Chapter 3: Water Conservation

3.1 Overview

This chapter describes the statistical analysis of water savings (water conservation) among customers who installed ET controllers and customers given irrigation education in the study area. Specific information includes:

- A summary of study methods and evaluation approach.
- Evaluation results for large landscape customers and for single-family residences.
- Effect of ET controllers on seasonal peak demand.

More detailed information is provided in Appendix C.

3.2 Evaluation Approach

This section summarizes the overall evaluation approach, the records, review process, and data assessment techniques.

3.2.1 Overall Evaluation Approach

Historical water consumption records for a sample of participants and for a sample of nonparticipating customers were examined statistically. The hypothesis was that installation of new irrigation technology or better management of existing equipment would reduce the observed water consumption of customers participating in this program. This study empirically estimates the water savings that resulted from two types of "interventions"—1) customers receiving both ET controllers and follow-up education and 2) customers receiving an education-only intervention. Both single-family residences and medium-size landscapes were evaluated. (See Tables 3-1 and 3-2.)

Table 3-1
Summary of Water Conservation Evaluation Approach for Single-family Residences

Site	Number of Usable Accounts	
Site 1001 Retrofit Group	Retrofit Non Participants	97***** 213
Site 1004 Control Group		264
Site 1005 Education Group	Education Non Participants .	192***** 346

*****Note: These sample numbers are smaller than the total number of original participants in each group due to changes in tenants, anomalous data, and other data quality issues.

Table 3-2
Summary of Water Conservation Approach for Medium-size Landscapes

Type	**Number of Usable Accounts**	**Average Acres Per Account**
Participating Landscapes	15*	0.93
Matched Controls	76	0.92
Unmatched Controls	895	0.96

Note: This sample number is smaller than the total number of original study participants due anomalous data, and other data quality issues.

Since installation of ET controllers required the voluntary agreement of the customer to participate, this sample of customers can be termed "self-selected." Customers in the education–only group were initially approached by mail about their interest in participating in the study. 137 customers initially expressing interest were included in the study group. However, because sufficient interest in the study was not generated through this mailing to meet the study saturation goals for this group, the remaining 112 participants self selected. While this analysis does quantitatively estimate the reduction of participant's water consumption, one may not directly extrapolate this finding to nonparticipants. This is because self-selected participants can differ from customers who decided not to participate.

The explanatory variables in these models include:

- Deterministic functions of calendar time, including
    - the seasonal shape of demand
- Weather conditions
    - measures of air temperature
    - measures of precipitation, contemporaneous and lagged
- Customer-specific mean water consumption
- "Intervention" measures of the date of participation and the type of intervention

3.2.2 Records Review Process

Consumption records were compiled from IRWD's customer billing system for customers in the study areas. Billing histories were obtained from meter reads between July 1997 and August 2002. It is important to note that a meter read on August 1 will largely represent water consumption in July. Since the ET controllers were installed in May and June of 2001, the derived sample contained slightly more than one year of data for each participant. More information is presented in Appendix C.

The landscape-only customers (15 accounts) were handled separately. Two control groups were developed for these irrigation accounts: A matched control group was selected by IRWD staff by visual inspection, finding three-to-five similar control sites for each participating site. Similarity was judged by irrigated area and type of use (HOA, median, park, or streetscape). Since the City of Irvine was improving irrigation efficiency on the City-owned sites during the post-intervention period, this matched control group also had potential water savings. A second control group was developed where the selection was done solely based on geographic area. In this way, the statistical models could separately estimate the water savings effects for each group. (See Appendix C.)

3.2.3 Data Assessment Techniques

The first major issue with using meter-read consumption data is the level and magnitude of noise in the data. The second major issue is that records of metered water consumption can also embed non-ignorable meter mis-measurement. To keep either type of data inconsistencies from corrupting statistical estimates of model parameters, the modeling effort employed a sophisticated range of outlier-detection methods and models. These are described in Appendix C.

Daily weather measurements—daily precipitation, maximum air temperature, and evapotranspiration—were collected from the California Irrigation Management Information System (CIMIS) weather station located in Irvine. Daily weather histories were collected as far back as were available (January 1, 1948) to provide the best possible estimates for “normal” weather through the year. Thus, 54 observations were available upon which to judge “normal” rainfall and temperature for January 1^{rst} of any given year.

Robust regression techniques were used to detect which observations were 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.

3.3 Evaluation Results

This section presents evaluation results for single-family residences and landscape-only customers. The effect of ET controllers on peak demand is also discussed.

3.3.1 Estimated Single-family Residential Water Demand

Table 3-3 presents the estimation results for the model of single-family water demand in the R3 study sites. Twenty-one variables are listed. This sample represents water consumption among 1,525 single-family households between June 1997 and July 2002. This sample contains 97 ET controller/education participants (in Site 1001) and 192 education-only participants (in Site 1005). This sample is smaller than the total number of participants in each group due to changes in tenants and anomalous data.

The constant term (1) describes the mean intercept for this equation. (A separate intercept is estimated for each of the 1,525 households, but these are not displayed in Table 3-3 for reasons of brevity.) The independent variables 2 to 8—made up of the sines and cosines of the Fourier series described in Appendix C (Equation 2)—are used to depict the seasonal shape of water demand.

Table 3-3
Single-family Residential Water Demand Model

Dependent Variable: Average Daily Metered Water Consumption in gallons per day (gpd)		
Independent Variable	**Coefficient**	**Std. Error**
1. Constant (Mean intercept)	405.6593	3.1660
2. First Sine harmonic, 12 month (annual) frequency	-45.4215	0.9636
3. First Cosine harmonic, 12 month (annual) frequency	-89.1494	0.9629
4. Second Sine harmonic, 6 month (semi-annual) frequency	3.6549	0.6798
5. Second Cosine harmonic, 6 month (semi-annual) frequency	1.0709	0.6733
6. Third Cosine harmonic, 4 month frequency	1.7312	0.7151
7. Fourth Sine harmonic, 3 month (quarterly) frequency	4.4016	0.7403
8. Fourth Cosine harmonic, 3 month (quarterly) frequency	3.3491	0.7865
9. Interaction of contemporaneous temperature with annual sine harmonic	48.7897	17.1559
10. Interaction of contemporaneous temperature with annual cosine harmonic	-72.4672	22.3626
11. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	284.7163	13.542
12. Interaction of contemporaneous rain with annual sine harmonic	10.1102	1.8546
13. Interaction of contemporaneous rain with annual cosine harmonic	5.9969	2.6904
14. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-34.0117	1.8931
15. Monthly lag from rain deviation	-13.3173	1.0549
16. Average Effect of ET controller/Education (97 participants)	**-41.2266**	**4.0772**
17. Interaction of ET intervention with annual sine harmonic	38.9989	5.3327
18. Interaction of ET intervention with annual cosine harmonic	-6.3723	4.8980
19. Average Effect of Education-only intervention (192 participants)	**-25.5878**	**2.8081**
20. Interaction of Ed.-only intervention with annual sine harmonic	6.0357	3.5870
21. Interaction of Ed.-only intervention with annual cosine harmonic	-3.0703	3.3826
Number of observations	94,655	
Number of customer accounts	1,525	
Standard Error of Individual Constant Terms		120.85
Standard Error of White Noise Error		129.81
Time period of Consumption	June 1997 - July 2002	

The predicted seasonal effect is the shape of demand in a normal weather year. This seasonal shape is important because it represents the point of departure for the estimated weather effects (expressed as departure from normal). The effect of the landscape interventions on this seasonal shape was also tested.

The estimated weather effect is specified in "departure-from-normal" form. Variable 11 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated in an analogous fashion (Variable 14). One month lagged rainfall deviation is also included in the model (Variable 15). It is also noted 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 temperature (Variables 9 and 10) elasticities. Thus, departures of temperature 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 landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers/education (Variable16) suggests that the mean change in water consumption is 41.2 gpd (reduction) while the education only participants (Variable 19) saved approximately 25.6 gpd. Because residential meters serve both outdoor and indoor demand, the model cannot say whether education-only participants saved this water through improved irrigation management or by also reducing indoor water consumption. Since the sample includes only one year of post-intervention data, the model cannot say how persistent either effect will be in future years.

3.3.2 Estimated Landscape Customer Water Demand

Table 3-4 presents the estimation results for the model of medium-size landscape (irrigation-only) customer water demand in the R3 study sites. Seventeen variables are listed. This sample represents water consumption among 992 accounts between June 1997 and August 2002 and contains 21 ET controller accounts, 76 matched control accounts, and 895 unmatched control accounts.

The constant term (1) describes the intercept for this equation. The independent variables 2 to 9—made up of the sines and cosines of the Fourier series described in Appendix C (Equation 2)—are used to depict the seasonal shape of water demand. The estimated weather effect is specified in "departure-from-normal" form. Variable 10 is the departure of monthly temperature from the average temperature for that month in the season. (Average seasonal temperature is derived from a regression of daily temperature on the seasonal harmonics.) Rainfall is treated similarly (Variable 11). One month lagged rainfall deviation is also included in the model (Variable 12). The next variable accounts for the amount of irrigated acreage on the site. (Note that while measured acreage is available for all irrigation-only accounts, this is not true for single-family accounts.)

The effect of the landscape conservation program interventions is captured in the following rows. The parameter on the indicator for ET controllers (Variable 14) suggests that the mean change in water consumption is 545 gpd (reduction), approximately 21 percent of the pre-intervention water use. The matched control group (Variable 16) did experience water savings, approximately 241 gpd or 8.7 percent of their pre-intervention water use. As noted previously, this group included City of Irvine landscape accounts for which a parallel water efficiency program was conducted. The variables testing for differences in pre-intervention use cannot distinguish any differences between the different types of accounts.

Table 3-4
Landscape Customer Water Demand Model

Dependent Variable: Average Daily Metered Water Consumption (in gallons per day)

Independent Variable	**Coefficient**	**Std. Error**
1 Constant (Mean intercept)	2624.0890	235.5602
2. First Sine harmonic, 12 month (annual) frequency	-810.6712	26.4690
3. First Cosine harmonic, 12 month (annual) frequency	-1979.1650	26.1149
4. Second Sine harmonic, 6 month (semi-annual) frequency	103.7890	26.7195
5. Second Cosine harmonic, 6 month (semi-annual) frequency	-18.6126	27.1067
6. Third Sine harmonic, 4 month frequency	-123.5511	28.2926
7. Third Cosine harmonic, 4 month frequency	106.4412	28.6328
8. Fourth Sine harmonic, 3 month (quarterly) frequency	38.3819	30.6999
9. Fourth Cosine harmonic, 3 month (quarterly) frequency	-61.4848	30.9128
10. Deviation from logarithm of 31 or 61 day moving average of maximum daily air temperature	6293.6890	565.6084
11. Deviation from logarithm of 31 or 61 day moving sum of rainfall	-748.2235	52.1792
12. Monthly lag from rain deviation	-209.9027	46.5477
13. Irrigated Acreage (in acres)	485.1284	140.1746
14. ET controller sites, test for difference in pre-intervention use	-327.6321	1511.6870
15. Average Effect of ET controller (21 accounts)	-545.3841	330.3669
16. Matched accounts, test for difference in pre-intervention use	-166.6455	693.9447
17. Average Effect of city efficiency improvements (76 accounts)	-240.4067	148.4015
Number of observations		56666
Number of customer accounts		977
Standard Error of Individual Constant Terms		5766.8
Standard Error of White Noise Error		4189.5
Time period of Consumption	June 1997 - July 2002	

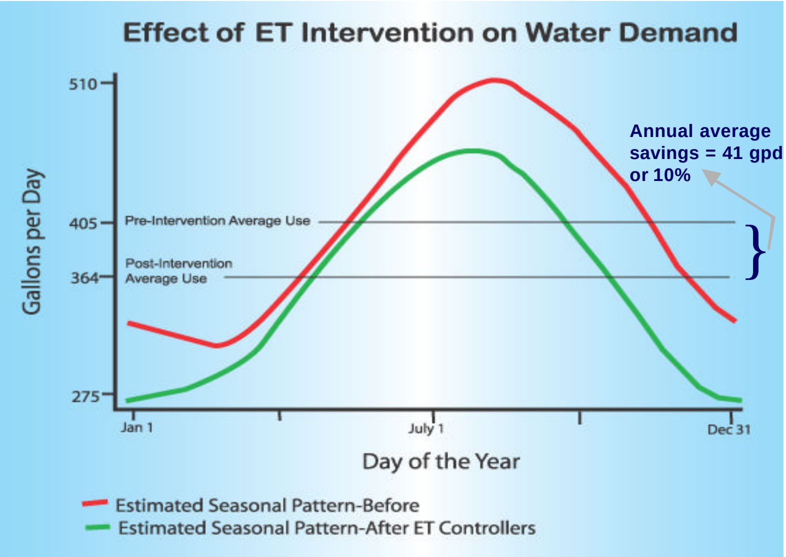
3.3.3 Effect of ET Controllers on Seasonal Peak Demand (Single-family Residential)

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.

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.

On Figure 3-1, several observations should be made. First, the difference between the two horizontal lines corresponds to the estimated mean reduction of approximately 41 gpd. Second, the assumption of a constant 41 gpd effect does not hold true throughout the year. The reduction is barely noticeable in the spring growing season and is much larger in the fall.

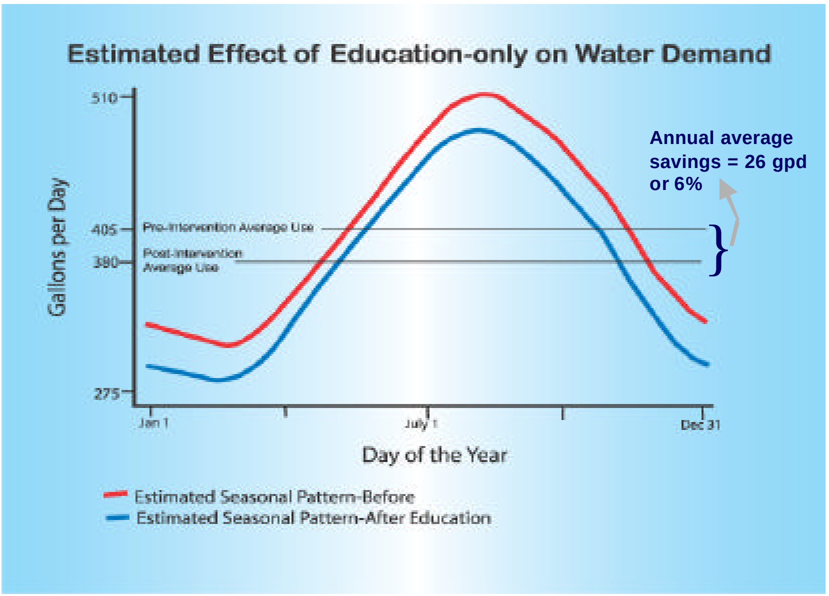
Figure 3-1
Effect of ET Intervention on Seasonal Water Demand for Single-family Residential



The reduction in peak demand—though dependent upon how the seasonal peak is defined—is greater than the average reduction. The estimated peak day demand, occurring on August 8, is reduced by approximately 51 gallons. This "load-shaping" effect of the ET controller intervention can translate into an additional benefit to water agencies. The benefits from peak reduction derive from the avoided costs of those water system costs driven by peak load and not average load—the costs for new treatment, conveyance, and distribution all contain cost components driven by peak capacity requirements

Figure 3-2 plots the corresponding estimates for the education-only intervention. The reduction in average demand is less—approximately 25 gpd. The effect upon the estimated seasonal shape of demand is much more muted. In fact, the change to the estimated seasonal shape of demand induced by the education-only intervention is not significantly different from zero at classical levels of significance.

Figure 3-2
Estimated Effect of Education-only on Seasonal Water Demand for Single-family Residential



3.4 Conclusions

This modeling effort focused on developing the best depiction of net changes in water consumption due to the landscape interventions of ET controllers and / or education. Much of the modeling effort was expended on data cleaning, diagnosis, and validation. The most serious data issues were identified and appropriately handled. To the extent that future data quality can be improved, future work could provide several statistical refinements in model specification. These are described in Appendix C.

The documentation provided in this report describes the shape of water savings achieved by the landscape interventions of ET controllers and / or education. Households participating in these programs saved significant amounts of water. Savings for the education-only program were less than for the retrofit group, but were still significant. The ET controller / education program changed both the level and shape of water demand.