observed in the Control group.



**Figure 16: Average change in use as a percentage of outdoor water use**

It is possible to use this data to make projections of the volumes of changes in outdoor water use associated with the WBIC program. The first step is to determine what percent of the Test group fell into each antecedent application ratio bin. These percentages are shown in Figure 17. By combining the percentage of customers falling into each bin, with the average change in outdoor water use for each group, estimates can be made of the overall volumes of change in outdoor water use for each group. This analysis is shown in Table 13.



**Figure 17: Percent of group falling into application ratio bins**

Table 13 shows the numbers and percent of the Test group that fell into each of the antecedent application ratio bins and their raw change in weather-corrected outdoor water use. It also shows what happens if the raw changes are adjusted to account for the fact that there was a general decrease in outdoor water use that averaged 14.4 CCF per home during the study period. This adjustment was made by adding 14.4 CCF for each home in the bin to the raw change volume. This had the effect of increasing the change volumes, and making some apparent reductions in use turn into an increase in use. For example, there was an apparent decrease in outdoor water use for the 0.75 to 0.9 bin of 1,314 CCF, but when the adjustment is made to account for the Control group this becomes a net increase in outdoor water use of 224 CCF.

Table 13 shows that the only group that showed an actual decrease in outdoor water use that could be attributed to the WBICs was the group with application ratios >1.2. This represents 316 homes or 35% of the homes in the Test group. These homes account for total reductions in outdoor water use of 11,015 CCF, but this reduction is submerged by the increase in outdoor water use of 14,625 CCF associated with the four groups at the bottom of the distribution, which all have antecedent application ratios less than 1.2. The last column of the table shows the adjusted change in outdoor use as a percentage of the pre WBIC outdoor use. This table shows that when the changes in the control group are accounted for the increases in the low application ratio bins is magnified, with homes at < 0.5 showing a 75% increase in their outdoor use.

**Table 13: Analysis of actual and potential water savings**

Antecedent Application Ratios	Number	% of Group	Weather Corrected Change (CCF)	Conf. Interval (95%)	Avg Pre-WBIC Outdoor Water Use (CCF/H)	Pre-WBIC Outdoor Water Use for Group (CCF)	Raw Change (CCF) (=Change *Number)	Adjustment for Control (CCF) (=14 CCF * Number)	Adjusted Change (CCF) (=Raw Change + Adjustment)	Adjusted Change per Household (CCF)	Adjusted Change as % of Pre WBIC Outdoor Use	Conf. Interval (95%)
0.0 - 0.5	132	15%	48	24	83.2	10,978	6370	1897.4	8268	63	75%	29%
0.5 - 0.75	159	18%	4	9	147.3	23,419	651	2285.5	2936	18	13%	6%
0.75 - 0.9	107	12%	-12	24	225.7	24,155	-1314	1538.0	224	2	1%	11%
0.9 - 1.2	177	20%	4	22	216.6	38,345	653	2544.2	3197	18	8%	10%
More than 1.2	316	35%	-49	19	376.9	119,113	-15,558	4542.2	-11,015	-35	-9%	5%
Total in Group	891	100%	-10	9	242.4	216,010	-9198	12807.3	3610	4	2%	4%
Total Number of Homes that Saved Water	316	35%	-49	18	376.9	119,113	-15,558	4542.2	-11015	-35	-9%	5%

## Other Comparisons

The most important comparisons are the paired comparisons discussed above. These included the most important variable for explaining the changes in the water use – the antecedent application ratio. There are several variables however that are of interest for comparison purposes. Since we simply want to see which of these were associated with the performance of the WBIC Test group in a relative manner they will be described in terms of how they affected the gross changes in the weather-corrected seasonal<sup>14</sup> water use, without making any corrections for the Control group. The purpose is to simply show if any of the factors appear to be associated with better or worse relative performance of the WBIC program. This also explains why it was not necessary to redo all of these comparisons using the outdoor use data, since the outdoor use is primarily a scaling up of the seasonal use data, which would not affect the relative changes among the groups.

### *Change by Agency*

When the mean and median weather-corrected changes in seasonal water use are plotted by agency the averages for Valencia and Santa Clarita were seen to decrease, while the averages for Newhall and Los Angeles<sup>36</sup> rose as shown in Figure 18. This suggests that there were more deficit irrigators in the latter two agencies. When the median values are compared (as shown in Figure 19) they all tended to decrease. This suggests that there were more outliers in Newhall and LA<sup>36</sup>, since these are the sites that increase the means, while leaving the medians relatively untouched.

---

<sup>14</sup> The effect of the individual agency and the method of installation had on water use was examined prior to making the change from seasonal water use to outdoor water use. Because the change from seasonal water use to outdoor water would have no impact on the relationships presented in the following four figures further analysis was deemed unnecessary.

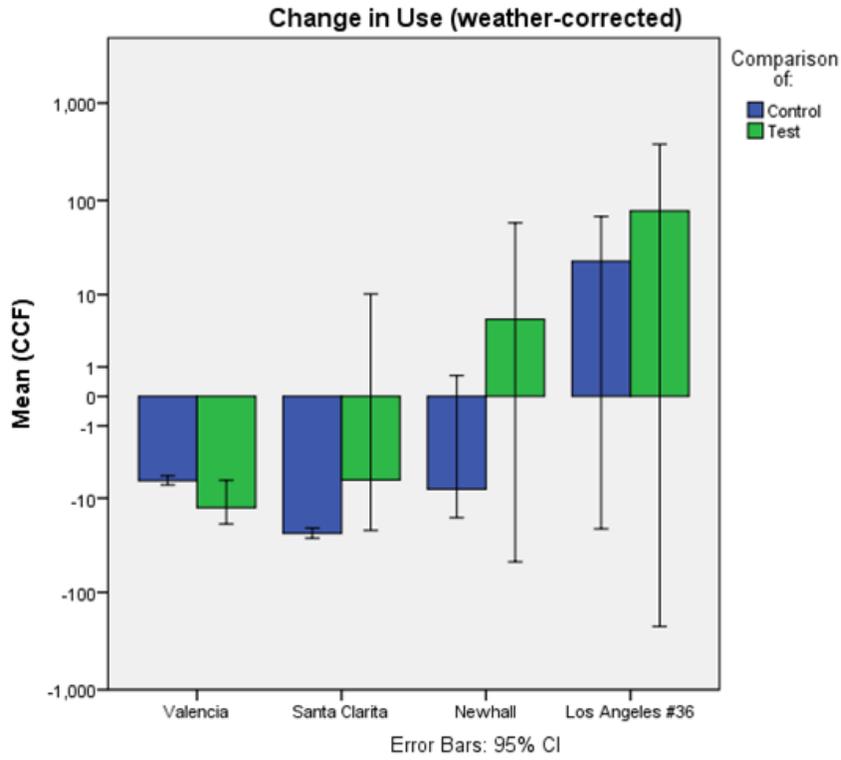


Figure 18: Comparison of mean changes by agency

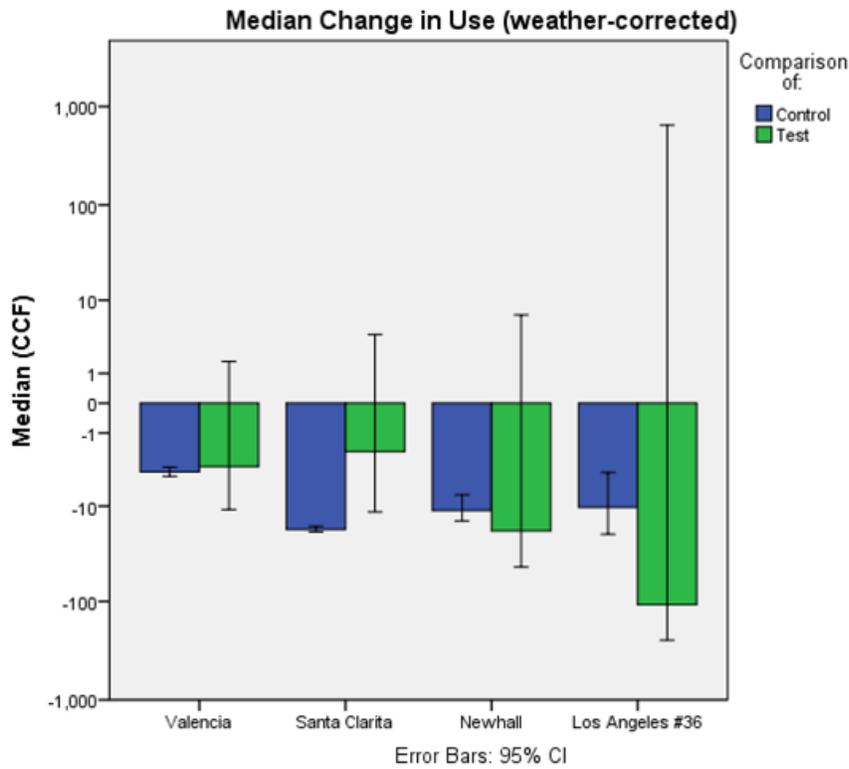


Figure 19: Comparison of median changes by agency

*Comparison by Method of Installation*

Table 14 shows that there was no difference in the weather-corrected change in the seasonal water use for the homes in which a contractor installed the unit compared to the homes in which the homeowner did the installation. Both showed the same change. It is interesting that there was less variability in the performance in the homeowner installation, as measured by the standard deviation of the change data. This data is shown graphically in Figure 20. Also of note is that the homeowners were installing on homes with lower antecedent application ratios, and the contractors were installing on homes with higher ratios on which they would be expected to have had a greater change. This suggests that the homeowners were doing slightly better than the contractors when application ratios are factored in since they achieved a similar change, but started from a lower antecedent application ratio.

**Table 14: Comparison by method of installation**

Method	Number of Installs	Ave App Ratio	Mean Change (CCF)	Std. Deviation
Homeowner	276	1.08	-13	62
Contractor	233	1.24	-13	81



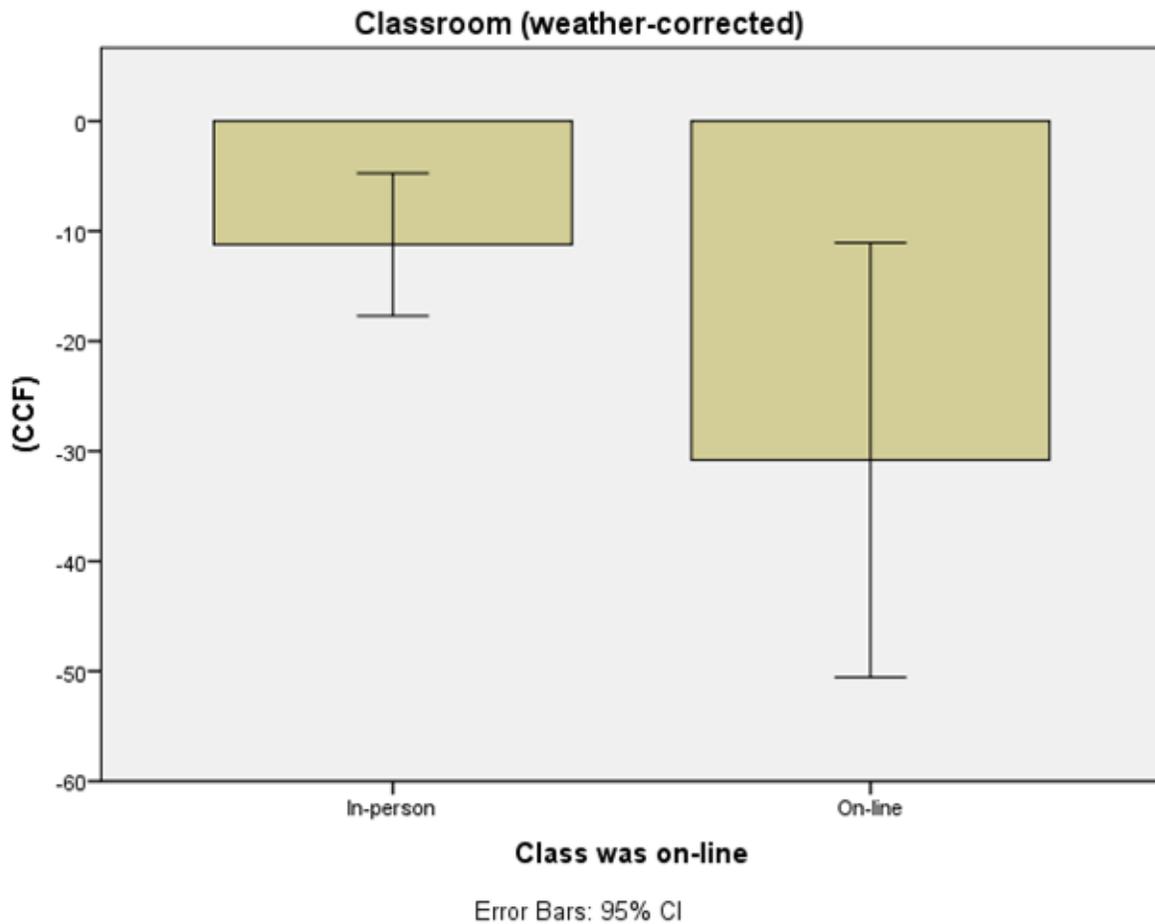
**Figure 20: Comparison of changes by method of installation (-1=contractor, 0=homeowner)**

**Comparison by Method of Instruction**

As shown in Table 15 there were 470 sites in which the participant attended an in-person class and 42 sites in which the participant took an online class. The performance of the online group appeared much better than those who took the in-person class, but the online group also was starting from a significantly higher application ratio, so it is not clear that the difference in their performance is due to the class experience or higher starting application ratios. In any case, it seems as if the shift in program design from face-to-face instruction to online instruction is not detrimental to water savings. Figure 21 shows the method of instruction graphically.

**Table 15: Comparison by method of instruction**

Method	Number	Ave App Ratio	Mean Change	Std. Deviation
In Person	470	0.97	-11	71
Online	42	1.19	-31	63



**Figure 21: Comparison of changes by method of instruction**

### Bias Test

If the results of this study are to be projected to the population of the Agency as a whole, then one would want to know whether the Test group was biased compared to the general population. If, for example, the distribution of prior water use of the Test group was significantly different from the larger population then one could not extrapolate the results reliably. Of special concern was that if the Test group was biased towards homes in the low application ratio then this might make the finding of overall water use increases invalid when extended to the population.

In order to test for this bias in the Test group a comparison was made of the application ratios between the Valencia sites – a group of over 26,000 homes for which landscaped areas were provided – and the Test group as shown in Figure 17. The reason for making this comparison was that having the irrigated areas for the Valencia group made it possible to calculate their application ratios. Since the Valencia group was such a large one it was thought to be a good match for the overall population of the Agency. The figure shows that the application ratios for the Test homes closely match the application ratios of the Valencia group, and that the Test group was not biased toward having a larger percentage of homes in the low application ratio bins. In fact, the Valencia homes had more homes in the 0-50% bin than did the Test group. The Valencia group also had more homes in the >120% bin. This suggest that while the potential of increase in use from the very low application homes is present, there is a greater potential savings if the homes with >120% could be selected for participation.

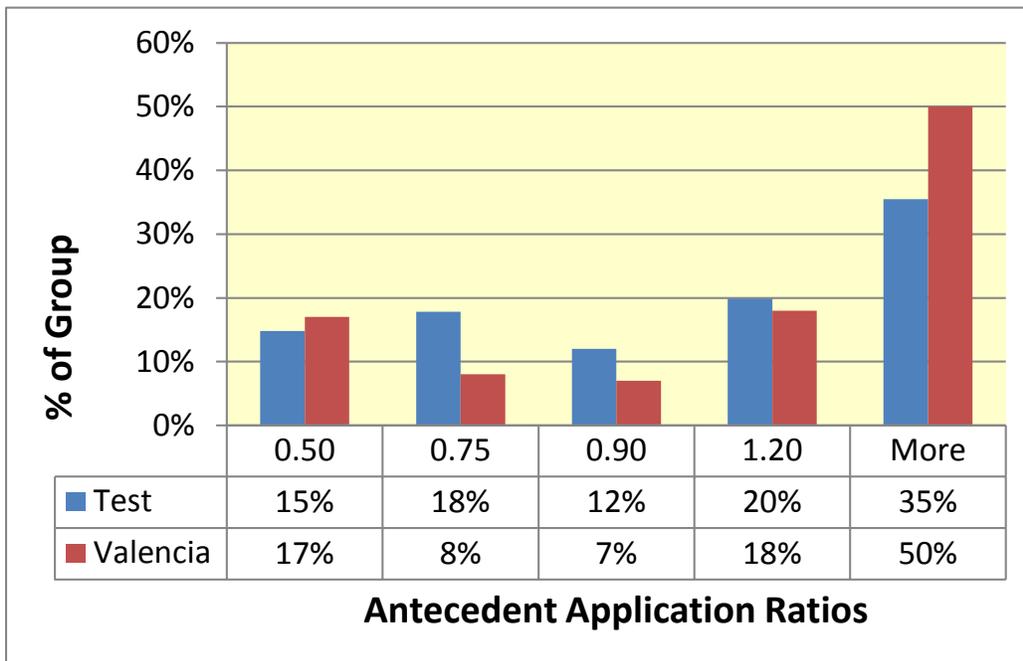
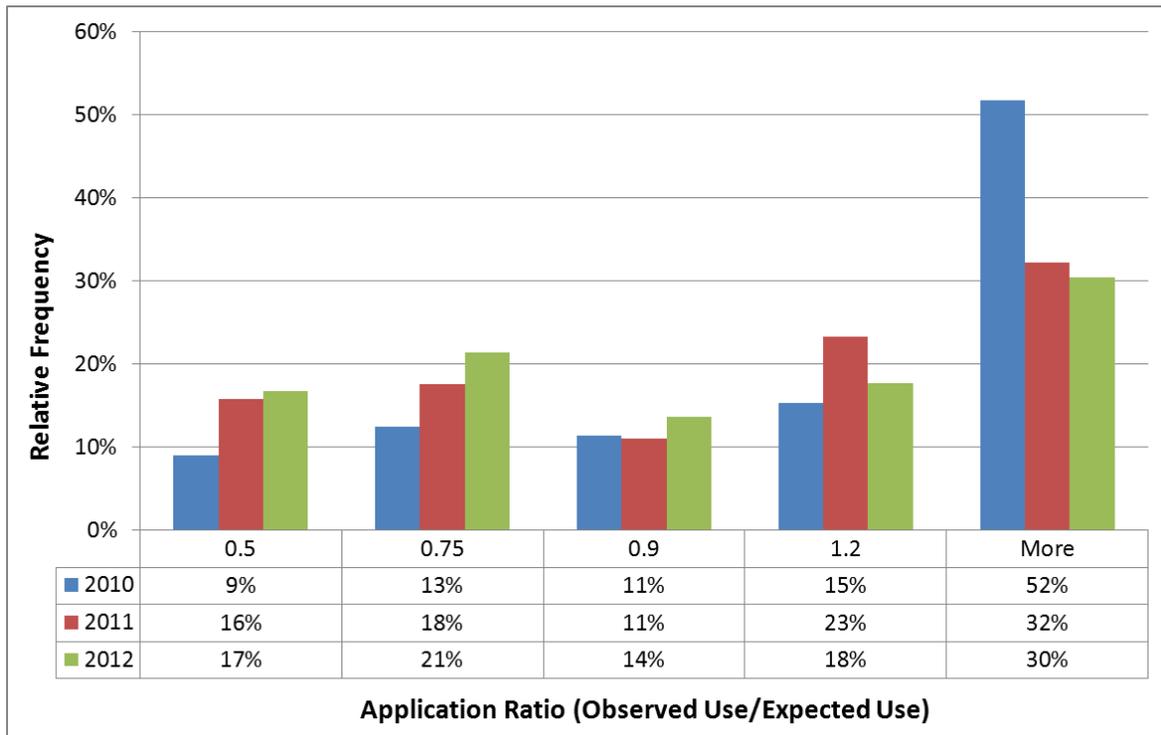


Figure 22: Comparison of application ratios of Test group to the Valencia population

The question was also raised as to whether the early participants in the WBIC program, were biased toward low water users, which would tend to inflate the water use increases. In fact, the data in Figure 23 show the opposite trend to be true. The homes that installed WBICs in 2010 had the lowest percentage of very low application ratios, and the highest percentage of very high application ratios. So, this would suggest that the early adopters should have shown the strongest water savings.



**Figure 23: Application ratio for the year of WBIC installation**

### *Saving Projections for Population*

If the corrected savings from Table 13 are used in conjunction with the application ratios from Valencia, shown in Figure 22, then reasonable approximations of the potential changes in water use for the entire single family population can be made. If the savings and distributions cited above prove valid then the savings for a population of 60,000 homes would be as shown in Table 16. This table shows that if the entire population were equipped with WBICs a total of 60,000 units would be required and the total savings would amount to 263 acre feet of water. If however, just the homes with application ratios > 1.2 were included in the program only half of the WBICs would be required and the savings would be 2401 AF, which is 9.1 times the water savings for half the hardware and installation expenses.

If the life cycle costs for each controller is approximately \$450 per unit, then the total cost of installation of 60,000 WBICs would be \$27 million, and the unit cost for the 263 acre feet of saved water would be \$102,661/AF. If, however, the program was targeted to just the 30,000

homes in the top bin, the costs would drop to \$13.5 million and the unit cost for the 2401 acre feet of saved water would likewise drop to \$5623/AF.

**Table 16: Projected savings based on Valencia Application Ratio distributions**

App Ratio	% of group	Savings/HH (CCF)	HH's in group	Estimated Outdoor Use Change	
				(CCF)	(af)
<b>0.50</b>	17%	62.6	10200	638,859	1467
<b>0.75</b>	8%	18.4	4800	88,649	203
<b>0.90</b>	7%	2.1	4200	8,800	20
<b>1.20</b>	18%	18.1	10800	195,058	448
<b>More</b>	50%	-34.9	30000	(1,045,763)	(2401)
<b>Total</b>	100%		60000	(114,397)	(263)

## CONCLUSIONS AND RECOMMENDATIONS

The overarching conclusion of this report is that after all of the confounding factors due to weather and the economy are taken into consideration, the WBIC program appeared to result in a net *increase* in landscape water use in the Test group compared to the rest of the population of single family homes. The weather corrected water use of the Test group dropped by 10 CCF per home, but the water use of the Control group dropped by 14 CCF. So the difference between these two values was a net increase of 4 CCF for the Test group.

If, however, just the 50% of homes that were applying more than 120% of their theoretical irrigation requirements were targeted there would have been a net decrease approximately 34 CCF per household.

If the program were extended so that every household in the entire service area had a WBIC installed then the data indicate that there would be a net decrease in system-wide landscape use of 263 AF, at an estimated cost of \$27 million, and a unit cost per acre feet of saved water of \$102,661/AF. If, however, just the top bin households had a WBIC installed the data suggest that there would be a net decrease of 2401 AF, for a total cost of \$13.5 million, and a net cost of \$5623/AF.

This study investigated the changes in outdoor water use in a group of 891 homes that had been provided with weather based irrigation controllers (WBICs) as part of the Residential Landscape Program, which was developed as part of the Santa Clarita Valley Water Use Efficiency Strategic Plan in 2008. The goal of the program was to reduce outdoor water use in the participating homes, and thereby reduce the per capita water use for the Santa Clarita Valley, and assist with reaching the compliance targets specified in SBx7-7.

The study was conducted by comparing the pre and post weather normalized outdoor water use for the Test group to the change observed in a Control group. This is a standard pre-post and side-by-side analysis that is often used to measure the changes attributable to an intervention of some type.

After correcting for weather changes during the test period of 2007-2013, and normalizing outdoor use based on the average ET during the period an annual change of -10 CCF was observed in the Test group, while a change of -14 CCF was observed in the Control group. The fact that the water use in the Test group dropped by 10 CCF, while the use in the Control group dropped by 14 CCF means that the water use in the WBIC group, as a whole, *increased* by a net 4 CCF as a result of participation in the program (See Figure 12).

The change in outdoor water use, however, was not uniform across the Test group. It was found that the change in water use was heavily affected by the application rates prior to receiving a WBIC. Homes that applied less than the irrigation requirement of their landscapes tended to increase their outdoor use after having a WBIC installed, while homes that were applying more than the theoretical irrigation requirement tended to decrease their water use after the WBIC installation. The application ratio was used as the measure of the intensity of the over or under-irrigation. This is the ratio of the actual outdoor use to the theoretical irrigation requirement of the landscape.

As shown in Figure 15, households with an antecedent application ratio of less than 50% showed an increase of 48 CCF in their outdoor use, while households that had an antecedent application ratio of greater than 120% showed a decrease of 49 CCF in their outdoor use. The homes between these extremes showed a net change of -4 CCF. The critical finding here is that almost all of the water savings were found in the homes that had an antecedent application ratio greater than 120%. The other homes tended to show increases in use that approximately cancelled out the savings in the group with a high application ratio.

Approximately 35% of the households in the Test group showed antecedent application ratios greater than 120% and the remaining 65% of the households had antecedent application ratios less than 120%. These distributions are shown in Figure 17. The fact that the savings potential for the WBIC program was found in just 35% of the homes indicates that the process of random distribution of a WBIC to anyone who requests one appears to be defeating the intention of the program which is to cause a net decrease in outdoor use. The same can be said for the Valencia homes, shown in Figure 22, but in this group there was a higher percentage of homes in the greater than 120% group.

Overall, the data indicated that the WBICs performed as they were designed to. As expected, they tended to bring the application ratios closer to 1.0, which had the result of increasing water use in the under-irrigators and decreasing it in the over-irrigators. On a volumetric basis, after factoring the change in water use of the Control group, a net increase of 3,610 CCF or 4 CCF/hh for the Test group, was observed. This equates to 2% of their pre-WBIC outdoor water

use. The water savings for just the homes that saved water amounted to 11,015 CCF, or a 35 CCF/hh savings.

Other factors such as the type of installation or the type of instruction that the participant received were of much less significance. There was virtually no difference in the changes in use between the homeowner and contractor installed homes. While the homes in which the instructions were online achieved a better reduction in outdoor water use they also started with a higher application ratio. The fact that the results of the online instruction were strong does show that there was no reduction in performance by relying on online instructions, and the savings may have been increased.

These findings imply that if the Suppliers wish to continue providing WBICs, they should do so only for homes which are known to be over-irrigating. This could amount to approximately 35% of the single family customers in the four agencies, using the 120% application ratio as the benchmark. As part of the modified program, there would need to be additional analysis to ensure that only over-irrigators were receiving the devices. While this will require increased work, the results show that the failure to screen out the homes that are under-irrigating will defeat the water conservation purpose and may actually lead to an increase in outdoor use.

Because the Test group was not chosen scientifically there was a chance that it did not reflect the water use patterns of the larger population. Since any bias in the Test group would cause inaccuracies if the results were extrapolated from the Test group to the population two bias tests were conducted. The first test was to determine if the distribution of application ratios in the Test group was significantly different from the distribution in the entire Valencia single family population (Valencia was used as a proxy for the entire service area). The results of this comparison are shown in Figure 22, which shows that there is a fairly good match between the distribution of application ratios in the Test group and Valencia population. Of special note is that the percentage of homes with a very low application (AR<50%) was slightly higher in the Valencia group than it was in the Test group. The Valencia data also showed a higher percentage of homes in bins with a very high application ratio (AR>120%). This suggests that there are more homes with high savings potential in the Valencia group.

The second bias test was to see if the early adopters of the WBIC were weighted towards low irrigators, who would be expected to bias the results towards increased usage. The analysis shown in Figure 23 showed that this was not the case, and that the early adopters tended to include more high-irrigators than low irrigators.

The savings, projected to a population of 60,000 homes having the same application ratio distribution as Valencia and the same water savings as the Test group, show that the way to optimize the water savings would be to install WBICs on the 50% of homes that were over-irrigating in Valencia by at least 120% and to avoid installation on the other homes. This would result in a total savings of over 2400 AFY, while installation on the entire population would show a savings of only 263 AF/yr.

The results of this study have significant implications for the CLWA. On one hand the study shows that continued WBIC installations need to be limited to just over-irrigators in order to avoid negating the water savings goal of the program. This puts the Agency in the position of giving away expensive controllers just to households that are wasting water on their landscapes, which appears to be a “reward-for-waste” program. On the other hand, if the existing program is continued then a large amount of time and expense is going to be expended for marginal results at best or adverse results at worst.

Another option for the Agency and Suppliers to consider is to modifying the WBIC program and tying it into a water budget rate structure that includes serious financial penalties for exceeding the household water budget. The existing water rate structure, shown in Table 2, has too small a difference between the bottom and top rates to send a strong price signal to the customer. A water budget rate structure would be used to assign much higher rates<sup>15</sup> to the excess use blocks and the revenue generated from the top billing tiers, which is paid by the excess users, could be used to fund a program of WBIC installation for those users. The billing system could be used to identify households that are candidates for participation, since these would be the ones in the top billing tiers, and WBICs could be offered to these customers with the incentive of getting them out of the penalty consumption tiers. This approach could resolve the present dilemma faced by the Agency and do so in an equitable manner. The current water rates are too low to accomplish this goal, and they are not linked to specific and individual budgets.

Whatever the Agency and Suppliers decide, some modifications to the WBIC program are warranted, and the 2015 Urban Water Management Plan would be the place to discuss this issue.

---

<sup>15</sup> The value of water use over the budget could be based on the marginal cost of new dry year water, plus an allowance to capture the cost of water shortages and curtailments to the economy.