FINAL
MWDOC Smart Timer Rebate Program Evaluation

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

RECLAMATION
Managing Water in the West

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Acknowledgements

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Executive Summary

The Municipal Water District of Orange County (MWDOC) received a CalFed grant from the Bureau of Reclamation (USBR) for the SmarTimer Rebate Project. The purpose of this evaluation is to measure the effectiveness of installing weather-based irrigation controllers (aka smart timers) as a Best Management Practice (BMP) landscape intervention in a suburban setting within Northern Orange County. Additionally, the project assessed alternative weather measures for use in program implementation and evaluation.

Findings—Evaluation of Evapotranspiration

This evaluation provided an evaluation of evapotranspiration including California Irrigation Management Information System (CIMIS) weather station data, Irvine Ranch Water District (IRWD) data, NOAA stations, and CIMIS spatial reference evapotranspiration (ET_o) data. This research found statistically significant improvements when using *both* precipitation (due the geographic spread of most rain storms specific location matters less) and spatially accurate CIMIS measures of ET_o.

Findings—Water Savings from Smart Timers

Water savings per site were estimated from the statistical impact evaluation to be, on average, 9.4 percent at Single Family Residential sites and 27.5 percent at Commercial sites. By construction of the statistical models, these are estimates of "net water savings": that is, in addition to the ongoing level water savings attributable to regional messaging, ordinances, etc that can be observed in the control group. To isolate water savings attributable to this program, the consultant compared participant water use to that of a similar control group. Additional savings information by sector is provided in subsequent sections. The data shows a higher savings rate at Commercial sites than Single Family sites. This disparity in the savings rates can be explained by the nature of the site types. Single family sites tend to be smaller than Commercial sites offering less potential for the gains from smart irrigation timers.

Single Family Residential Accounts: The analysis sample of 70 single family customer accounts available to this evaluation that participated in the Smart Timer Rebate Program saved an average 9.4 percent, approximately 49.3 gallons per day. [1] The high resolution methods of this evaluation are able to distinguish this level of water savings from zero at very high levels of statistical confidence. By contrast, simpler evaluation techniques (t-statistics of difference of mean annual use) have been unable to distinguish a 10 percent difference of water use. The methods of this report yield a relative standard error of 14.6 percent (standard error surrounding mean use as a percentage of mean use.) Thus the statistical models of this report could distinguish a 3 percent change in water use at very high levels of statistical confidence. Readers are urged to compare the statistical power of the methods contained within this report with methods used elsewhere.

[1] 6.5 percent to 12.3 percent, or 34.3 gpd to 64.4 gpd is the 95 percent confidence level

Commercial Accounts: Among a smaller sample of 132 commercial accounts (representing 166 separately metered sites), significant net water savings of approximately 27.5 percent, or 726.6 gallons per day, were obtained from participation in the Smart Landscape Grant Program[2]. The savings rate for CII sites was 0.46 acre-feet or 149,891 gallons per acre, per year.

The total volume of water savings, including single-family residential sites and commercial sites funded by USBR —is estimated to be 2,615 acre-feet over the expected lifetime. The following section assesses the cost-effectiveness of this program by site type (SF versus CII sites), for all sites in the program, and for USBR-funded sites.

Findings—Cost Effectiveness

The Smart Timer Rebate Programs offers a savings in cost per acre-foot that is favorable when compared to the cost of additional water supplies imported into Orange County. Each acre-foot of water conserved by the Smart Timer Rebate Program avoids the cost of importing an additional acre-foot of water. Additional water supplies imported into Orange County currently cost $851 per acre-foot and are projected to increase in the future. This is a lower bound in that it does not include any water supplier costs within the county. The cost per acre-foot for Smart Timer Rebate Participants sites is also favorable ($291/AFY, nominal unit cost) relative to imported water.

[2] 24.4 percent to 30.5 percent, or 646 gpd to 806 gpd, is the 95 percent confidence level.

Section 1: Introduction

Overview

The impact evaluation seeks to develop sound empirical answers to the following questions:

1. Was the change in water use at one site attributable to participation in the landscape water use efficiency programs?
2. How do the program benefits compare to the program costs?
3. To the extent that time, budget, and available data allow, what explains the variation in observed water savings, over time and across different types of landscape sites and landscape contractors?

The answer to the first question is simpler and requires less data (consumption records, the time of adoption). The answers to the second and third questions are necessarily more complex and require more data.

The Smart Timer Rebate program was implemented in different parts of the Municipal Water District of Orange County (MWDOC) service area between September 2008 and June 2010. We created a combined database of consumption records inclusive of *both* participating and nonparticipating customers.

Each implementation phase used somewhat different methods and procedures for recording program implementation data. For the data assessment subtask we first created a sketch of available program databases, their fields, and an indicator for the likely internal validity of these records. Sampling strata (categories) were developed to control for the areas of interest, namely:

1. Calendar time period—This is important for two reasons. First, implementation methods have varied over time. Second, the threats to validity also vary over time (due, for example, to weather and ongoing conservation).

2. Different retail agencies—Some participants are likely to have better follow-through than others are. This variation in savings will not be the primary focus of any program-specific evaluation. This variation in savings can be critical, however, for addressing how future programs can be improved.

3. Type of landscape site—some sites may demonstrate greater potential for cost-effective savings than others.

The Smart Timer Rebate Project

The MWDOC Smart Timer Rebate Program was funded through a CalFed grant from the United States Department of Interior Bureau of Reclamation (USBR) and a Cooperative Agreement with the United States Department of Agriculture Natural Resource Conservation Service. The purpose of this project was to evaluate the effectiveness of installing weather-based irrigation controllers (aka Smart Timers) as a Best Management Practice (BMP) landscape intervention in a suburban setting within Northern Orange County. Figure 1-1 provides a map of the study area which included 19 local water agency service areas.

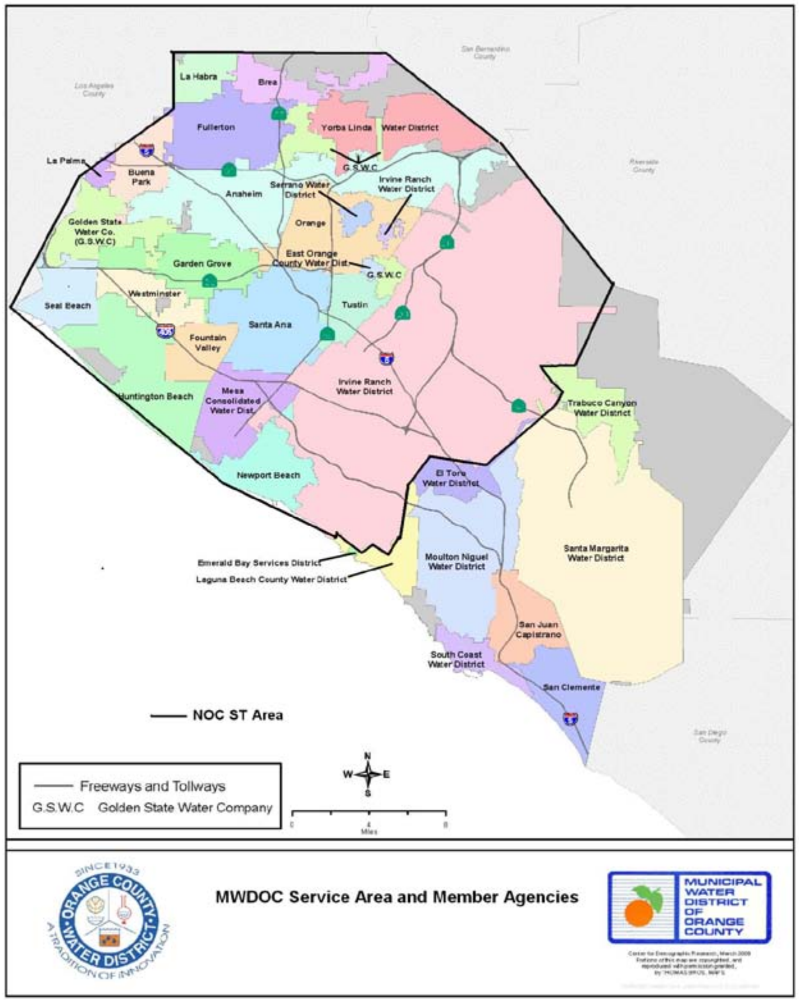

Figure 1-1 MWDOC Service Area Map

Smart timers were installed in both single-family homes (residential) and commercial settings with the aid of the Metropolitan Water District of Southern California rebate programs SoCal Water $mart and Save-A-Buck, respectively. From September 2008 through June 2010, there were 836 North County Smart Timer Rebate program participants with 588 from the commercial sector and 248 from the residential sector. Figure 1-2 illustrates the program participation by agency.

Table 1-1 Smart Timer Participation by Retail Agency

North County Smart Timer Program Participation by Agency				
	FY 08/09		FY 09/10	
Agency	Commercial	Residential	Commercial	Residential
Anaheim	59	12	46	5
Brea	9	1	0	0
Buena Park	1	6	0	0
Fountain Valley	0	2	6	0
Fullerton	2	4	39	2
Garden Grove	1	4	0	6
Golden State Water Company	2	2	22	7
Huntington Beach	1	23	27	6
Irvine Ranch Water District	55	41	136	13
La Habra	0	0	21	0
Mesa Water District	7	12	7	13
Newport Beach	27	13	46	7
Orange	2	10	13	2
Santa Ana	6	4	8	1
Seal Beach	0	0	1	0
Serrano Water District	0	0	0	11
Tustin	9	8	14	9
Westminster, City of	0	6	0	3
Yorba Linda Water District	0	11	21	4
Grand Total	181	159	407	89

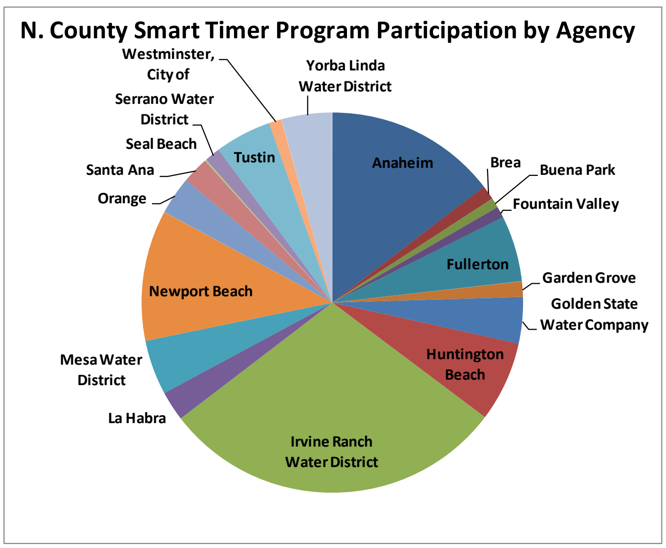

Figure 1-2 Smart Timer Participation by Retail Agency

Overview of Evaluation

This report is designed to meet the statistical evaluation requirements set forth by the granting agencies for the Smart Timer Rebate Program Project. Table 1-2 lists these reporting requirements and where they are fulfilled in this report.

Table 1-2 Evaluation Requirements

Evaluation Requirements per Granting Agencies	
Requirement	**Refer to:**
Evaluate sample sizes and data to provide recommendations regarding plausible analyses and any other appropriate conclusions that can be drawn.	Chapter 2
Report options for establishing control groups to achieve more robust multidimensional water use evaluation.	Chapter 2
Provide an evaluation of evapotranspiration including CIMIS weather station data, CIMIS zip code-based data, Irvine Ranch Water District (IRWD) data, NOAA stations. Recommend the most appropriate data set to use in the statistical evaluation.	Chapter 3
Provide statistical water savings analysis of weather normalized pre- and post-retrofit water consumption data for single-family and commercial installations including: — Pre- vs. post-retrofit analysis — Control vs. Retrofit group analysis — By Smart Timer manufacturer in the commercial, residential, and overall study area (includes up to 14 manufacturers).	Chapter 4
Compare water use between Smart Timer retrofits and California Assembly Bill 1881 (AB188)1 legislative goals in study area. AB1881 stipulates that all existing landscapes be managed not to exceed a theoretical Maximum Applied Water Allowance (MAWA) of 80% of evapotranspiration (ET)	Chapter 4

Section 2: Data and Methods Review

Data Review

The project team conducted a review of data and documentation generated by the Smart Timer Rebate Program including:

- Customer information data, as well as rebate amounts
- Records of applications and receipts including documentation of hardware and devices installed
- Sample applications
- Sample outreach materials
- Progress reports and invoices

Database Construction

The database constructed by the implementing vendor contained customer identifiers for 836 successfully completed Smart Timer Rebate Program applications with estimated acreage where available, customer characteristics, and rebate payment timing and amounts. Each application in the program transaction database was assigned a unique identification number (ANTS_ID) for this project. In this way additional identifying information did not need to be retained in subsequent analyses. The ANTS_IDs were created by sorting the program database according to the following program parameters. The database was first sorted by sub-program and check date to isolate those using USBR funding (check dates between September 1, 2008 and June 30, 2010). This Smart Timer Rebate Program list was then sorted by participating water agency name and given a sequential identifier, ANTS_ID, from 10000 to 10835 where the first digit, 1, signifies a Smart Timer Rebate Program applicant.

Consumption Data

Consumption data were requested from the following subset of participating MWDOC member agencies.

- Huntington Beach
- Irvine Ranch Water District
- Newport Beach
- Yorba Linda

The research team issued a data request to participating retail agencies with “data structure” for the water consumption data on participants and nonparticipants to be transmitted for this analysis. The research team worked closely with the retailers to assist in translating easily formatted water consumption data dumps into this data structure. The Requested Consumption data format is described in Table 2-1.

Table 2-1 Consumption Data Field names and Descriptions

Field Name	**Description**
Study ID	Unique Study ID Number (A&N Technical assigned and provided)
Account No.	Account No. within the agency billing system and MWDOC program participant database
Meter No.	Meter No. within the agency billing system (If there is more than 1 meter associated to an account)
Meter size	Size of meter serving account
Customer Type	Single or Multi Family, Commercial, Irrigation, etc.
Read Date	End of read period
Read Date 2	Beginning of Read period (optional)
Days in Read	Total number of days in read period
Period Use	Volume of consumption in read period (typically HCF)
Billing Unit	Type of billing unit – HCF, 1,000 gal, etc.
Use	Use, gallons per day in billing period – optional, as this can be calculated from the above
MAWA	Maximum Applied Water Allowance (=ETo*(ET_Adj.* Landscape Area) * .623/325,851)
YYMMDD	Year, Month, Date
Participation Date	Date of Participation
Program Name	R.O.S.P., Smart Timer Rebate Program, Rotating Nozzle Rebate
Customer Characteristics	Any additional cross sectional data on customer characteristics (APN, Parcel Size, Irrigated Area, Etc.) from billing system that the agency was willing to provide.

The research team issued a data request to participating retail agencies with “data structure” for the water consumption data to be transmitted for this analysis. The research team worked closely with the retailers to assist in translating easily formatted water consumption data dumps into this data structure.

A randomized and stratified control group was developed based on these categories. This control group will be updated and reused in the Rotating Nozzle Rebate Program impact evaluation.

We analyzed the available consumption data, at least three years of pre-intervention consumption and one year of post-intervention data. While we would have preferred to analyze a longer post-installation water consumption data history—the cost of the analysis turns more on the number of originating billings systems than the length of history—the available data was sufficient to formed the basis for defensible and credible estimates of the initial net water savings attributable to the smart irrigation controllers and efficient landscape practices. The persistence of water savings over the long term will necessarily wait for a longer post installation period.

The quantity of data required is driven by a key finding of earlier research. Prior impact evaluations found that water savings varies through the year. Figure 2-1 is taken from the Residential Runoff Reduction study[3]; it shows that the water savings were lowest in the spring growing season and greatest in the late summer and fall season. Our impact evaluation plan, the tasks of which are described below, avoided this problem through modeling to control for potential biases.

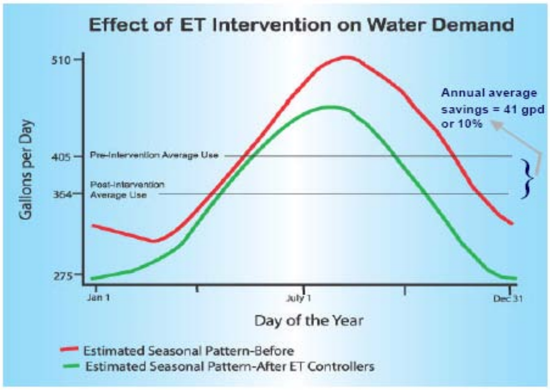

Figure 2-1 Effect of ET Intervention on Demand (see Residential Runoff Reduction Study, op. cit.)

Historical account level water use records and multiple climatic measures were used to develop climate-adjusted estimates of water savings using panel data (time series cross section) regression methods. (See Appendix A for an illustration.) A comparable "control group" of nonparticipants was developed to permit an assessment of net conservation. This control group consisted of 407 single family control customers from 4 MWDOC member agencies: Huntington Beach, Irvine Ranch Water District, Newport Beach, and Yorba Linda.

The statistical evaluation addressed the issues requested by granting agencies, including:

- Evaluation of most complete and accurate evapotranspiration data available including CIMIS weather station data, CIMIS Spatial ET_o data, Irvine Ranch Water District (IRWD) data, and NOAA stations. A recommendation will be made identifying the most appropriate data set to use in the statistical evaluation;
- Evaluation of sample sizes and data to provide recommendations regarding plausible analyses and any other appropriate conclusions that can be drawn beyond those listed herein;
- Options for establishing control groups to achieve a more robust multidimensional water use evaluation;
- Statistical water savings analysis of weather normalized pre- and post-retrofit water consumption data for single-family and commercial installations including:
  — Pre- vs. post-retrofit analysis
  — Control vs. Retrofit group analysis
- Comparison of water use between Smart Timer retrofits and California Assembly Bill 1881(AB1881) legislative goals in study area. California AB1881 stipulates that all existing landscapes be managed not to exceed a theoretical Maximum Applied Water Allowance (MAWA) of 80% of evapotranspiration.

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[3] *The Residential Runoff Reduction Study*,
Municipal Water District
of Orange County,
Irvine Ranch Water District,
July 2004

Section 3: Evaluation of Available Evapotranspiration Measures

Evapotranspiration (ET) is a measurement of the water requirements for a plant–soil–atmosphere system to function in a healthy manner[4]. The water requirement represents a loss of water from the plant and soil through evaporation or transpiration. Irrigation is used to replace the water requirement remaining after any effective rainfall received.

Briefly, these water losses occur as follows: transpiration is the loss of water vapor through plant stomata (leaf) to the atmosphere[5]. As water transpires from a leaf, water moves from the roots to replace water losses in the leaf. The roots take up water from surrounding soil. Additional losses occur by direct evaporation from the soil. The combination of water lost from transpiration and evaporation is referred to as evapotranspiration.

ET rates are influenced by environmental factors, including: temperature, relative humidity, solar radiation and wind speed. As weather conditions vary from place to place, from day to day, and from season to season, ET rates vary. Generally, hot temperatures and windy conditions increase ET, while cloudy conditions and high humidity reduce ET rates.

Local weather parameters are influenced by nuances of microclimates, a few of which are: topography, elevation, proximity to buildings and masses that may constitute a heat island, proximity to large water bodies – especially the ocean, steepness of the ground surface, shade, materials covering the ground surface, aspect of slope, reflectivity of adjacent surfaces and vegetation, wind variations with time of day, fog, atmospheric clarity, cloud cover and nearby activities.

These rates also vary among plant species because of differences in water requirements and the ability of different plants to adapt physiologically to avoid water deficiencies[6]. A basis for comparing and quantifying the amounts of water used by different types of plants is called reference evapotranspiration and denoted by the subscript, ET_o. ET_o is the estimate for a standardized grass crop such as a well watered pasture[7], which requires only meteorological data to calculate[8]. To standardize ET_o measurements, specific growing conditions and a well watered site are required. CIMIS Station #75, for example, uses fescue grass as the standardized grass crop in determining the ET_o value using a modified Penman equation[9].

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[4] Q.JHart, M.Brugnach, B.Temesgen, C.Rueda, S.L.Ustin, K.Frame, *Daily Reference Evapotranspiration for California Using Satellite Imagery and Weather Station Measurement Interpolation*, 2007

[5] D.Pittenger, *California Master Gardener Handbook*, University of California Agriculture and Natural resources Publication 3382, 2002.

[6] D. Pittenger, Ibid

[7] CIMIS website http://wwwcimis.water.ca.gov/cimis/infoStnSiting.jsp

[8] O.J Hart, Ibid

[9] Also known as the CIMIS Penman equation, it uses a wind function developed at UC Davis to use hourly wind measurements to estimate hourly ET_o. Daily ET_o is then inferred from the sum of estimated hourly ET_o. The Penman-Monteith ET_o equation uses average daily values to calculate average daily ETo. For details of steps in the calculation of the CIMIS Penman equation, see http://wwwcimis.water.ca.gov/cimis/infoEtoCimisEquation.jsp

Figure 3-1 Potential ET Sample Sites

Crop coefficients, K_c, are important for determining the irrigation requirement of specific plant types. Evapotranspiration of a specific type of crop is denoted as ET_c. and calculated by multiplying ET_o by K_c:

$$\mathrm{ET_c} = \mathrm{ET_o} \times \mathrm{K_c}$$

To determine the irrigation requirement of landscape types, the landscape coefficient, K_l may be used. Landscape coefficients are calculated from factors representing species (K_s), density of plantings (K_d), and microclimate (K_{mc}):

$$\mathrm{K_c} = \mathrm{K_s} \times \mathrm{K_d} \times \mathrm{K_{mc}}$$

The landscape coefficient can determined for different mixes of plant species, of different densities, and microclimates (such as shading, proximity to pavements, and exposure to wind).

Although replacement of waters lost to ET is the major destination of applied irrigation waters within the soil [10]. Superfluous or improperly scheduled irrigation water may also end up as deep percolation or runoff, and can lead to soil leaching.

Quantifying Evapotranspiration

One of the keys to successful irrigation management is to apply the 'right amount of water to the right place at the right time'. The importance of quantifying ET is to inform the irrigation manager the volume of water to apply to plants during a specific time period.

ET_o may be quantified through calculation using climate factors including, air temperature, soil temperature, wind speed, relative humidity, and solar radiation. There are several formulas for the calculation, with different degrees of complexity.

Applying these equations to evaluate the MWDOC programs requires locating reliable temperature data sets geographically close to the points of interest. The data should represent weather conditions before and after the programs, so a range of 2004 to 2010 is desirable.

The following describes several methods to quantify evapotranspiration:

Physical Weather Station Methods:

- Physical weather stations California Irrigation Management Information System, CIMIS
- Physical weather stations operated by Irvine Ranch Water District
- Physical stations operated by various agencies as cooperators of NOAA

Other Methods:

- Additionally, formulas can calculate ET_o using data collected from weather stations that are not specifically designed to provide ET information.

Quantifying ET_o using Physical Weather Stations

CIMIS

The California Department of Water Resources manages a network of 120 automated weather stations, called the California Irrigation Management Information System[11] (CIMIS). The primary purpose of CIMIS is to make available to the public, free of charge, information useful in estimating crop water use for irrigation scheduling.   Figure 3-2 is a photo of a typical CIMIS weather station.

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[10] *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California*, University of California Cooperative Extension, California Depart of Water Resources and U. S. Bureau of Reclamation, 2000

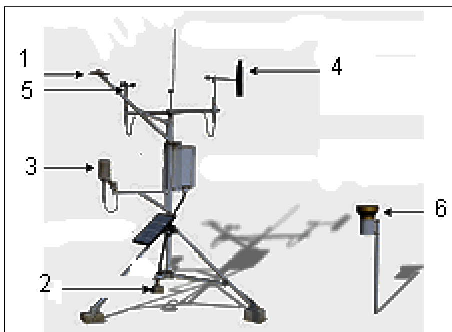
[11] http://wwwcimis.water.ca.gov/cimis/infoEtoEquation.jsp

Figure 3-2 CIMIS Weather Station

CIMIS uses the Modified Penman equation, also known as the CIMIS Penman to calculate ETo values referred to as CIMIS ET_o. Climatic factors such as solar radiation, air temperature, wind speed, and relative humidity are all measured at the CIMIS weather stations. CIMIS employs these data as input to calculate hourly ET_o. The 24 hourly ET_o values for the day (midnight-to-midnight) are then summed to produce estimates of daily ET_o. The data are distributed via the CIMIS website (www.cimis.water.ca.gov.)

For quality control, CIMIS calculates hourly Penman-Monteith[12] (ASCE-PM) ETo values and sums them up to obtain daily PM ET_o for consistency with the daily CIMIS ET_o. Both methods (CIMIS Penman and ASCE-PM) involve calculations of intermediate values from the measured parameters using analytical and/or empirical relationships. The measured and estimated intermediate values are then used to calculate ETo. Since the immediate site environment influences ET, CIMIS sites are standardized by well irrigated and regularly mowed grass.

Sensors used at a CIMIS station are identified in Figure 3-3. For sensor specifications, see Appendix 1.



1. Total solar radiation (pyranometer)
2. Soil temperature (thermistor)
3. Air temperature/relative humidity (HMP35)
4. Wind direction (wind vane)
5. Wind speed (anemometer)
6. Precipitation (tipping-bucket rain gauge)

Figure 3-3 CIMIS Station Sensors

One CIMIS station is operated in Orange County. Station #75, “Irvine”, is located at latitude 33°41'19"N / 33.69, longitude 117°43'14"W / -117.72, at elevation 410 feet, on the grounds of the University of California Field Station on a grass plot that is well maintained, irrigated and mowed. The Pacific Ocean is approximately 10.5 miles to the southwest. The station was activated on October 07, 1987. Daily and monthly data are available from 2003 to present. Reported data fields from the CIMIS #75 Irvine station include:

- Total ETo (inches)
- Total Precipitation (inches)
- Average Dew Point (F)

[12] Allen, R.G., Walter, I.A., Elliot, R., Howell, T., Itenfisu, D., and Jensen, M., *The ASCE Standardized Reference Evapotranspiration Equation*, The American Society of Civil Engineers, 2005.

- Average Solar Radiation (Langley/Day)
- Average Vapor Pressure (mBars)
- Average Wind Speed (mph)
- Average Air Temperature (F)
- Average Max Air Temperature (F)
- Average Min Air Temperature (F)
- Average Soil Temperature (F)
- Average Maximum Relative Humidity (%)
- Average Minimum Relative Humidity (%)
- Average Relative Humidity (%)

Average annual ETo reported at CIMIS station #75 since 1987 is: 49.63 inches.
Average annual ETo reported at CIMIS station #75 from January 2003 to December 2010 is 49.66 inches.

Additionally there are four other CIMIS stations located in the general vicinity of Orange County, These stations are also listed Table 3-1 and the locations are shown on Figure 3-1 map. None of them are characterized as having an 'urban setting'. Below, in Figure 3-4, are photos of the Temecula and Irvine CIMIS stations.[13]

CIMIS Station # 62 Temecula

CIMIS Station #75 Irvine

Figure 3-4 Temecula and Irvine CIMIS Stations

[13] http://wwwcimis.water.ca.gov/cimis/frontStationDetailInfo.do?stationId=75&src=info and http://wwwcimis.water.ca.gov/cimis/frontStationDetailInfo.do?stationId=62&src=info

Figure 3-5 Weather Stations in the Orange County Region

Irvine Ranch Water District Stations

The Irvine Ranch Water District (IRWD) operates three weather stations to provide evapotranspiration data to customers. Table 3-1 lists the IRWD stations. Station locations are shown on the map, Figure 3-5.

IRWD provides the ET allocation data through its website, http://www.irwd.com/alwayswatersmart/weather-center.html. Data is reported daily for the current year and is provided in weekly increments from 1997 up to the current year. Overhead views of IRWD sites are shown in Figure 6. Reported data fields for each of the three weather stations are:

- Daily ET allocations (in)
- Weekly ET (in)

- Weekly CCF per acre
- Percent change from the previous week

IRWD weather stations use Campbell Scientific CR-10X Data Logger equipment, to maintain similarity of equipment with the California Department of Water Resources CIMIS stations around the state.

Central ET Station

Foothill ET Station


Coastal ET Station

Figure 3-6 Overhead views of ET Station Sites Operated by Irvine Ranch Water District

National Weather Service Cooperative Stations

In Orange County, weather stations with available data sets are limited in number. Station locations are inconvenient with respect to the landscape irrigation programs being evaluated. Therefore, four sites that are part of the National Weather Service (NWS) Cooperative Observer Program (COOP) should also be noted.

Additional sites are operated by the Automated Surface Observing Systems. The system favors airport runway touchdown zone(s) to provide critical aviation weather parameters. These are not representative of MWDOC program participants, nor do they meet the desired ‘well watered’ vegetation requirements.

Table 3-1 Physical Weather Stations

Station Operator	Station ID	Latitude	Longitude	Reference Crop	Approximate Elevation	Approximate Distance from Pacific Ocean	Available Period of Record
CIMIS	# 75, Irvine	33^{o} 69' N	117^{o} 72' W	grass	410 ft	10.5 miles	Oct.07,1987 - present
	#174, Long Beach	33^{o} 80' N	118^{o} 09' W	grass	17 ft	3.8 miles	Sept.22, 2000 - present
	#62, Temecula	33^{o} 49' N	117^{o} 64' W	grass	1420 ft	19.1 miles	Nov. 25,1986 - present
	#78, Pomona	34^{o} 06' N	117^{o} 81' W	grass	730 ft	27.7 miles	Mar.14, 1989 - present
	#44, U.C. Riverside	33^{o} 96' N	117^{o} 34' W	grass	1020 ft	38.3 miles	June 2, 1985 - present
IRWD	Foothill Station	33^{o} 66' N	117^{o} 78' W	brush	1450 ft	13.5 miles	1997 - present
	Central Station	33^{o} 69' N	117^{o} 64' W	grass	160 ft	7 .8 miles	1997 - present
	Coastal Station	33^{o} 61'N	117^{o} 81' W	brush	1150 ft	2.8 miles	1997 - present
NCDC	WBAN #93114, Tustin MCAF	33^{o} 72' N	117^{o} 83' W	bare soil	59ft	11 miles	Dec.1, 1927 - present
	#7888, Santa Ana Fire Station	33^{o} 75' N	117^{o} 87' W	--	135 ft	--	July 1,1948 - present
	Santa Ana Field Station (backup for #7888)	33^{o} 68' N	117^{o} 72' W	bare soil	45 ft	10.5 miles	July 28,1981 – Nov.30, 1987
	#9847, Yorba Linda	33^{o} 88' N	117^{o} 82' W	--	350 ft	18.4 miles	July 1,1948 - present
	#44647 Laguna Beach	33^{o} 53' N	117^{o} 77' W	--	35 ft	0.1 miles	Mar. 1, 1928 - present
	#46175 Newport Beach /Balboa Is.	33^{o} 60' N	117^{o} 90' W	--	10 ft	0.1 miles	Nov. 1, 1934 - present
	#47836 San Juan Canyon, San Juan Capistrano	33^{o} 53' N	117^{o} 55' W	bare soil	360 ft	8.1 miles	Oct.1, 2001 - present
	#47731 San Clemente Municipal Pier	33^{o} 42' N	117^{o} 62' W	over ocean	35 ft	0.0 miles	July 20, 2006 - present

Quantifying ET using other Methods

CIMIS Spatial

The California Department of Water Resources CIMIS Program[14] has developed 'Spatial CIMIS', a sophisticated method using CIMIS weather stations, satellite imagery and geographic computer modeling techniques to estimate ET_o and related data. Spatially calculated ET_o can be obtained from the CIMIS website by clicking on the Spatial CIMIS tab as shown in Figure 3-7.[15] Spatial CIMIS calculates and provides on-line access to current and historical reference evapotranspiration at 2 km spatial resolution. The methodology uses the American Society of Civil Engineers version of the Penman-Monteith equation (ASCE-PM). Required input parameters for the ASCE-PM ET_o equation are solar radiation, air temperature, relative humidity, and wind speed. Due to the significant gaps in input data and limitations from limited standard CIMIS stations, remotely sensed satellite data with point measurements from the CIMIS weather stations are used to generate spatially distributed ET_o values creating the ET_o maps. These techniques apply throughout most of California, including Orange County.

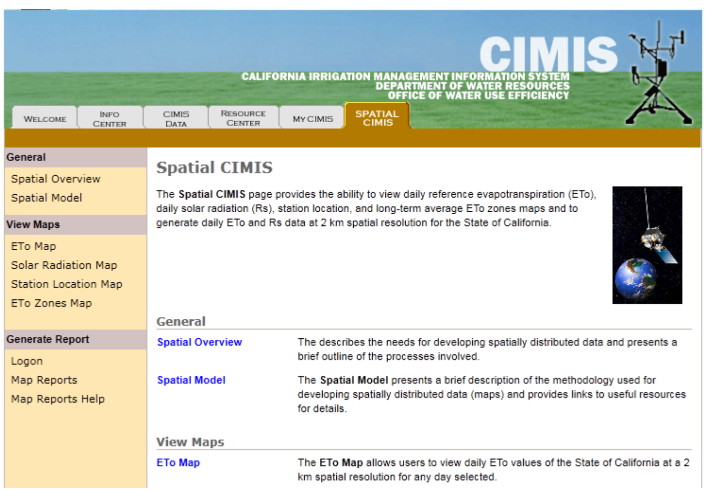


Figure 3-7 Spatial CIMIS Webpage

For any specified latitude and longitude, and many zip codes, CIMIS Spatial reports the following data: user location designation, latitude, longitude, CIMIS ETo in inches per day and solar radiation in Langleys per day.

Daily historical data may be downloaded from the CIMIS website in CSV, PDF or web formats and is available from November 2003 to present. Sample CIMIS Spatial data for the Costa Mesa Country Club, served by Mesa Water District, is shown in Table 3-2.

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[14] O.J Hart, Ibid

[15] http://wwwcimis.water.ca.gov/cimis/cimiSatSpatialCimis.jsp

Table 3-2 Sample CIMIS Spatial Data Report

Sample CIMIS Spatial Data Report for a location at the Costa Mesa Country Club served by Mesa Water District					
Point	Lat	Long	Date	CIMIS ETo (in) (in/day)	Sol Rad (Ly/day)
MESA WD	33° 67' N	117° 93' W	1/1/2010	0.08	264.25
MESA WD	33° 67' N	117° 93' W	1/2/2010	0.10	285.54
MESA WD	33° 67' N	117°.93' W	1/3/2010	0.11	258.41
MESA WD	33° 67' N	117° 93' W	1/4/2010	0.10	241.64
MESA WD	33° 67' N	117° 93' W	1/5/2010	0.09	284.15

CIMIS also provides a Spatial ET_o map with color gradations to indicate ET_o levels. Figure 3-8 is an example of a CIMIS ET_o map from May 28, 2011.

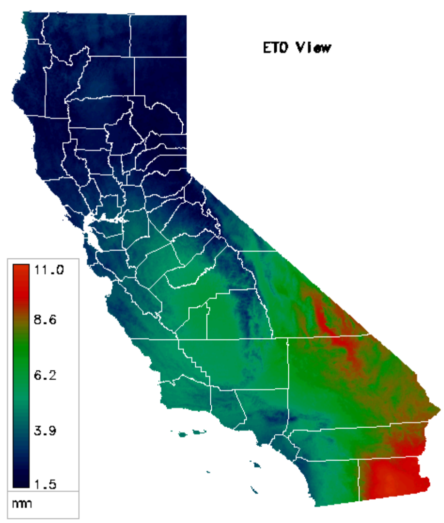

Figure 3-8 CIMIS ET_o Map

Review of Prior Approaches to Estimating ET_o

Review of the estimating techniques, makes them less appealing than ET stations or Spatial CIMIS. Academically, it may be helpful to know that such methods can be used where sophisticated weather measurements, such as those from CIMIS and IRWD stations are unavailable.

Hargreaves[16], Contor[17], Linacre[18] and others have developed a succession of estimating methods during the past 60 years. These methods all use available temperature data and solar radiation values.
The 1985 Hargreaves equation is:

$$ET_o = 0.0022\ R_a\ (TC + 17.8)\ TR^{(0.50)}$$

Allen provided another variation in 1993:

$$ET_o = 0.029\ R_a\ (TC+20)\ TR^{0.4}$$

where, R_a represents solar radiation, TC represents temperature in degrees Celsius, and TR represents the daily temperature range.

These calculating techniques were applied to ET estimates in many arid and semi arid locations worldwide where weather data was limited. Researchers used 5 day and 7 day or monthly temperature periods for their calculations of ET requirements. Hargreaves provides a convenient summary: "...where data quality is questionable or where historical data are missing, both the reduced set FAO-Penman Monteith and the 1985 Hargreaves equation are recommended since the two methods are surprising equivalent over a wide range of climates."

These calculating techniques are not recommended for this evaluation due to the availability of ET stations and CIMIS Spatial values.

Comparison of CIMIS SPATIAL and directly measured IRWD ET_o

Annual and monthly ET_o values were compared for the three IRWD sites: Sand Canyon (Central station), Foothill station, and Coastal station; CIMIS station #75; and CIMIS Spatial applied to the IRWD site locations. Annual data are displayed in Figures 3-9 to 3-12 and monthly data are displayed in Figures 3-13 and 3-14.

Figures 3-9 and 3-10 compare direct ET_o measures against CIMIS spatial ETo estimates for two centrally located Irvine locations: Sand Canyon (Central station) and CIMIS station #75. The annual ET_o values from each of the four data sources are different in each year. Generally CIMIS #75 values are highest and the IRWD station values are lowest. The CIMIS Spatial values are generally within 5 percent of the CIMIS #75 values. The IRWD Sand Canyon Central station values are within 10 percent of CIMIS #75 and range from 102 to 78 percent of CIMIS #75. Note: the IRWD Sand Canyon (Central) station is located about 3 miles from the CIMIS #75 site.

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[16] GH Hargreaves, FASCE, RG Allen, *History and Evaluation of Hargreaves Evapotranspiration Equation*, Journal of Irrigation and Drainage Engineering, January February, 2003.
[17] BA Contor, *Traditional Evaporation Calculations*, Idaho Water resources research Institute Technical Report 04-009, 2004.
[18] ET Linacre, *A Simple Formula foe Estimating Evaporation Rates in Various Climates, Using Temperature Data Alone*, Agricultural Meteorology, Volume 18, Issue 6, 1977.

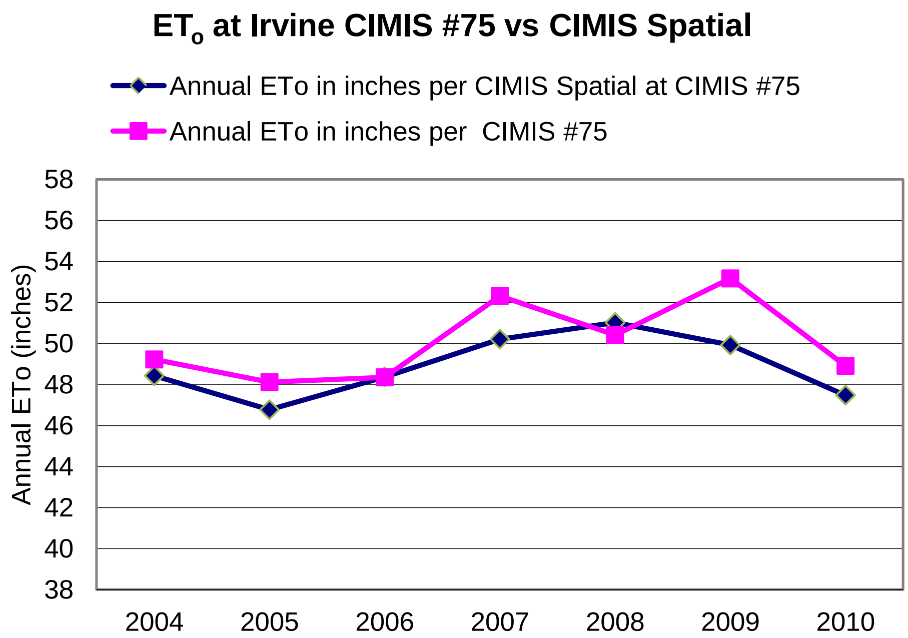


Figure 3-9 Comparison of Annual ET$_o$ Estimates for CIMIS station #75 and CIMIS Spatial at same location

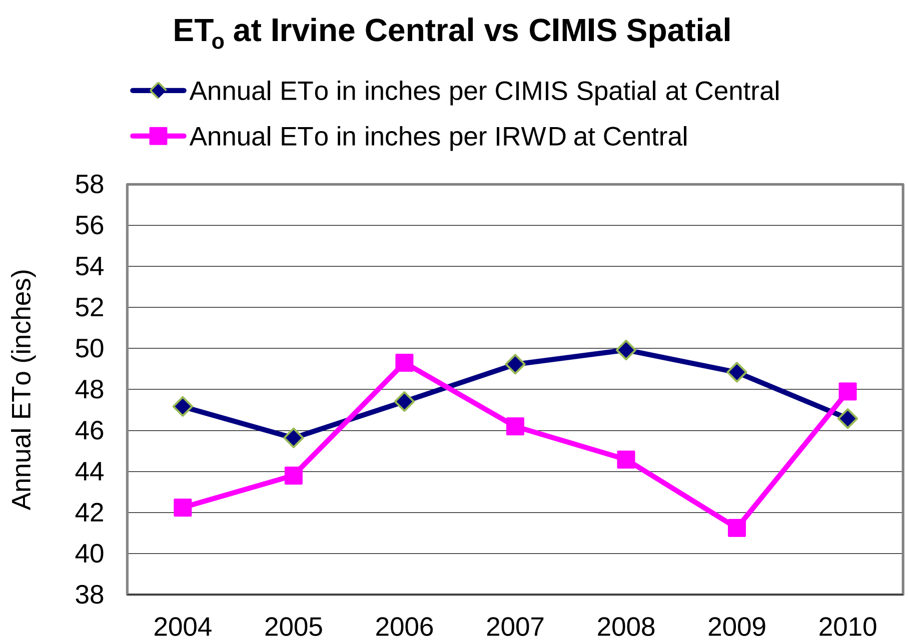


Figure 3-10 Comparison of Annual ET$_o$ Estimates for Sand Canyon Central station and CIMIS Spatial at same location

For the Coastal location during 2004-2009 (Figures 3-11 and 3-12), the annual IRWD ET_o values are lower that the CIMIS Special values. The difference in the annual values ranges from 3 to 22 percent, with an average difference of 13 percent. For the Foothill location during 2004-2009 (Figure 3-11), the annual IRWD ET_o values are very similar (generally less than 5 percent difference) to the CIMIS Spatial values.

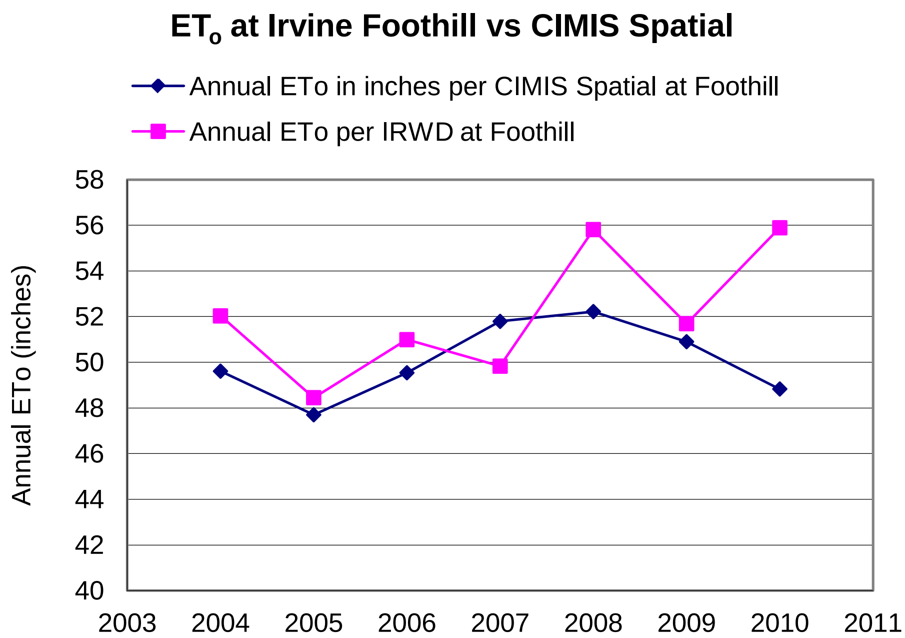


Figure 3-11 Comparison of annual ET_o Estimates for Irvine Foothill Station vs. CIMIS Spatial at the same location

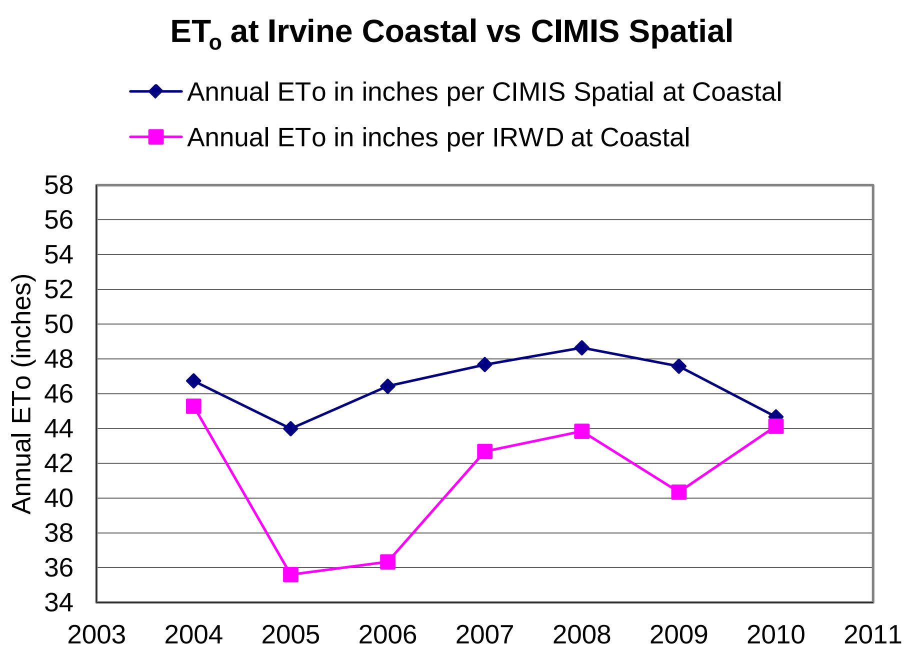
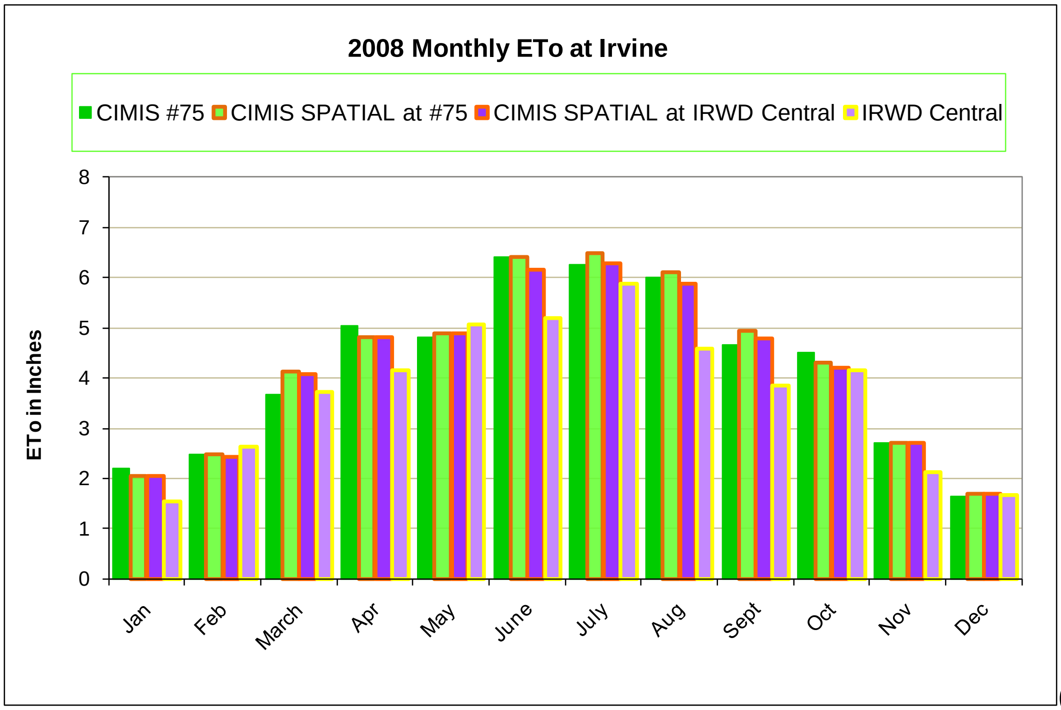


Figure 3-12 Comparison of annual ET_o Estimates for Irvine Coastal Station vs. CIMIS Spatial at the same location

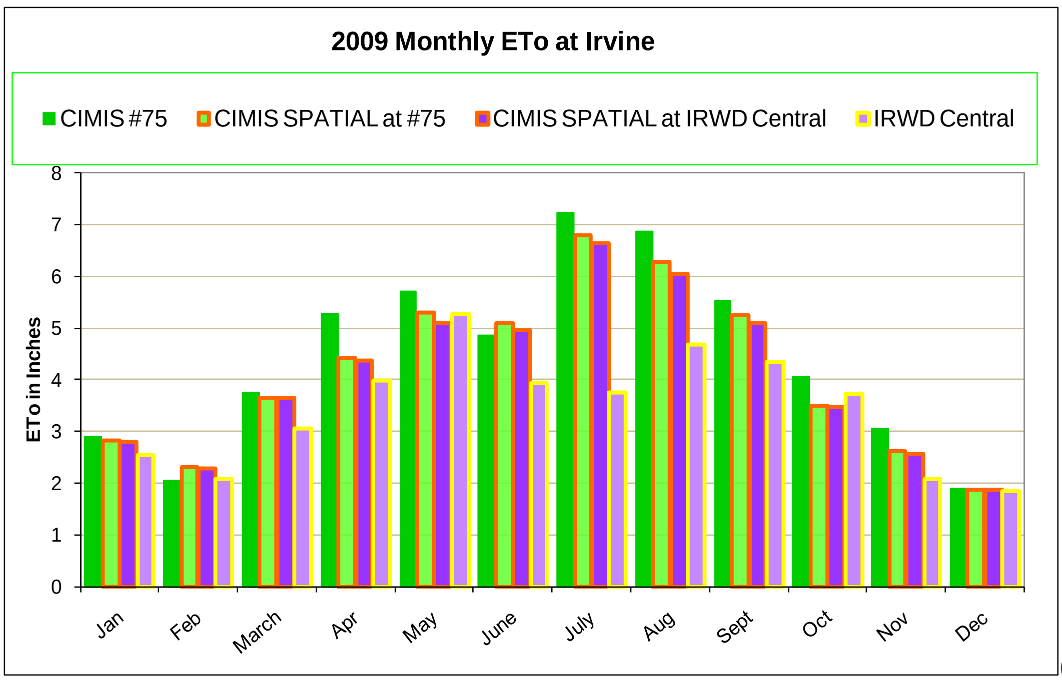
To illustrate monthly ET_o differences, two CIMIS Spatial daily ET_o measures (a coastal area and an inland area) are contrasted against Irvine Station #75. Statistical software was used to plot a smoothed version of daily ET_o measures by month.

Monthly ET_o values for 2005, 2006, 2008, and 2009 are displayed in Figure 3-14 for the IRWD Coastal and Figure 3-15 for the Foothill ET sites. Where 2005 is considered a wet year with precipitation 150 percent greater than normal and 2009 is indicative of a dry year with precipitation 40 percent below normal[19]. For the Coastal location, comparing the monthly ET values between IRWD and CIMIS Spatial measurements shows differences ranging from 1 percent to 44 percent per month. Annual standard deviations of the monthly percentage differences range from 0.10 to 0.17. See Table 3-3. For the Foothill location, comparing side by side monthly ET values appear close in the graphs, but have a difference ranging from 1 to 37 percent during the four years considered.

[19] Compared to the National Climatic Data Center 1981-2010 Monthly Normals.

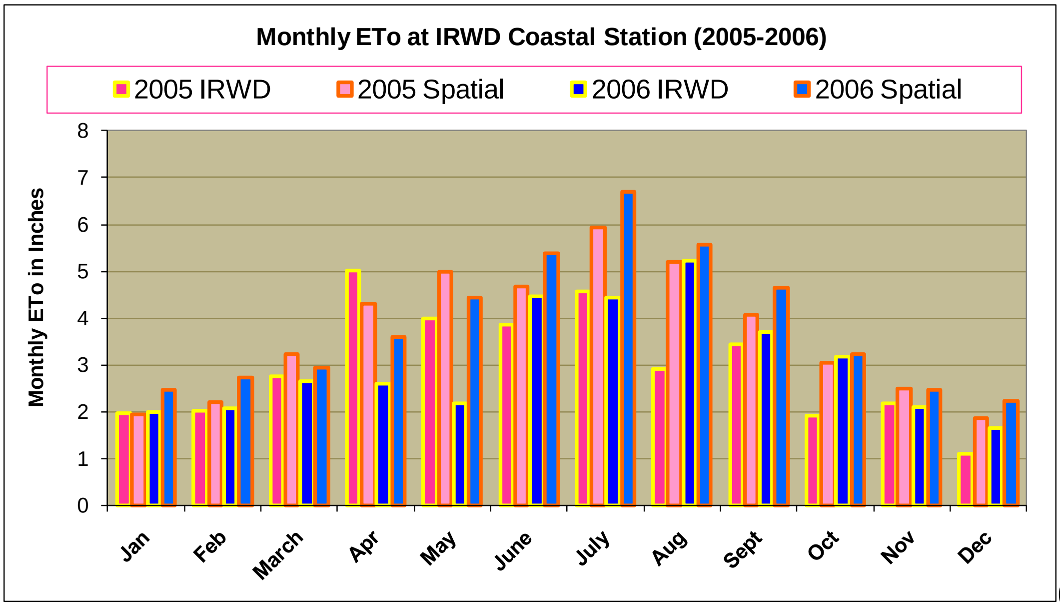


(a)

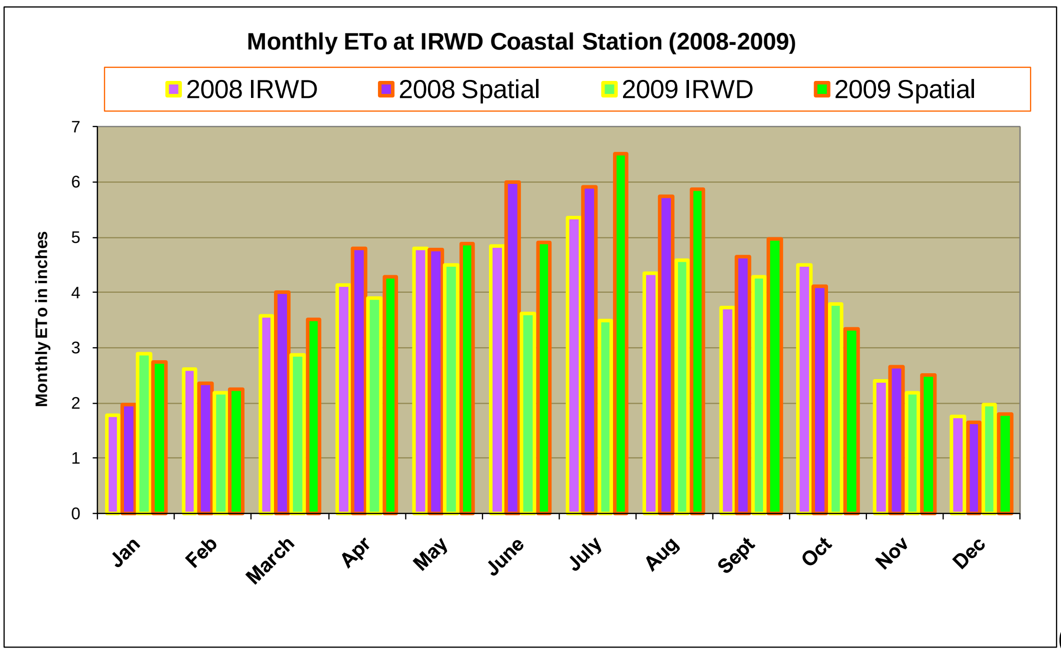


(b)

Figure 3-13 Monthly ET_o Comparisons at Irvine for (a) 2005 - 2006 and (b) 2008 - 2009

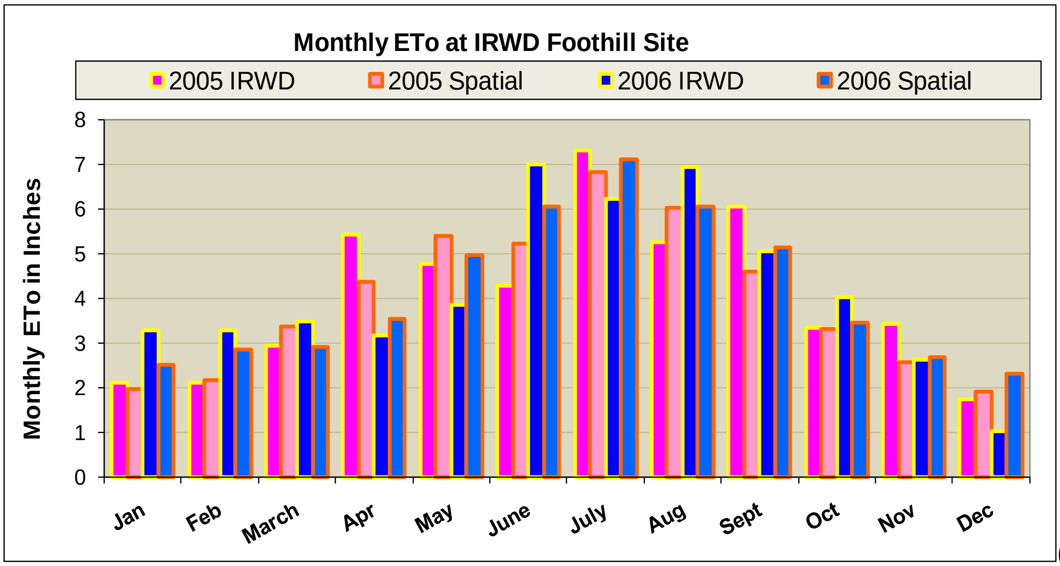


(a)

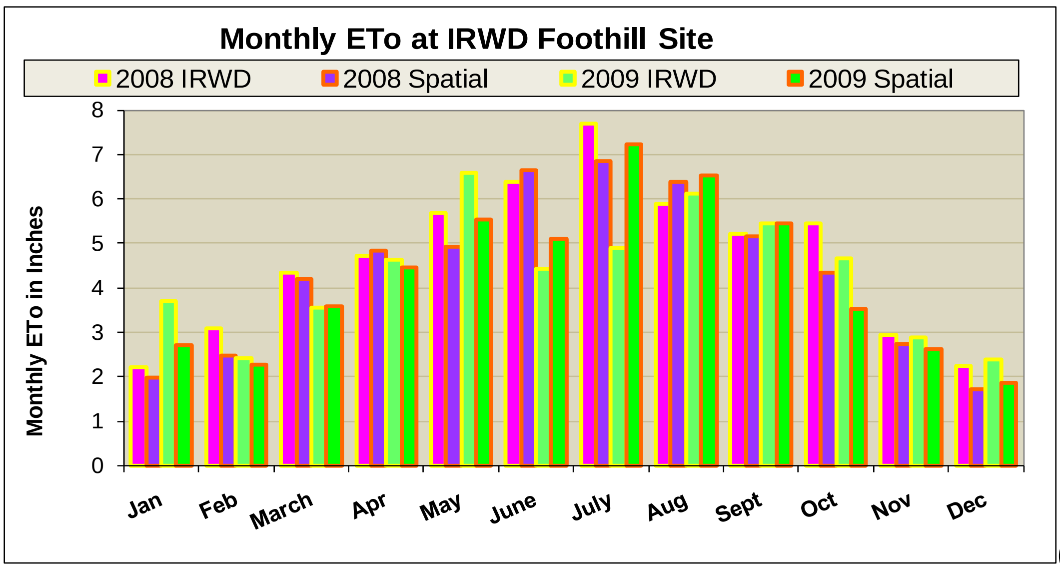


(b)

Figure 3-14 Monthly ET_o Comparisons at Irvine Coastal Station (a) 2005 and 2006, and (b) 2008 and 2009



(a)



(b)

Figure 3-15 Monthly ET_o Comparisons at IRWD Foothill Site (a) 2005 and 2006, and (b) 2008 and 2009

Table 3-3 Comparison of ETo values for the IRWD Coastal Site

Average difference between data sources (IRWD Coastal vs CIMIS Spatial) on monthly basis					
	2005	2006	2007	2008	2009
Jan	-2%	18%	11%	10%	-5%
Feb	9%	24%	15%	-11%	3%
March	15%	10%	1%	11%	18%
Apr	-16%	28%	20%	14%	9%
May	20%	51%	9%	0%	8%
June	18%	17%	16%	19%	26%
July	23%	34%	22%	9%	46%
Aug	44%	6%	1%	24%	22%
Sept	15%	20%	14%	20%	14%
Oct	37%	2%	-4%	-9%	-13%
Nov	12%	15%	20%	10%	12%
Dec	41%	26%	-8%	-6%	-9%
Average Difference	18%	21%	10%	7%	11%
Std Deviation	0.17	0.13	0.10	0.12	0.17

Figure 3-16 plots the CIMIS Spatial daily ET_o for Newport Beach (a coastal locality) against CIMIS Station #75. Both sets of daily ET_o measures are smoothed using a Lowess smoother (bandwidth = 1.5) to better reveal local patterns within the month. The localized measure of ET_o at the coast is distinctly beneath the centrally located measure, most evident in summer months. This is in accordance with expectation.

Similarly, Figure 3-17 plots the CIMIS Spatial daily ET_o for Yorba Linda (an inland locality) against CIMIS Station #75. Predictably the localized measure of ET_o in an inland locality that is higher than the centrally located Station # 75 measure, especially in the spring growing season and summer. Other years and other localities exhibit similar differences.

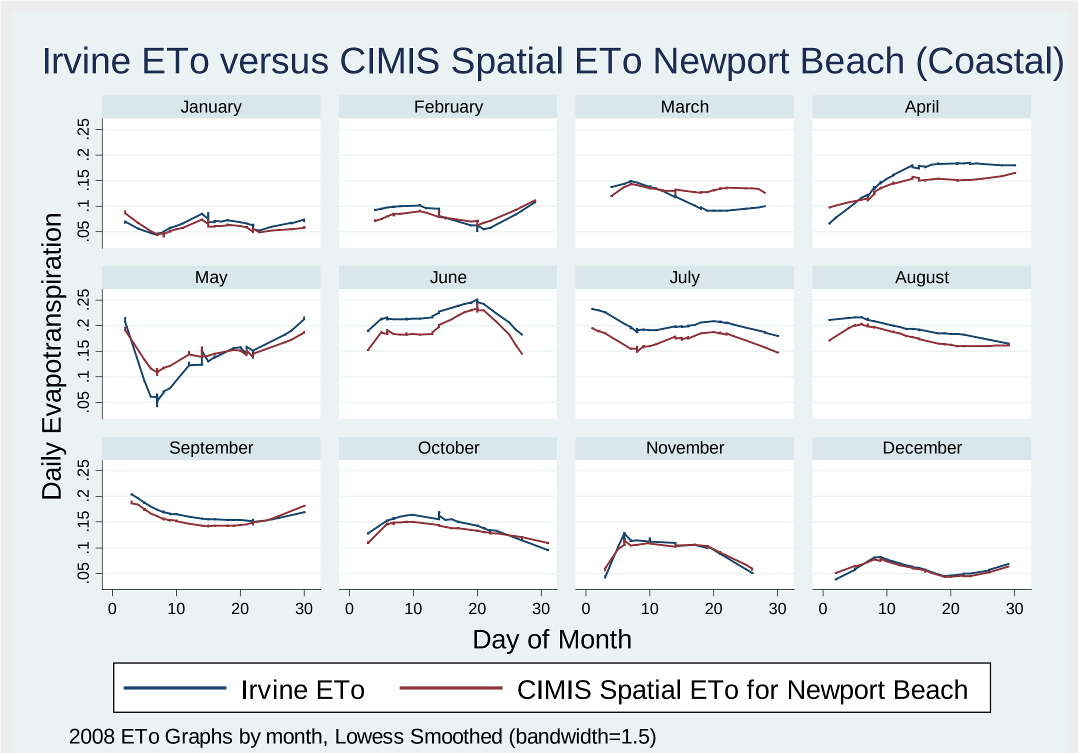


Figure 3-106 Irvine ET$_o$ VS CIMIS Spatial ET$_o$ Newport Beach

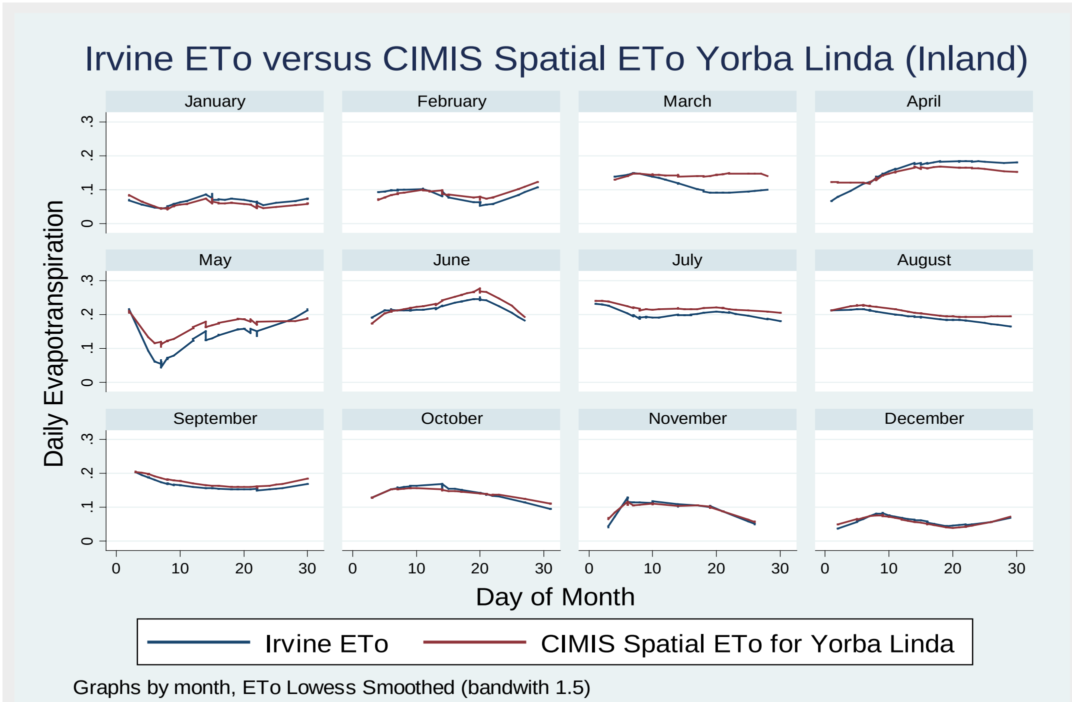


Figure 3-117 Irvine ET_o VS CIMIS Spatial ET_o Yorba Linda

Recommendation on ET_o Measures

The localized measures of ET_o (CIMIS Spatial) provide measures that reflect local differences from a central location. It is an open question whether these locally more accurate measures actually help improve prediction of customer water demand over a centralized measure. Unsurprisingly, they do as is evidenced in the statistical models of the next chapter that describes the impact evaluation.

Based on this evaluation of centrally located ET_o measures versus CIMIS Spatial ET_o, the research team recommended that CIMIS Spatial ET_o measures be developed for one or more selected locations for each retail water supplier providing data for the statistical models of the impact evaluation. The following CIMIS spatial measures were developed:

- IRWD Coastal Zone 1- latitude 33.41 N, longitude 117.6 West;
- IRWD San Canyon Zone 2- latitude 33.66 N, longitude 117.78 West;
- IRWD Foothill Zone 3- latitude 33.67 N, longitude 117.64 West;
- Newport Beach - latitude 33.605 N, longitude 117.865 West;
- Yorba Linda - latitude 33.88 N, longitude 117.797 West.

Section 4: Impact Evaluation: Actual Water Savings

This chapter describes the statistical analysis conducted in order to derive estimates of the net water savings due to participation in the Smart Timer Rebate Program.

Approach

Historical water consumption records (January 2006 through January 2011) were examined from two distinct sample groups: participants and nonparticipating customers. The hypothesis was that installation of new irrigation technology (automated "smart" timers that adjust applied water to match evapotranspiration requirements) or better management of equipment would reduce the observed water consumption of customers participating in this program. (The null hypothesis is that installation of new irrigation technology or better management of equipment has zero effect on the observed water consumption of customers participating in this program.) Since observed water consumption can also change due to weather and vary by customer and/or site characteristics, it is important to statistically control for weather and customer/site heterogeneity. This study empirically estimates the water savings that resulted from professional installation of water efficient irrigation equipment.

As installation of Smart Timers requires the voluntary agreement of the customer to participate, this sample of customers can be termed "self-selected." While this analysis does quantitatively estimate the reduction of participant's water consumption, one may not directly extrapolate this finding to non-participants. This is because self-selected participant can differ from customers that decided not to participate.

The explanatory variables in these models include:

- Deterministic functions of calendar time, including the seasonal shape of demand, low in the winter and high in the summer
- Weather conditions
    - measures of CIMIS Spatial Evapotranspiration
    - measures of precipitation, contemporaneous and lagged
- Customer-specific historical water consumption records
- "Intervention" measures of the date of participation and the type of customer site

Data and Methods

Consumption records were compiled from the member agency customer billing system for customers in the study areas. Billing histories were obtained from meter reads between January 2006 and January 2011. It is important to note that a meter read on August 1 will largely represent water consumption in July for a system with monthly meter reads. A meter read on August 1 in a system reading meters bimonthly will represent consumption in June and July. Since the number of days contained in a meter read can vary, the analysis converts customer water consumption in gallons to average daily value (gallons per day, gpd) in a meter read period. In this way, consumption reads can be standardized across varying lengths of meter read periods. Table 4-1 presents descriptive statistics on the sample.

Table 4-1 Smart Timer Rebate Program Participant and Control Account Statistics

North Orange County Smart Timer Accounts Descriptive Statistics			
	Participants	**Control**	**Total**
Single Family Accounts			
Number of Usable Accounts	70	407	477
Meter reads in Sample	3,892	22,609	26,501
Pre-Intervention, Mean Unadjusted Use (gpd)	521	401	419
Commercial Accounts			
Number of Usable Accounts	132	1,195	1,327
Meter reads in Sample	5,372	48,651	54,023
Pre-Intervention, Mean Unadjusted Use (gpd)	3,673	2,100	2,257

The first major issue with using meter-read consumption data is the level and magnitude of noise in the data—meter reads do not generally coincide with discrete calendar months and some meter reads are estimated reads rather than actual reads. The second major issue is that records of metered water consumption can also embed non-ignorable meter mis-measurement (bad meter reads). To keep either type of data inconsistencies from corrupting statistical estimates of model parameters, this modeling effort employed a sophisticated range of outlier-detection methods and models. These are described in *Appendix A: A Statistical Intervention Analysis of Smart Timer Rebate Program Customer Water Demand.*

Daily weather measurements—daily precipitation, maximum air temperature, and evapotranspiration—were collected from the NOAA WSO weather stations located in Orange county, the CIMIS station #75, and Irvine Ranch Water District weather stations. Additionally, the previously evaluated CIMIS spatial interpolations of evapotranspiration data were developed for each participating agency. Additional weather zones were specified for IRWD—inland, middle, and coastal—with customer accounts were assigned to one of the three Spatial ETo measures on the basis of zip code. This "Spatial ETo" was statistically tested against nonlocal ETo measurements. The daily weather histories for rainfall and temperature were collected as far back as were available (January 1, 1948 for NOAA stations) to provide the best possible estimates for "normal" weather through the year. Thus we have at least 63 observations upon which to judge what "normal" rainfall and temperature for January 1st of any given year. CIMIS Spatial

ETo measures were available back to 2004. Rolling monthly and bimonthly averages of rainfall, temperature, and evapotranspiration were created to exactly match to meter read dates for all customer water consumption histories. More information on the exact construction of weather measures for use in the statistical models can also be found in *Appendix A.*

Robust regression techniques were used to detect which observations are potentially data quality errors. This methodology determines the relative level of inconsistency of each observation with a given model form. A measure is constructed to depict the level of inconsistency between zero and one; this measure is then used as a weight in subsequent regressions. Less consistent observations are down-weighted. Other model-based outlier diagnostics were also employed to screen the data for any egregious data quality issues. Interviews with conservation staff and site visits were conducted to track down and confirm data quality issues.

Sample Selection: Of 87 unique account numbers found among Smart Timer Rebate Program participants consumption sample, the review of data quality identified 17 participants that did not reliably fit the estimated regression model. These customers were treated separately in the outlier analysis documented in Appendix A.

Findings

Detailed information on the statistical modeling specification and estimation are provided in *Appendix A: A Statistical Intervention Analysis of Smart Timer Rebate Program Customer Water Demand* at the end of this report. To isolate water savings attributable to this program, the analysis compared participant water use to that of a similar control group of nonparticipants. The empirically measured water savings of this analysis can be summarized.

Effect of Smart Timers on Average Single Family Water Use: Net water savings per single family customer were estimated from the statistical impact evaluation to be, on average, 49.3 gallons per day, an approximate 9.4 percent reduction. “Net” savings infers that these water savings are in addition to ongoing water savings attributable to regional messaging, ordinances, rate changes etc. Net water savings per commercial customer were estimated to be, on average, 726.4 gallons per day, an approximate 27.5% reduction. These estimated savings are averages, taken across the entire year. The statistical model also suggests how these results change throughout the year.

Effect of Smart Timers on SF Water Use throughout the Year: The question of how these programs affected the seasonal shape of water demand derived graphically. For example, Figures 4-1 and 4-2 depict the seasonal shape of water demand before and after Smart Timer Rebate Program participation for residential and commercial participants, respectively.

Several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 49.3 gallons per day.

Second, the assumption of a constant 49.3 gallon per day effect does not hold true throughout the year. Smart Timers and any irrigation system improvements apply water in the spring where ET_o is high—the shape of seasonal demand is very similar in the spring growing season represented by the K_c curve. For both the residential and commercial sites, the greatest reduction occurred during the fall and winter months.

Figure 4-2 provides a similar depiction for Commercial Customers and shows an even more pronounced affect of Smart Timer interventions on the shape of Commercial customer's water demand. For commercial customers, the difference between the two horizontal lines corresponds to an estimated mean reduction of approximately 726 gpd. Although the amount of reduction does not hold constant throughout the year, for the commercial customer sample set there was a consistent reduction estimated throughout the year ranging from a minimum of 350 gpd to a maximum of 1102 gpd.

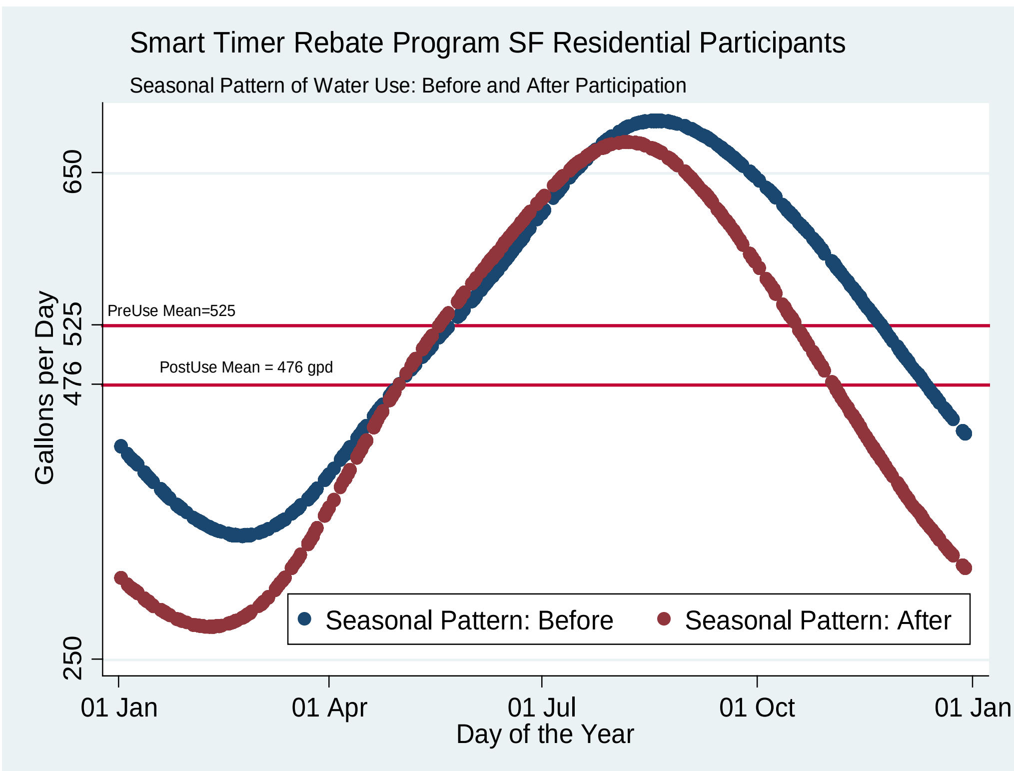


Figure 4-1 Smart Timer Rebate Program Single Family Participants: Seasonal Pattern of Water Use

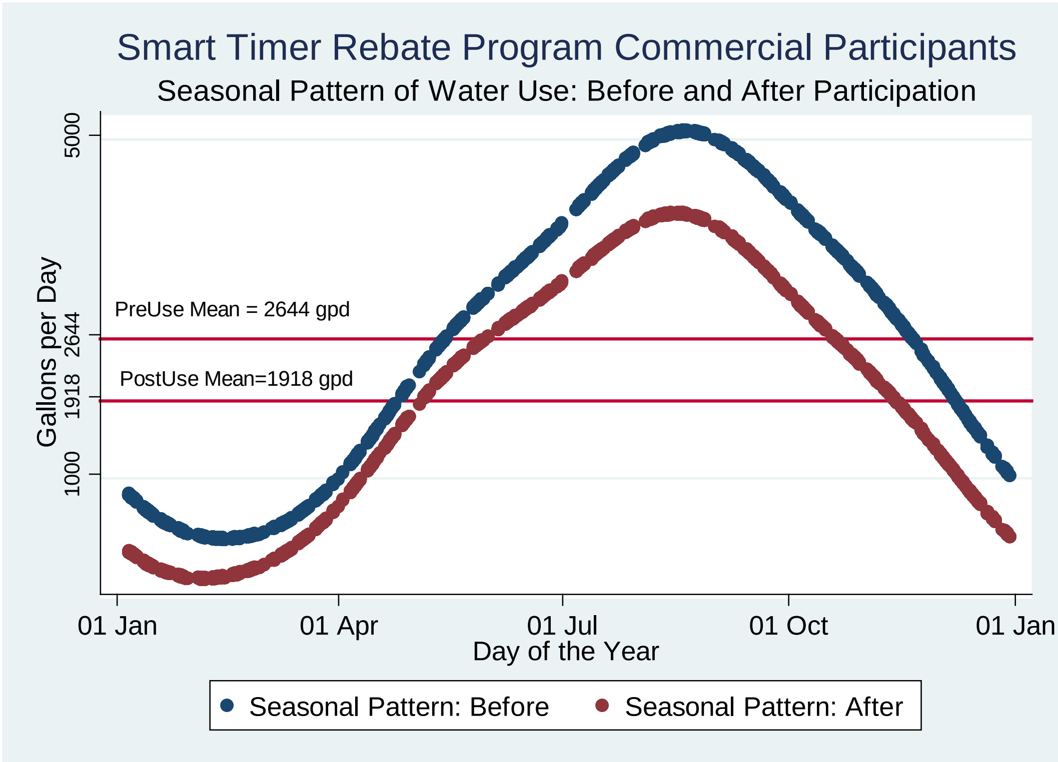


Figure 4-2 Smart Timer Rebate Program Commercial Participants: Seasonal Pattern of Water Use

Effect of Smart Timers on Water Use compared to MAWA

Figures were developed to compare water use between Smart Timer participants and AB1881 legislative goals in study area. California AB1881 stipulates that all existing landscapes be managed not to exceed a theoretical Maximum Applied Water Allowance (MAWA) of 80% of ET. The definition of MAWA was amended in the 2009 Model Water Efficient Landscape Ordinance (effective January 2010) to a tighter threshold of 70% of evaporation, with an exception allowing 100% of ET for 'special' Landscape Areas (SLA).

For single family participants, we developed an estimate of outdoor water use by subtracting a constant indoor water use allowance derived from typical water budgets used in Orange County. Where, an assumption of 4 residents is multiplied by 55 gpcd for a constant indoor allowance of 220 gpd.

Our implementation of the MAWA to display monthly is presented bellow, where there the irrigated area is only considering the landscaped area with no SLA portion:

$$\text{MAWA}_{\text{monthly}} = \text{ET}_{\text{o}} \times \text{Days} \times 0.62 \times (0.7 \times \text{Area})$$

where, MAWA = Maximum Applied Water Allowance (inches per month)
ET_o = Spatial ET_o for a 30 day average (inches per day)

Days	= Number of days in the meter read (day)
0.62	= Conversion factor (to gallons)
0.7	= ET adjustment factor (ETAF)
Area	= Landscape area (square feet)

Figure 4-3 plots the estimated outdoor use for Single Family Smart Timer participants in 2007 (prior to participation) versus the Monthly MAWA. Figure 4-4 plots the estimated outdoor use for Single Family Smart Timer participants in 2010 (after participation) versus the Monthly MAWA. The effect of participation in the Smart Timer Rebate program was to shift applied water closer to the recommended Monthly MAWA. Note that even after participation the match is not perfect. The direction of the change is unambiguously more congruent to the monthly interpretation of the statewide Maximum Applied Water Allowance goal.

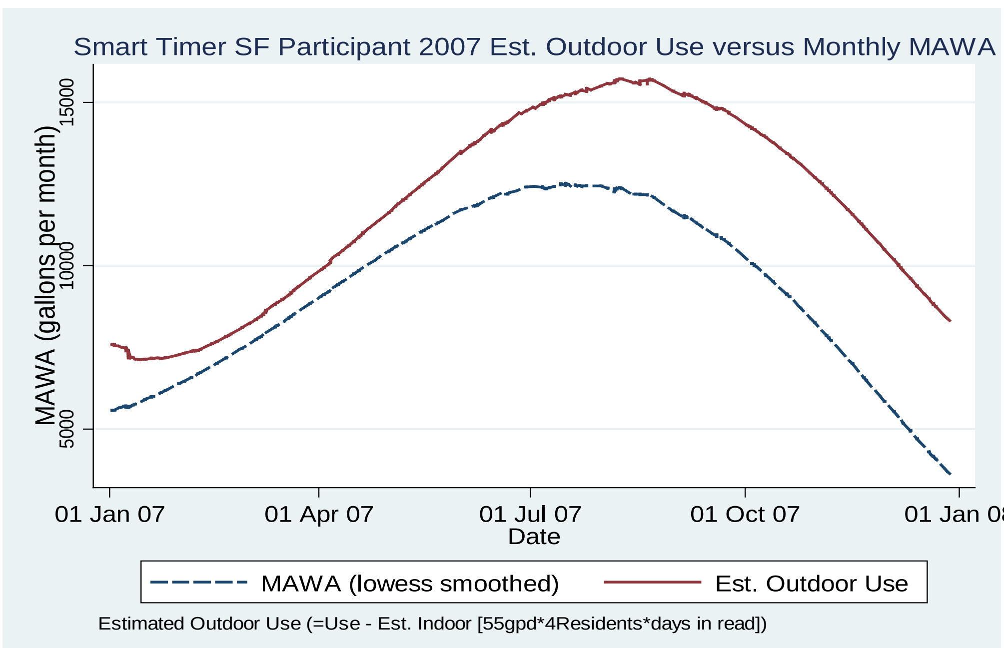


Figure 4-3 Smart Timer SF Participant 2007 Est. Outdoor Use VS Monthly MAWA prior to participation

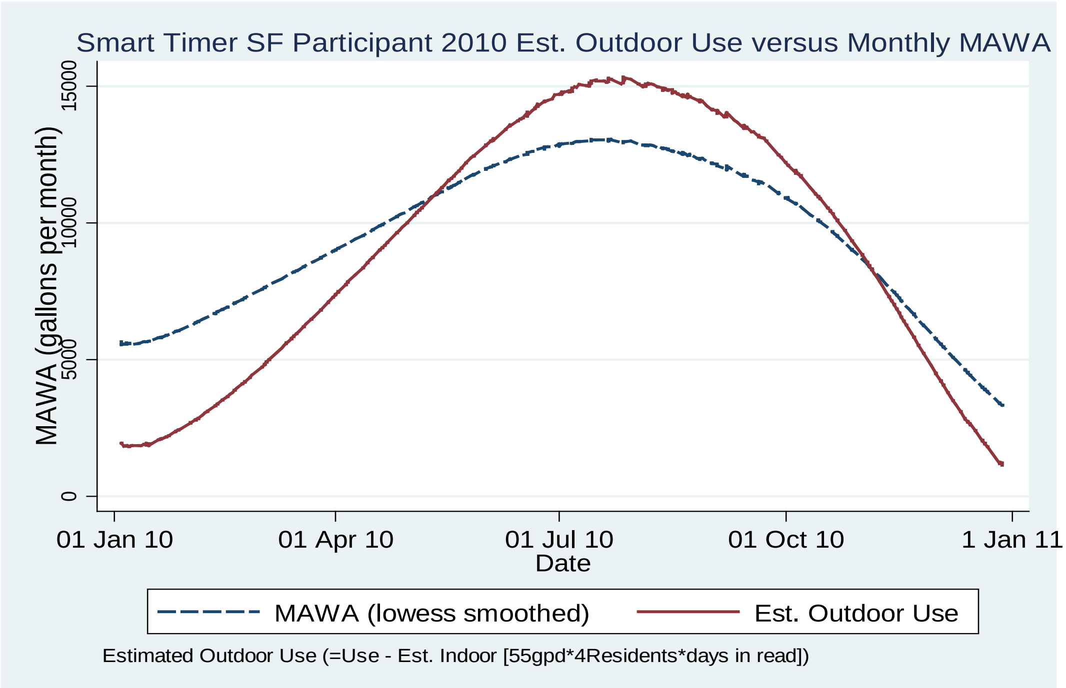


Figure 4-4 Smart Timer SF Participant 2010 Est. Outdoor Use VS Monthly MAWA after participation

Section 5: Cost Effectiveness Analysis

The Cost-Effectiveness Analysis uses the following steps:

- Identification Project Costs and Benefits—by the different perspectives of customers, water suppliers, and society
- Water Savings—quantitative summaries of water savings from the statistical impact models
- Cost and Savings—comparison of project costs to project savings
- Summary of Project Costs and Benefits by Perspective

Identification Project Costs and Benefits

The identification step seeks to describe costs and benefits prior to quantification. This step can help avoid the tendency to conclude:

Customer/Participant

Costs: Participating customers did incur additional direct costs related to the Smart Timer Rebate Program intervention since the grants were limited.[20] Direct installation costs and site survey costs were sometimes borne by customers, depending on the mode of installation. Customers typically incurred additional indirect costs related to any disruptions during the period of landscape retrofits or learning costs of adapting to new systems following the intervention.

Benefits: Since the Smart Timer Rebate Program produced water savings, participating customers benefit from reduced water bills. [Though not directly quantified, the benefit per customer depends on the retail price of water in the upper tier, the value of which varies by customer and retail agency.] If the direct costs of the program to the water supplier are less than the benefits (the avoided costs of additional water supply), then non-participating customers will benefit: the expected revenue requirement of the retail water supplier will be reduced over time.

Water Supplier

Water suppliers co-funded the direct project costs and also incurred costs to design, run, and evaluate the Smart Timer Rebate Program. Water suppliers' chief benefit is the avoided cost of additional water supply. While there are state-wide standards for

[20] Customer installation costs were reported for a subset of participants (non-self installers who reported). The mean Smart Timer installation cost for reporting commercial customers was $297 per application with a standard deviation of almost $800. The mean Smart Timer installation cost for residential customers was $177 with a standard deviation of about $500. Since customer installation costs can include both the cost of Smart Timer installation and site survey and repair, there is a wide variation in reported installation costs.

estimating water utility direct avoided costs[21], an easy-to-understand estimate of a lower bound can also be made.

A Lower Bound Estimate for the Avoided Cost of Imported Water Supply: Each acre foot of water conserved by the Smart Timer Rebate Program avoids the cost of importing an additional acre-foot of water. Additional water supplies imported into Orange County currently cost $869 per acre foot (Metropolitan's 2011 Tier 2 Treated Water Rate) and are projected to increase to $1,700-$1,800 per acre foot in 2020. This is a lower bound on water supplier avoided costs in that it does not include any water supplier costs within the county.

Society

In addition to the costs and benefits listed above, the water savings produced by the Smart Timer Rebate Program produce additional societal benefits:

***Cal-Fed Benefits* –** Water savings in North Orange County produces a benefit for the State of California by containing demand growth and reducing the need to import water from impacted areas.

***Stormwater Management & Water Quality*–** By reducing over-irrigation, Smart Timer Rebate Program irrigation upgrades reduce dry weather runoff and overspray from urban landscapes into the stormwater system, and therefore, fewer pollutants are carried to our ocean.

***Market Transformation* –** The Smart Timer Rebate Program produced additional accomplishments to those documented in a narrow cost-effectiveness analysis of program participants alone. Irrigation equipment suppliers now widely carry a variety of smart timers. Even big-box retail store (e.g. Home Depot and Lowes) are now beginning to carry Smart Timers. Landscape contractors developed experience installing water use efficiency equipment upgrades and now market on this basis. These collateral improvements in the marketing, distribution and contractor knowledge of efficient landscape irrigation equipment produces water savings among non-participants. The collateral improvement of Market Transformation can be thought of as having the opposite effect of "free-ridership", when customers are paid to do something they would have done anyway.

Water Savings

Table 5.1 provides the estimates of net water savings produced by the USBR funded portion of the Smart Timer Rebate Program.

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[21] See "*Water Utility Direct Avoided Costs From Water Use Efficiency*," A & N Technical Services and Gary Fiske and Associates, CUWCC and AWWARF, November 2006. http://www.cuwcc.org/WorkArea/showcontent.aspx?id=2676

Table 5-1 Estimated Net Water Savings

Estimated Net Water Savings Smart Timer Rebate Program			
Site Type	**Label**		**Units**
Single Family Residential	PreST, MeanUse	521	gallons per day per metered account (weather normalized)
	meter reads in sample	3,892	
	Mean savings, %	9.4%	Percent
	Mean savings, gpd	49.3	gallons per day per metered account
	SF metered sites in sample	70	accounts
	Estimated savings, AFY	3.87	Acre-Feet per Year
	Coverage of Sample	35%	(n = 70 accounts in consumption sample/198 accounts in all SF ST Rebates)
	Estimated ST Rebate savings, AFY	10.9	Acre-Feet per Year
		7.6 to 14.3 AFY	95 percent confidence interval
Commercial	PreST, MeanUse	3673	gallons per day per metered site
	meter reads in sample	5,372	
	Mean savings, %	27.5%	Percent
	Mean savings, gpd	726.4	gallons per day per metered site
	CII metered sites in sample	132	accounts
	Estimated savings, AFY	107.4	Acre-Feet per Year
	Coverage of Sample	42.9%	(n = 132 accounts in consumption sample/308 accounts in all Comm ST Rebates)
	Estimated ST Rebate savings, AFY	250.6	Acre-Feet per Year
		223. to 278.2 AFY	95 percent confidence interval

Costs and Savings

Table 5.2 presents the estimated cost-effectiveness of the Smart Timer Program for a 10 year lifetime. A simple nominal unit cost—in nominal dollars per nominal acre foot—is presented for simplicity of interpretation. Care should be taken as this nominal unit cost for conserved water cannot be used to compare dissimilar water resource alternatives as no adjustment is made for the time value of cost and benefit streams. Note too that the MWDOC staff costs are included in the summary across all sites of the direct regional project costs. State and federal staff costs were not provided and have not been estimated.

Table 5-2 Smart Timer Rebate Program Cost Effectiveness

Estimated Cost-Effectiveness Smart Timer Rebate Program			
Site Type	**Label**	**Value**	**Units**
Residential	SF Lifetime (10 Year) Savings	109.41	Acre-Feet over 10 Years
	Direct Project Costs	$142,641	Rebates, Admin, Inspection (248 ST applications, 198 unique accounts)
	Unit Cost	$1,303	Nominal $ per Nominal AF
Commercial	CII Lifetime (10 Year) Savings	2,506.05	Acre-Feet over 10 Years
	Direct Project Costs	$574,704	Rebate, Admin, Inspection (588 ST applications, 308 unique accounts)
	Unit Cost	$229.33	Nominal $ per Nominal AF
All Sites	Lifetime Water Savings All Sites (SF+Commercial)	2,615.46	Acre-Feet over 10 Years
	Total Direct Funding	$717,346	Rebate, Admin, Inspection
	MWDOC Staff Cost	$ 43,915	Salary and Benefits Paid, 8/1/08-8/31/11, Activity Code 8102
	Regional Unit Cost All Sites (SF+CII)	$291.06	Nominal $ per Nominal AF

Section 6: Recommendations

Recommendations

Additional Research on Variation in Customer Acceptance and Water Savings:
Additional research on customer uptake of water efficient irrigation technology and high resolution measurement of how water savings vary (over site types, manufactures, and alternative installation/delivery methods) can inform the design of future WUE programs.

Create a Sustainable Funding Mechanism for Water Efficiency Programs:
MWDOC has been successful in procuring outside funding to fund a significant portion of program costs. This is a noteworthy and significant achievement. However funds from outside Orange County are variable. In addition, support for funding WUE programs within Orange County can vary with the hydrologic cycle and with cash flow constraints. Yet the need for cost-effective long term Water Use Efficiency will not vary with hydrologic and business cycles; it is driven by long term water resource economics. Therefore, MWDOC and its member agencies should consider other more sustainable and innovative funding sources such on-bill financing, third party financing, and water budget tiered rates as additional methods for program funding.

Appendix A: A Statistical Intervention Analysis of Smart Timer Rebate Program Customer Water Demand

Model Specification: A Model of Smart Timer Rebate Program

Water Use

The model for customer water use seeks to separate several important driving forces. In the short run, changes in weather can make demand increase or decrease in a given year. These models are estimated at a household level and, as such, should be interpreted as a condensation of many types of relationships—meteorological, physical, behavioral, managerial, legal, and chronological. Nonetheless, these models depict key short-run and long-run relationships and should serve as a solid point of departure for improved quantification of these linkages.

Systematic Effects

This section specifies a water demand function that has several unique features. First, it models seasonal and climatic effects as continuous (as opposed to discrete monthly, semi-annual, or annual) function of time. Thus, the seasonal component in the water demand model can be specified on a continuous basis, then aggregated to a level comparable to measured water use (e.g. monthly). Second, the climatic component is specified in different form as a similar continuous function of time. The weather measures are thereby made independent of the seasonal component. Third, the model permits interactions of the seasonal component and the climatic component. Thus, the season-specific response of water demand can be specific to the season of the year.

The general form of the model is:

Equation 1

$$Use = \mu_i + S_t + W_t + I_{i,t}$$

where ***Use*** is the quantity of water demand within time *t*, the parameter $\boldsymbol{\mu_i}$ represents mean water consumption per meter *i*, $\boldsymbol{S_t}$ is a seasonal component, $\boldsymbol{W_t}$ is the weather component, $\boldsymbol{I_{i,t}}$ is the effect the landscape interventions for meter *i* at time period *t*. Each of these components is described below.

Seasonal Component: A monthly seasonal component can be formed using monthly dummy variables to represent a seasonal step function. Equivalently, one may form a combination of sine and cosine terms in a Fourier series to define the seasonal component as a continuous function of time.[1] The following harmonics are defined for a given day T, ignoring the slight complication of leap years:

Equation 2

$$S_t \equiv \sum_{1}^{6}\left[\beta_{i,j}\cdot\sin\left(\frac{2\pi\cdot jT}{365}\right)+\beta_{i,j}\cdot\cos\left(\frac{2\pi\cdot jT}{365}\right)\right]=Z\cdot\beta_S$$

where T = (1,..., 365) and j represents the frequency of each harmonic.[2] Because the lower frequencies tend to explain most of the seasonal fluctuation, the higher frequencies can often be omitted with little predictive loss.

To compute the seasonal component one simply sums the multiplication of the seasonal coefficient with its respective value. This number will explain how demand changes due to seasonal fluctuation.

Weather Component: The model incorporates two types of weather measures into the weather component–reference evapotranspiration and rainfall.[3] The measures of ETo and rainfall are then logarithmically transformed to yield:

Equation 3

$$R_t \equiv \ln\left[1+\sum_{t=T}^{T_d} Rain_t\right], E_t \equiv \ln\left[\sum_{t=T}^{E_d}\frac{ETo_t}{d}\right]$$

where d is the number of days in the time period. For monthly aggregations, d takes on the values 31, 30, or 28, ignoring leap years; for daily models, d takes on the value of one. Because weather exhibits strong seasonal patterns, climatic measures are strongly correlated with the seasonal measures. In addition, the occurrence of rainfall can reduce expected air temperatures. To obtain valid estimates of a constant seasonal effect, the seasonal component is removed from the weather measures by construction.

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[1] The use of a harmonic representation for a seasonal component in a regression context dates back to *Hannan* [1960]. *Jorgenson* [1964] extended these results to include least squares estimation of both trend and seasonal components.

[2] If measures of water demand are available on a daily basis, the harmonics defined by Equation 2 can be directly applied. When measures of water demand are only observed on a monthly basis, two steps must be taken to ensure comparability. First, water demand should be divided by the number of days in the month to give a measure of average daily use. Otherwise, the estimated seasonal component will be distorted by the differing number of days in a month. The comparable measures of the seasonal component are given by averaging each harmonic measure for the number of days in a given time period.

Specifically, the weather measures will be constructed as a departure from their "normal" or expected value at a given time of the year. The expected value for rainfall during the year, for example, is derived from regression against the seasonal harmonics. The expected value of the weather measures ($\hat{\boldsymbol{E}}=\boldsymbol{Z}\boldsymbol{\beta}_E$) is subtracted from the original weather measures:

Equation 4

$$W_t \equiv (R_t - \widehat{R}_t) \cdot \beta_R + (E_t - \widehat{E}_t) \cdot \beta_E$$

The weather measures in this deviation-from-mean form are thereby separated from the constant seasonal effect. Thus, the seasonal component of the model captures all constant seasonal effects, as it should, even if these constant effects are due to normal weather conditions. The remaining weather measures capture the effect of weather departing from its normal pattern.

The model can also specify a richer texture in the temporal effect of weather than the usual fixed contemporaneous effect. Seasonally-varying weather effects can be created by interacting the weather measures with the harmonic terms. In addition, the measures can be constructed to detect lagged effects of weather, such as the effect of rainfall one month ago on this month's water demand.

Effect of Landscape Interventions: Information will be compiled on the timing and location of each Smart Timer controller installation. The account numbers from these data will be matched to meter consumption histories going back to the beginning of available consumption history. All raw meter reads were converted to average daily consumption by dividing by the number of days in the read cycle. Using these data, "intervention analysis" models were statistically estimated where, in this case, the intervention is participation in the Smart Timer Rebate Program. The form of the intervention variables will be:

Equation 5

$$I_{i,t} \equiv I_{ST} \cdot \beta_{ST} + I_{ST} \cdot \sin 1 \cdot \beta_{ST\_\sin 1} + I_{ST} \cdot \cos 1 \cdot \beta_{ST\_\cos 1}$$

The indicator variable I_{ST} takes on the value one to indicate the presence of a working smart timer controller and is zero otherwise. The parameter $\hat{\beta}_{ST}$ represents the mean effect of installing a smart controller only and is expected to be negative (installing a smart timer controller reduces water use.) This formulation also permits formal testing of the hypothesis that landscape interventions can affect the seasonal shape of water consumption within the year. Since numerous studies have identified a tendency of customers to irrigate more than ET requirements in the fall and somewhat less in the spring, it will be informative to examine the effect of Smart Timer controllers designed to irrigate in accord with ET requirements. The formal test is enacted by interacting the participation indicators with the sine and cosine harmonics. The model will also include parameters to formally test for preexisting differences between Smart Timer participating customers and nonparticipating (control) customers.

Stochastic Effects

To complete the model, we must account for the fact that not every data point will lie on the plane defined by **Equation** 6. This fundamental characteristic of all systematic models can impose large inferential costs if ignored. Misspecification of this "error component" can lead to inefficient estimation of the coefficients defining the systematic forces, incorrect estimates of coefficient standard errors, and an invalid basis for inference about forecast uncertainty. The specification of the error component involves defining what departures from pure randomness are allowed. What is the functional form of model error? Just as the model of systematic forces can be thought of as an estimate of a function for the "mean" or expected value, so too can a model be developed to explain departures from the mean—i.e., a "variance function" If the vertical distance from any observation to the plane defined by **Equation 6** is the quantity **ε**, then the error component is added to **Equation 6**:

Equation 6

$$Use = \mathbf{f}\left(\mathbf{S}_t, \mathbf{C}_t, E_t\right) + \varepsilon$$

The error structure is assumed to be of the form:

Equation 7

$$\begin{aligned} &\varepsilon_{it} = \mu_i + \xi_{it} \\ &where \\ &\mu_i \sim N(0, \sigma_\mu^2) \\ &\xi_{it} \sim N(0, \sigma_\xi^2) \end{aligned}$$

The X and ξ are assumed to be independent of each other and of μ. The individual component μ represents the effects of unmeasured household characteristics on household water use. An example of such an unmeasured characteristic might be the water use behavior of household members. This effect is assumed to persist over the estimation period. The second component ξ represents random error. Because μ and ξ are independent, the error variance can be decomposed into two components:

Equation 8

$$\sigma_\varepsilon^2 = T \cdot \sigma_\mu^2 + \sigma_\xi^2$$

This model specification is accordingly called an error components or variance components model. The model will be estimated using maximum likelihood methods.

Model Estimation: Water Demand Models for Smart Timer Rebate Program Customers

Table A.1 presents the estimation results for the model of single family water demand in North Orange County. This sample represents water consumption among 477 single family households between January 2006 and January 2011. This sample contains 70 Smart Timer participants and 407 single family control customers from 4 MWDOC member agencies--Huntington Beach, Irvine Ranch Water District, Newport Beach, and Yorba Linda.

The constant term (1) describes the mean intercept for this equation. (A separate intercept is estimated for each of the 477 customers but these are not displayed in Table A.1 for reasons of brevity.) The independent variables 2 to 9—made up of the sines and cosines of the Fourier series described in Equation 2—are used to depict the seasonal shape of water demand. The predicted seasonal effect (that is, $Z \cdot \widehat{\beta}_S$) is the shape of demand in a normal weather year. This seasonal shape is important in that it represents the point of departure for the estimated weather effects (expressed as departure from normal). We will also test to see if the landscape interventions have any effect on this seasonal shape. The estimated weather effect is specified in "departure-from-normal" form. Variable 10 is the departure of monthly rainfall from its seasonal average. . (Average seasonal rainfall is derived from a regression of the rolling average of daily rainfall on the seasonal harmonics.) The one month lagged rainfall deviation is also included in the model (Variables 11). Variable 14 is the departure of monthly evapotranspiration from the average evapotranspiration for that month in the season. The reader should also note that the contemporaneous weather effect is interacted with the harmonics to capture any seasonal shape to both the rainfall (Variables 12 and 13) and the evapotranspiration (Variables 15 and 16) elasticities. Thus, departures of evapotranspiration from normal produce the largest percentage effect in the spring growing season. Similarly, an inch of rainfall produces a larger effect upon demand in the summer than in the winter.

The effect of the Smart Timer program interventions is captured in the following rows. The parameter on the indicator for the average effect of the Smart Timer intervention (Variable 17) suggests that the mean net change in water consumption is 49.3 gallons per day (an approximate 9.4% reduction from the weather normalized mean pre-intervention consumption of 525 gpd). The 95 percent confidence interval is between 34.3 gpd and 64.4 gpd. The estimated mean net water savings of 49.3 gpd is more than 6 standard errors from zero implying that the null hypotheses (β_{ST} ==0) can be rejected at very high levels of statistical confidence. Since the sample includes an average of only two years of post-intervention data, the model is limited in determining how persistent either effect will be in future years.

Note that formal test for preexisting differences in average water use (Variables 20-22) suggests that nonparticipating (control) customers were characterized water use that was lower than participating customers by 125.9 gallons per day. That single family customers participating in the Smart Timer Rebate program had higher levels of water consumption than nonparticipants is consistent with the hypothesis that this Water Use Efficiency Program attracts customers who have the most to gain from improving their landscape water use efficiency.

Table A.2 presents the estimation results for the water demand model of commercial water demand in North Orange County. This sample represents water consumption among 477 single family households between January 2006 and January 2011. This sample contains 132 Smart Timer participants and 1,195 commercial control customers from 4 MWDOC member agencies who agreed to provide consumption data for this study.

The effect of the Smart Timer program interventions for commercial customers is captured in the parameters on Variables 17-19. The parameter on the indicator for the average net effect of the Smart Timer intervention (Variable 17) suggests that the mean net change in water consumption is 726.4 gallons per day (an approximate 27.5% reduction from the weather-normalized mean pre-intervention commercial participant consumption of 2,644 gpd). The 95 percent confidence interval for the estimated mean net change in customer water demand is between 646 gpd and 806 gpd. Interpretation of the parameters on the interaction of the intervention variable with the annual harmonic terms is best accomplished graphically and is addressed next.

Table A.1 Smart Timer Rebate Program Single Family Water Demand Model

Smart Timer Rebate Program Single Family Water Demand Model Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)		
Independent Variable	**Coefficient**	**Std. Error**
1. Constant (Mean intercept)	525.3206	28.5665
2. First Sine harmonic, 12 month (annual) frequency	-138.1829	7.1788
3. First Cosine harmonic, 12 month (annual) frequency	87.7313	7.3679
4. Second Sine harmonic, 6 month (semi-annual) frequency	1.9575	2.0660
5. Second Cosine harmonic, 6 month (semi-annual) frequency	1.3086	2.1117
6. Third Sine harmonic, 4 month frequency	-10.7106	2.1252
7. Third Cosine harmonic, 4 month frequency	-9.4577	2.1388
8. Fourth Sine harmonic, 3 month (quarterly) frequency	1.6886	2.2940
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	2.9976	2.2603
10. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-63.7921	6.0856
11. Monthly lag from rain deviation	-24.3579	3.6808
12. Interaction of contemporaneous rain with annual sine harmonic	31.0931	8.8112
13. Interaction of contemporaneous rain with annual cosine harmonic	-9.5947	5.7038
14. Deviation from logarithm of 31 or 61 day moving average of CIMIS Spatial Evapotranspiration	86.8968	15.7788
15. Interaction of contemporaneous CIMIS Spatial Evapotranspiration with annual sine harmonic	-79.2886	18.3610
16. Interaction of contemporaneous CIMIS Spatial Evapotranspiration with annual cosine harmonic	-95.1426	21.6483
17. Mean Effect of Smart Timer Participation (70 participants)	-49.3290	7.6777
18. Interaction of Smart Timer Participation with annual sine harmonic	-50.8439	10.2879
19. Interaction of Smart Timer Participation with annual cosine harmonic	-40.6021	10.3204
20. Mean difference of Control Customers (407 accounts)	-125.9277	30.8528
21. Interaction of Control Indicator with annual sine harmonic	32.0116	7.3291
22. Interaction of Control Indicator with annual cosine harmonic	-36.8788	7.4761
Number of observations	26,501	
Number of customer accounts	477	
Standard Error of Individual Constant Terms (sigma_u)		234.19496
Standard Error of White Noise Error (sigma_e)		211.15886
Time period of Consumption	Jan. 2006 - Jan. 2011	

Table A.2 Smart Timer Rebate Program Commercial Water Demand Model

Smart Timer Rebate Program Commercial Customer Water Demand Model Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)		
Independent Variable	**Coefficient**	**Std. Error**
1. Constant (Mean intercept)	2644.0730	114.8133
2. First Sine harmonic, 12 month (annual) frequency	-2064.7110	33.3509
3. First Cosine harmonic, 12 month (annual) frequency	1092.9870	33.7258
4. Second Sine harmonic, 6 month (semi-annual) frequency	-3.1304	12.2705
5. Second Cosine harmonic, 6 month (semi-annual) frequency	86.0391	13.2441
6. Third Sine harmonic, 4 month frequency	-39.0215	13.5092
7. Third Cosine harmonic, 4 month frequency	-98.9472	13.4270
8. Fourth Sine harmonic, 3 month (quarterly) frequency	90.7335	15.3737
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	-29.7522	15.3360
10. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-637.5796	28.7202
11. Monthly lag from rain deviation	-221.1316	19.9555
12. Interaction of contemporaneous rain with annual sine harmonic	374.7001	45.8680
13. Interaction of contemporaneous rain with annual cosine harmonic	33.6347	28.9718
14. Deviation from logarithm of 31 or 61 day moving average of CIMIS Spatial Evapotranspiration	898.5476	95.4395
15. Interaction of contemporaneous CIMIS Spatial Evapotranspiration with annual sine harmonic	399.2432	125.8670
16. Interaction of contemporaneous CIMIS Spatial Evapotranspiration with annual cosine harmonic	-1372.1330	113.8726
17. Mean Effect of Smart Timer Participation (132 participants)	-726.3832	40.8533
18. Interaction of Smart Timer Participation with annual sine harmonic	111.6965	48.4584
19. Interaction of Smart Timer Participation with annual cosine harmonic	-363.3458	48.6130
20. Mean difference of Control Customers (1,195 accounts)	-805.4381	113.1464
21. Interaction of Control Indicator with annual sine harmonic	711.3873	33.9785
22. Interaction of Control Indicator with annual cosine harmonic	-484.9286	34.6886
Number of observations	54,023	
Number of customer accounts	1,327	
Standard Error of Individual Constant Terms (sigma_u)		1881.171
Standard Error of White Noise Error (sigma_e)		1680.446
Time period of Consumption	Jan. 2006 - Jan. 2011	

How the Smart Timer Rebate Program Affected the Seasonal Patterns of Water Demand

The question of how these programs affected the seasonal shape of water demand can be interpreted from the remaining interactive effects—the indicators interacted with the first sine and cosine harmonics. For example, the seasonal shape of single family water demand can be derived before and after Smart Timer Rebate Program participation:

$$\text{Pre\_Intervention}: \mathrm{S}_{\mathrm{t,SF}} = Z \cdot \hat{\beta}_S \approx -138.18 \cdot \sin_1 + 87.73 \cdot \cos_1 + 1.596 \cdot \sin_2 + 1.31 \cdot \cos_2 + ... + 2.998 \cdot \cos_4$$

$$\text{Post\_STIntervention}: \mathrm{S}_{\mathrm{t}}^{'} \approx Z \cdot \hat{\beta}_S - 50.84 \cdot I_{ST} \cdot \sin_1 - 40.60 \cdot I_{ST} \cdot \cos_1$$

When the pre/post seasonal patterns are combined with their pre/post mean water consumption, the following before and after picture can be seen throughout the year.

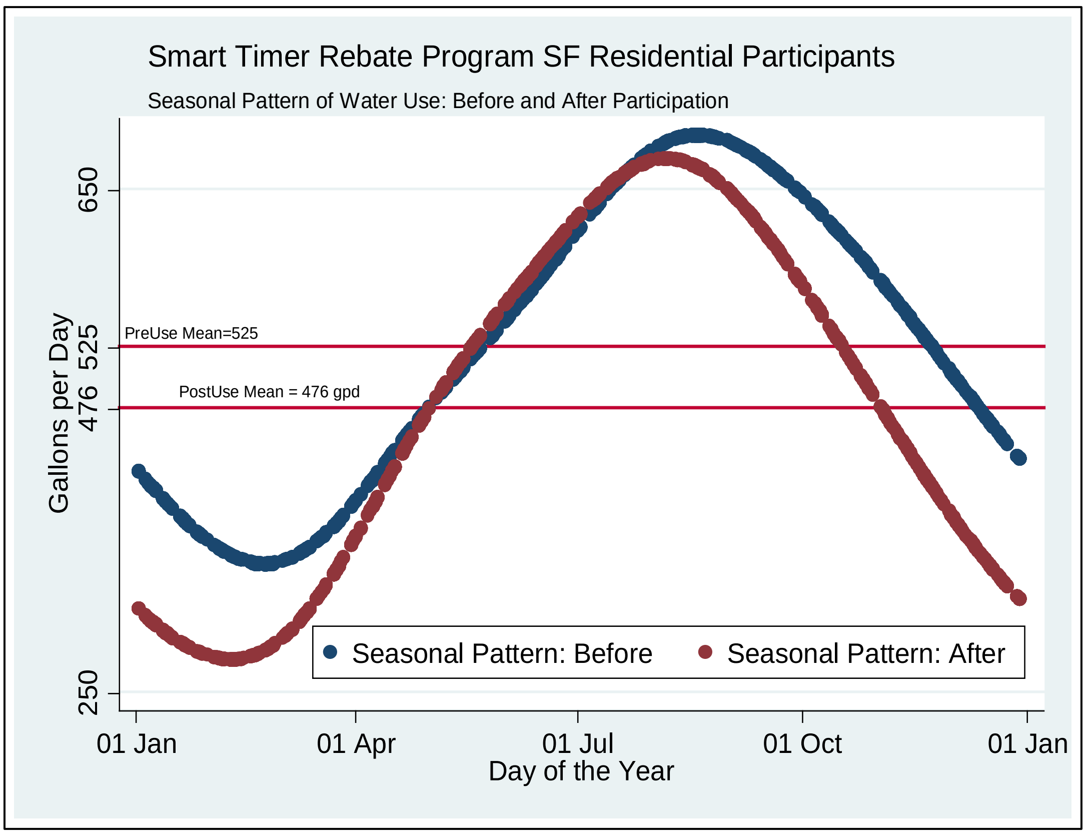

Figure A.1 Effect of Smart Timer Interventions on Water Demand

In Figure A.1, several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 49.3 gallons per day. Second, the assumption of a constant 49.3 gallon per day effect does not hold true throughout the year. Smart Timers and any irrigation system improvements apply water in the spring where ET_o is high—the shape of seasonal demand is very similar in the spring growing season and while the greatest reduction occurs in the fall. A peak reduction is also evident.

Figure A.2 provides a similar depiction for Commercial Customers and shows an even more pronounced affect of Smart Timer interventions on the shape of Commercial customer's water demand.

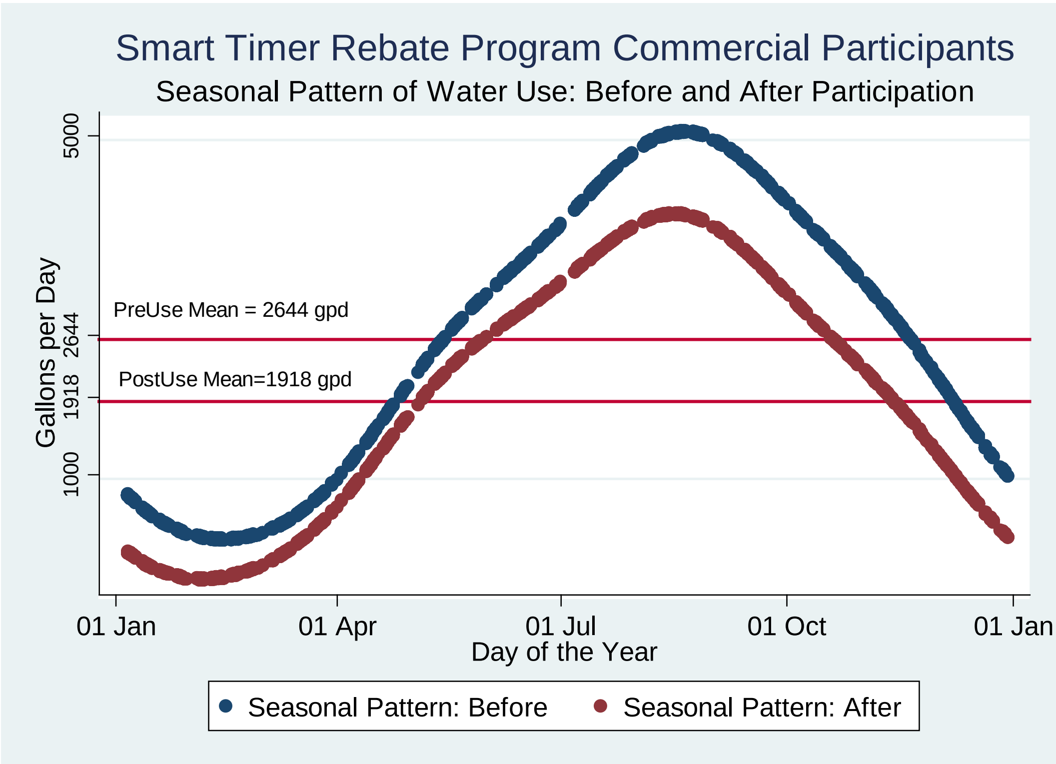

Figure A.2 Effect of Smart Timer Interventions on Water Demand - Commercial

Outlier Analysis

Robust regression techniques were used to identify participants whose water consumption histories did fit well with the models of water demand presented above. These Smart Timer participants—8 residential participants and 5 commercial participants—were excluded from the above analysis.

Table A.3 presents descriptive statistics on the pre-intervention mean water use and the delta change to post-intervention water use. These excluded participants appear to be much larger than average customers. Though the raw change in consumption cannot be directly compared to the average savings results (in that it does not control for weather or compare to a control group) but does appear to be in a negative direction.

Table A.3 Smart Timer Rebate Program Customer Water Demand Model Outlier Analysis

	Smart Timer Rebate Program Customer Water Demand Model Outlier Analysis Excluded Participants			
	ANTS ID Number	**Pre-Intervention Mean Water Use** (gpd)	**Raw Change in Mean Use Post-Intervention** (gpd)	**Raw Use Change Post-Intervention** (Percentage Change)
Residential	10403	1,617	(319)	-20%
	10368	1,492	394	26%
	10203	2,320	(353)	-15%
	10200	1,559	(58)	-4%
	10198	1,311	11	1%
	10417	2,338	(461)	-20%
	10327	1,758	(428)	-24%
	10569	2,784	(951)	-34%
			Residential Mean % Change	-14%
Commercial	10455	19,011	(5,997)	-32%
	10495	19,050	(2,430)	-13%
	10591	8,406	(1,788)	-21%
	10594	11,207	(593)	-5%
	10632	10,394	(2,857)	-27%
	10706	14,498	(4,733)	-33%
	10710	11,362	(2,393)	-21%
	10713	13,114	(3,388)	-26%
	10719	12,448	(4,433)	-36%
			Commercial Mean % Change	-24%