WATER CONSERVATION RESEARCH STUDY

EFFECTIVENESS OF RETROFIT IN SINGLE FAMILY RESIDENCES AND MULTI-FAMILY PROJECTS

Report Prepared by

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Study funded by

Texas Water Development Board
Harris County M.U.D. #55
Harris-Galveston Coastal Subsidence District

Executive Summary

This report presents the results of an evaluative research study of the effects of retrofit plumbing devices. The study itself, which was sponsored by the State of Texas Water Development Board, Harris County Municipal Utility District 55 and the Harris-Galveston Coastal Subsidence District, was conducted during the fall of 1991 through the early-spring of 1992. Its principal purposes included assessing the cost-effectiveness of retrofit plumbing devices with respect to water and energy savings; determining user satisfaction with the devices; and providing information useful to water utilities throughout the State of Texas.

Initially, staff members of the Harris-Galveston Coastal Subsidence District rated a number of water-conserving, retrofit plumbing devices for quality of manufacture. Their ratings were based solely upon personal perceptions. They did not conduct any tests and, specifically, they did not consider either water or energy savings. From such ratings, three devices, considered to be of "good quality" manufacture, were selected for systematic study. The three devices consisted of a water- conserving kitchen aerator, a bathroom aerator, and a low-flow showerhead.

Water and energy savings resulting from installing these devices in single family dwellings and in multifamily apartments were then studied. The single family residence portion of the study utilized an experimental design with random assignment of subjects. Enough subjects (192 controls and 288 experimentals) were included in the study to achieve more than adequate statistical power. Telephone surveys were conducted to verify device installation, to determine satisfaction with the devices, and to gather important baseline information (e.g., household size) both on experimental and control subjects. The apartment portion of the study involved equivalent groups. Retrofit devices were installed in all apartments (n=776) located in one large complex. A second set of apartments (n=320), equivalent to the first in date of construction, design and floor plan, rental market, and geographic location, was selected as the control or comparison group. The impact of the devices was assessed by comparing changes in water and in energy use, measured by actual billing data, before and after device installation. Finally, flow tests were conducted and observations recorded on 100 randomly selected showerheads that were replaced with retrofit, water-conserving ones during the study.

Results from the single family residence portion of the study indicate that installation of the three retrofit devices resulted in an average monthly water savings of over 1,400 gallons or about 18% of the average consumption for such a residence. These results were derived from comparing the pre-installation months of October and November with the post-installation months of February and March. Given the number of household residents in the study, these water savings amounted to approximately 14.13 gallons per person per day.

Installation of the devices in single family residences also was found to yield energy savings. Average electrical energy savings of about 18.6 kilowatt hours per month were found, a result that is likely attributable to a reduction in hot water heating.

Telephone surveys of single family residents in the study revealed that sizeable majorities were "very satisfied" with all three water-conserving devices. Among the devices, the kitchen aerator received the highest reported level of satisfaction. Further, a majority of the study's participants believed that they had saved money as a result of device installation. And the experimental subjects -- those who installed the devices -- were more likely to perceive that their water use had decreased than were their control counterparts (who did not install the devices). Of course, these perceptions were confirmed by actual water use data. Interestingly, the experimental subjects who installed the devices were also much more likely than other subjects to report increased concern about saving water.

Telephone survey results were also revealing about the installation and removal of the devices. Specifically, when a device was not installed, the main reason cited was that the device did not fit existing plumbing fixtures and required an adapter to install it. More subjects reported having problems installing the water-conserving showerhead than the other two devices. Finally, very few subjects reported removing devices after installing them; the principal reported reason provided for removal was "not enough water pressure."

In multifamily apartment residences, device installation was found associated with a water savings of approximately 27%. This larger savings in apartments relative to those for single family residences seems to be an artifact of the study's methods. Each single family participant in the study received only one bathroom aerator and only one showerhead regardless of the number of household bathrooms. In contrast, all bathrooms in the apartments were retrofit with water-conserving devices.

Device installation was also found related to natural gas savings in multifamily apartment residences. For the period studied, the retrofit devices appear to have resulted in a 12% to 14% savings in gas consumption. Since the period studied was from cooler to warmer months -- the cooler months of February and March in the Houston area (pre-installation period) were compared to the warmer months of August and October (post-installation period) -- it is likely that these energy savings estimates are conservative.

Flow tests were conducted and observations recorded on showerheads that were replaced with retrofit, water-conserving ones during the study. The average flow rate of these showerheads was found to be higher than that of the low-flow, water-conserving ones that replaced them. These data further corroborate the findings that the water and energy savings observed in the study resulted from the installation of water-conserving retrofit devices.

Taken together, the findings of this study suggest three important conclusions. First, installation of water-conserving plumbing devices of the quality utilized in this study is quite cost-effective. Of course, "devices of the quality utilized in this study" is an important qualifier. So also is cost; the current costs of utilities and of the devices in the Houston area are the basis for this conclusion. Second, from a regional or community-wide viewpoint, i.e., aggregating the savings from a number of individual households and apartments, the widespread installation of "good quality" retrofit devices will result in major water and energy conservation. Finally, prospective users can expect to be highly satisfied with the performance of "good quality" retrofit, plumbing devices as well as to perceive readily the resulting savings.

Table 4.1
Water Savings Resulting from Installation of Retrofit Devices
(in gallons)

Average Monthly Household Water Consumption

	Pre-installation Period (Oct - Nov 1991)	Post-installation Period (Feb - March 1992)	Difference (Post-Pre)
Controls (n=191)	7,317	7,439	+122
Experimentals (n=111)	7,890	6,541	-1349
		Total Savings	1471 *

Average Daily Per Person Water Consumption

	Pre-installation Period (Oct - Nov 1991)	Post-installation Period (Feb - March 1992)	Difference (Post-Pre)
Controls (n=191)	71.19	73.58	+2.39
Experimentals (n=111)	75.31	63.57	-11.74
		Total Savings	1471 *

Notes: * "Total savings" are calculated as the post-pre difference in water consumption for controls minus that for experimentals.

Table 7.1
Water Use in Experimental and Control Apartments:
Pre- and Post- Device Installation

	Pre-installation		Post-installation	
	Aug 1991	Sept 1991	Aug 1992	Sept 1992
Experimentals (n=776)	4230.4*	3730.3	3165.7	3371.0
Controls (n=320)	1498.0	1225.9	1385.1	1583.4

Differences (Post-Pre):

Experimentals	-1424.0
Controls	+ 244.6

Percentage Change (Difference/Pre-installation Amount):

Experimentals	-18% (or Water Savings=18%)
Controls	+ 9% (or Water Savings=-9%)

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Chapter 1
Introduction

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Among the individuals who conceived and developed the evaluation study were Mr. Bill Hoffman of the Texas Water Development Board and Mr. David Jessel, President of Harris County Municipal Utility District 55. In addition to helping conceive and develop the project, much of the project's direction was provided by Mr. Ronald J. Neighbors, Ms. Carole Baker, and Mr. Robert Thompson of the Harris-Galveston Coastal Subsidence District.

Much of the work of the study, including the formulation of a sampling plan, the development of a research design, the construction of measuring instruments, and the analysis of data, was conducted by a study team headed by Dr. Roger Durand, Professor in the School of Business and Public Administration, a specialist in evaluation research. Other principals on the study team included Judith H. Durand, M.S., Adjunct Professor in the Department of Human Development and Consumer Sciences at the University of Houston, a specialist in consumer economics and behavior, and Dr. Richard C. Allison, Professor of Environmental Management at the University of Houston-Clear Lake, whose specialty is water policy and management.

Outline of Report

In the chapter immediately following, a review of recent professional publications concerning retrofit devices and water consumption is provided. In Chapter 3 the methods and design of the evaluative study are presented in detail. Chapters 4 and 5 discuss results from studying water and energy consumption, respectively, in single family residences. In Chapter 6 user satisfaction with the retrofit devices and user perceptions concerning the devices are discussed. Chapter 7 reports on the effects of installing retrofit devices in an apartment complex. The results of "flow testing" old-style showerheads that were replaced with newer, low-flow showerheads in the course of the study are discussed in Chapter 8. Finally, Chapter 9 summarizes the study's principal findings and conclusions.

Chapter 2
Literature Review

In order to develop the research design, measuring instruments, and data analysis for this evaluative study, the study team conducted a computer-based library search of published materials pertaining to the topics of "retrofit plumbing devices," "water conservation," and "residential water use." Copies of the materials were obtained, read, and a determination made of relevance to the present study. Additionally, from the published materials obtained initially, other materials -- including unpublished works -- were identified and located. This chapter provides a brief synopsis of selections from this literature.

Retrofit Devices

In the literature review, the study team found few systematic, controlled studies of the effects of home retrofit plumbing devices on either home water or energy savings. Indeed, in a recent review essay on "indoor water conservation," Jensen (1991)[1] reached the same conclusion:

> ...although huge savings are projected,
> more follow-up studies are needed to examine
> whether the use of efficient fixtures
> actually reduced water use. Evidence is lacking
> that the anticipated savings will actually be
> realized. (Emphasis added)

In elaborating this conclusion, Jensen cited the results of a Texas Water Development Board (TWDB) survey of some 300 cities and utilities. In response to the survey, nearly 60% of the water managers who were interviewed in the survey said that additional information on indoor home conservation was "important," according to Jensen. Further, approximately 71% of those surveyed indicated that new data on fixture standards were either "very important" or "important." Additionally, 28% of those interviewed said that literature on retrofitting existing residences was "important."

While pointing to a need for more studies, Jensen (1991) summarized the results of several investigations of retrofit devices. The City of Austin evaluated the effectiveness of low-flow showerheads and toilet dams. Results estimate that residential water use has decreased and wastewater flows have been cut. Recent examinations in Llano, Schulenberg, and Marble Falls also point to water savings either from low-flow toilets or from a combination of low-flow toilets and showerheads.

Finally, Jensen (1991) also cited TWDB estimates that the use of water-efficient fixtures should save a typical 4-member household 55,800 gallons of water and $627 in reduced water

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[1] Full citations to literature are provided at the end of this report.

and energy costs annually. According to this estimate, most of the reduced costs ($342) would come in the form of energy savings because less water would be heated.

An actual investigation of the "noncrisis use of household water-saving devices" was reported by Palmini and Shelton (1983). The study itself sought to measure the proportion of households that participated in a community-wide water conservation program by voluntarily installing water-saving toilets, showerheads, and faucet aerators. Additionally, the study sought to estimate the reduction in water consumption that resulted as well as the costs of the program.

Unfortunately, this study suffered from a number of limitations. First, the number of subjects included in the study was relatively small. This small number limited analysis. Second, the proportion of available subjects who actually installed the devices was also small, thus further limiting study analyses. And finally, delays in distribution of the packets rendered it impossible to measure any savings in indoor water consumption because of the confounding effects of outdoor water use.

Despite these limitations, the study found through multiple regression, statistical techniques that the number of people in the household, the total (gross) household income, and the extent of participation in the program influenced water consumption in the expected direction. These findings led the authors to conclude that home water conservation was both "effective and cost-effective" (Palmini and Shelton, 1983).

In 1991 and 1992 Market Decision Corporation (MDC) conducted a survey for Portland General Electric Company which was intended to examine usage of energy-efficient, water-saving showerheads and user satisfaction with the showerheads (MDC, 1992). As part of the study, low-flow showerheads were distributed by mail to previously unsolicited single-family residential customers in the Portland area who had electric water heaters. The study, which was conducted by means of telephone interviews, also sought to develop a profile of households which installed the devices with respect to such factors as household size, income, and owning as opposed to renting one's home.

Unfortunately, this study failed to examine the impact of the devices on actual water or energy savings. However, it did find that nearly two-thirds of those who received the showerhead installed it after receiving it in the mail and that an additional group of subjects indicated an intention to install it in the future. Among the principal reasons cited for not installing the showerhead were "too busy/no time," and "difficult/need adapter." (MDC, 1992).

Selected Studies of Water Conservation

In addition to studies of retrofit devices, the study team also located pertinent investigations of water conservation. In a 1987 investigation, Flack and Greenberg (1987) surveyed consumer attitudes toward conservation in seven northeastern Colorado communities. Among the conservation alternatives presented to the study's subjects were installation of water-saving devices, restrictions on water use, metering and price increases. Consumers in communities with lawn watering restrictions were found more willing to install water-saving devices than those in unrestricted communities. Both the education and the income of subjects also affected preferences for water-saving alternatives. Finally, the study found widespread acceptance of home water-savings devices.

Olsen and Highstreet (1987) reported on socioeconomic factors affecting water conservation in southern Texas. This study included a survey which asked subjects questions regarding their knowledge and attitudes about water conservation as well as about the types of conservation measures the subjects actually implemented. The study found that during a single year about 19% of those interviewed by means of a telephone survey reported having installed a toilet bag or dam while an additional 36% reported having installed either a shower flow restrictor or a faucet aerator. The age of persons in the household, and household income were found related to the use of these water-saving devices. Contrary to expectations, however, education and length of community residence were not found related to use.

Finally, Hamilton (1985) reported the results of analyzing survey and water utility data with respect to water savings during a conservation campaign. Self-reports of water savings were found only weakly related to actual changes in water consumption. The accuracy of self-reports was found to increase with household socio-economic status (including income and education) and with the extent of "conservation behavior" (i.e., taking active steps to conserve water).

A Study of Residential Water Use in Texas

In a study of particular importance to the present investigation, Murdock and others (1988) reported the results of an "analysis of the effects of sociodemographic factors on daily per capita residential water use in Texas cities." Such an analysis proved particularly important to the present investigation because it illuminated variables likely to confound or otherwise influence results with respect to home water savings devices.

The analysis by Murdock and others (1988) examined the effects of a number of sociodemographic variables on water use through both primary and secondary data. Such data included random sample telephone surveys of the residents of eight locations in Texas rather than of the entire state population. These eight locations included Alice, El Paso, Hearne, Longview, Mathis, Rocksprings, Sonora, and Waco.

Results from analyzing the survey data revealed that the number of persons in the household, years of formal education, income, and home ownership were related to per capita residential water use at statistically significant levels. In particular, the findings suggested that larger households used less water per capita, while households with respondents who have higher levels of education, higher incomes, and those who own their residences have higher levels of water use.

Several other variables, though not statistically significant, were found to have what the authors described as "interesting relationships to water use." Younger adults appeared to have larger per capita water use than older adults. Additionally, it appeared that those who had pro-consumptive attitudes toward water management and conservation tended to use more water than those with pro-conservation attitudes toward water use (Murdock and others, p. 68).

The study also investigated relationships between sociodemographic characteristics and the use of water-using items (e.g., automatic lawn sprinklers) and of certain water-using behaviors. Smaller household sizes, more years of education and higher incomes were generally found more likely to use such items and practice water-using behaviors (p. 69).

Finally, Murdock and his collaborators (1988) studied the ability of sociodemographic variables to project water use and water demand by means of multiple regression, statistical techniques. Through such techniques, the authors found that such sociodemographic variables were generally important to projecting use and water demand.

Chapter Summary

This chapter has summarized the results of studies, located by means of a computer-based library search, that bear on the topics of "retrofit devices," "water conservation," and "residential water use." In general there have been few previous systematic, controlled studies of the effects of retrofit devices on water and energy savings. Moreover, those few that have been conducted are limited in important ways.

However limited, previous studies and reputable estimates suggest that both water and energy savings should derive from installing residential retrofit devices.

Previous investigations of water conservation and of residential water use have pointed to a number of important variables that are likely to confound or otherwise influence either residential water use or the installation of retrofit devices. Such "likely variables" include household income, home owning versus renting, household size, age, education, length of residence, and pro-consumptive versus pro-conservation attitudes about water. Quite evidently, these variables are among those that need to be included in any controlled study of the effects of residential retrofit devices.

Finally, previous studies have made use of methods which can be utilized in this investigation of retrofit devices. In particular, such studies have employed multivariate statistical methods, including multiple regression, to study the combined and partial effects of variables on water use. And they have employed surveys, principally telephone surveys, in addition to billing data to identify relationships and estimate savings.

Chapter 3
Study Methods and Design

This chapter discusses the methods and research design utilized to conduct the study. Initially, the manner of selecting the retrofit devices tested in the study is discussed. Then the methods utilized to investigate the effects of retrofit devices in single family residences are described. The topics include the sample selection plan of the single family residence investigation, the power of statistical tests, the research design, measures of important variables, and the analytical methods utilized in drawing inferences. Next, the methodology of examining the effects of the devices in apartments is discussed. Finally, the manner of "flow-testing" presently installed showerheads that were replaced with low-flow, water-conserving ones in the course of the study is described.

Selection of the Retrofit Devices

From the study's inception, those who conceived it desired to test the effects of residential, retrofit plumbing devices that were of "good quality" or "better than good quality." Members of the staff of the Harris-Galveston Coastal Subsidence District were aware of a number of retrofit devices that were available for retail purchase. However, they felt that not all of these devices would be equally trouble-free, of substantial manufacturing quality, and durable.

Several members of the District's staff agreed to serve as initial pre-test subjects and to try out a number of devices in their homes. Each was asked to try several devices from the viewpoint of "consumers." Such "consumer pre-testing" proceeded among the staff members until a consensus was reached about a particular set of devices. It should be emphasized that the District's staff members who served as "consumers" were asked only to rate device quality. They were neither asked nor did they attempt to measure water or electrical savings in their homes.

The devices selected for the study consisted of a kitchen aerator, a bathroom aerator and a low-flow showerhead all of which were manufactured by Energy Technology Laboratories (ETL) of Modesto, California. Officials of ETL were told of the study and agreed to make available and ship a sufficient number of each device for study purposes.

In order to insure the study's objectivity, officials of ETL were generally not permitted to participate in the study in any way. They had no involvement of any kind in subject selection, in designing the research, in data collection, in data analysis, or in interpreting results. The single exception is that ETL did conduct flow tests and record data on existing showerheads (i.e., those replaced during the course of this study). However, officials of ETL were not permitted to interpret the flow test results. Finally, ETL was not a financial sponsor of the study.

Sample Selection Plan for Single Family Residences

In early October of 1991 each single family residence located in Harris County Municipal District #55 was sent a letter inviting participation in this retrofit study. The letter, a copy of which is included in Appendix A of this report, stressed the importance of water conservation and invited each household to receive free of charge a home water savings kit that included a "newly-designed showerhead" for home installation. Further, the letter, which was sent on District #55 letterhead and signed by the District's president, stressed that no sales promotion was involved, but that State and local public agencies were conducting a reputable study. Finally, the letter contained a postage-paid return card, a copy of which is also included in Appendix A, for those electing to participate.

In total, return postcards were received from about 1,000 residents. Each resident was asked to provide his/her name, address and phone number on the postcard so that the water conservation kit, which included the retrofit devices, could be sent. In addition, each resident was asked to indicate on the card whether the residence had an electric or gas water heater. From prior knowledge of the District it was known that the vast majority of single family residences in the area had electric water heaters. Accordingly, the information supplied about source of water heating was used to eliminate from the study those who had gas water heaters.

The decision to eliminate this latter group from the study was made for two reasons. First, it was felt that energy savings from retrofit installation would be more readily discerned if the study were restricted to those residences that heated water with electricity. This followed from the hypothesis that the costs of heating water are greater with electricity than with natural gas. Second, restricting the study to those homes heating water with electricity allowed control of one possible confounding influence, namely, the manner of heating water.

After eliminating those homes with gas water heaters, 600 subjects were available for the study. Of this number, 240 were randomly assigned as "control subjects" while the remaining 360 were randomly assigned as "experimental subjects." The greater number was assigned randomly to the experimental group in anticipation of appreciable noninstallation or delayed installation of the devices (see, for example, MDC, 1992, and Palmini and Shelton, 1983, discussed in Chapter 2).

One important feature of this sample selection method should be emphasized. A problem common to many research studies is that of "self-selection bias" (Campbell and Stanley, 1963). Self-selection bias refers to the confounding influence of factors prior to an experiment, factors that cause a subject to self-select him/herself for participation in a study. Such factors are often the true cause of an observed effect rather than the presumed independent variable. For example, interest in conserving water, an interest prior to installation of retrofit devices, that caused subjects to volunteer for a study might be the true cause of water savings rather than, say, a low-flow showerhead. By randomly assigning volunteer subjects as control and experimental subjects, such self-selection bias was eliminated as a possible confounding influence in this study.

Power of Statistical Tests for Single Family Residents

An important consideration in any study that involves samples of subjects is called the "power of a statistical test." The power of a statistical test refers to the likelihood of a test leading to rejection of a null statistical hypothesis given that the null hypothesis is false. That is, the power of a test tells one the likelihood of finding a statistically significant difference given that the true proportion is different from the proportion under the null hypothesis. Power is a function of several factors including the standard deviation of a study variable (e.g., water savings) in the population. Moreover, in general the larger the sample sizes, the greater the statistical power.

As just noted, 240 control and 360 experimental subjects were originally available for study purposes. However, it was anticipated that approximately one in three or 120 experimentals might not install the devices in a timely manner. This anticipation was based upon the results of studies by Palmini and Shelton (1983) and by MDC (1992) (see Chapter 2). With 240 control and experimental subjects available to the study, the study was planned so that a true difference in water usage between experimental and control residences as small as 12.5 gallons per day could be detected as significant 95% of the time. This planned statistical power was based upon an expected mean water usage of 250 gallons per day and an expected standard deviation of 40 gallons per day for the population. These expectations were based upon the study team's previous experience and research.

Following data collection, however, actual rather than anticipated numbers of experimentals who had installed devices were known. Further, the number of control and experimental subjects who had to be eliminated from the study because they could not be contacted, because they refused to be interviewed, and the like also was known. (Data collection and data completeness are discussed more fully below.) By the end of data collection, complete data were available on 192 control subjects and 288 experimental subjects.

In addition, by the end of data collection, actual, rather than expected, water usage could be estimated for the population from the samples of subjects. For the initial study period, this water use was estimated for the population to average 246 gallons per day with a standard deviation of approximately 101 gallons. This standard deviation, considerably greater than expected, surprised the study team. In retrospect, this greater-than-anticipated variability in water use probably reflects the range of moisture conditions along the Texas Gulf Coast during the study period as well as the range of residents' responses to such conditions. Both the conditions and the responses are probably considerably more variable than in other geographic locations.

A slightly lower mean (246 vs. 250) and a considerably greater standard deviation (101 vs. 40) resulted in a statistical power that was less than originally planned. Instead of 12.5 gallons as planned, the data actually allowed the detection of a true, statistically significant difference between experimentals and controls of 30 gallons per day 95% of the time.

Even though statistical tests were somewhat less powerful than originally planned, this had no bearing whatsoever on the study's findings or conclusions. This is because the study found an average daily difference in water use between experimentals and controls of approximately 46 gallons per day as a consequence of the retrofit devices (see Chapter 4). Such a substantial difference could be detected easily as significant -- and, in fact, was detected -- by the statistical tests. Nonetheless, future investigators should be made aware of the variability in usage (reported here) in planning water studies along the Texas Gulf Coast.

Research Design for Single Family Residences

In late November of 1991 a water and energy savings kit was sent to each of the randomly assigned experimental subjects. The kit included ETL's low-flow showerhead, water-conserving kitchen aerator, and bathroom aerator that also was designed to save water. (See above for a discussion of device selection.) The kit also included information about water and energy conservation as well as a 24 hour toll-free "help" line phone number to call for assistance in installation. Finally, the kit also included a postage-paid envelope along with a request that the resident's existing showerhead, the showerhead which was to be replaced by the new, low-flow variety, be mailed back so that flow tests could be conducted.

Control subjects were not sent a kit at that time. Rather, each was sent a letter indicating that the kit would be sent at a later time. Subsequent to the study, kits were sent as promised to these subjects.

In early January of 1992 an attempt was made to interview by telephone all experimental and control subjects. In the case of the experimentals, each subject was asked a series of questions designed to obtain "baseline" information (e.g., household income, length of residence) as well as to verify device installation. The control subjects were asked only the baseline information questions. (A copy of both surveys is contained in Appendix B.) In addition to the purpose of gaining such important information, the control subjects were interviewed along with the experimentals in order to more equally sensitize both groups to the study. Experimental arrangements, including interviewing, have long been known to increase a subject's responsiveness to study variables, a phenomenon sometimes referred to as the "Hawthorne Effect." Interviewing control as well as experimental subjects tended to more nearly equalize such an effect among the study groups.

Complete initial interviews were obtained from 197 control subjects and from 300 experimental subjects, overall response rates of 82% and of 83%, respectively. These response rates are considered "good" for telephone surveys of targeted respondents. The principal reason for not obtaining more complete interviews was an inability to contact subjects during the interviewing period. This was so despite repeated call back attempts. Many simply did not answer their phones, although a sizeable number (32) failed to supply phone numbers on the return postcard.

The initial interview with experimental subjects revealed that a considerable number (23) had not installed the water-conserving showerhead because they lacked a necessary plumbing adapter. As a consequence, an adapter was sent immediately to these subjects. While this adapter -- as well as the "reminder" or "prod" provided by the initial interview -- increased the number of showerhead installations, it also introduced an element of ambiguity into the study with respect to the timing of the experimental variable. That is, not all subjects had the showerhead (and possibly another of the devices) installed for the entire measurement period. In the analysis which followed, it was necessary to take this ambiguity into account. This was accomplished (see Chapters 4, 5, and 6) at the cost of "losing" some subjects for portions of the analysis.

In late March and early April of 1992, subjects were again contacted by telephone, this time for a follow-up interview. This follow-up survey was scheduled to follow immediately the second period of observation of water and energy use (see below). On this survey, a copy of which is contained in Appendix B, experimental and control subjects alike were asked a series of questions about water use during the study period, about energy-related behavior, and about any changes in income or household composition. Experimental subjects were also asked questions about how satisfied they were with each retrofit device, whether they had installed a device since the time of the first telephone interview, and, most importantly, whether they had permanently removed any one of the three devices.

By the end of the follow-up interviewing period, complete survey data -- both initial and follow-up data -- were available for 192 control subjects and for 288 experimental subjects. These numbers amounted to 80% of those initially enrolled in the respective groups, quite a good interviewing completion rate for a targeted, two-wave panel survey. While a few subjects were "lost" to the study for reasons of a change in residence, the major reason for incomplete data was again an inability to contact subjects by phone during the interviewing period.

In addition to the surveys, data on water use and on electricity consumption were obtained for each single family residence in the study for each of two time periods. Such data were obtained for controls as well as for experimentals from the billing records of Harris County Municipal Utility District #55 and from Houston Lighting and Power Company. The first time period for which data were obtained was that immediately prior to the sending out of the retrofit devices to experimental subjects, namely, October and November of 1991. The second time period was February and March of 1992, a period that began approximately two months after the devices were sent initially and approximately a month following the initial survey.

Measures of Important Variables: The Single Family Study

The principal dependent variables in the single family residence study were change in water consumption and change in electricity usage. Both variables were computed as the change between October-November of 1991 and February-March of 1992. The billing data on water consumption and on electricity usage were the exclusive source of the evidence used in computing such change.

The principal independent variable in the study was installation of the retrofit devices -- the showerhead, the kitchen aerator, and the bathroom aerator. As already noted, the installation and nonremoval of each device was verified by means of the initial and the follow-up telephone surveys.

Other variables, including control variables, that were studied were measured principally by means of survey questions (Appendix B). Such variables included important change variables (e.g., change in household size, change in income) that were measured by means of questions on the initial and follow-up surveys.

The validity of findings concerning the effects of the retrofit plumbing devices depends upon experimental and control subjects being alike in all ways that affect water use except one -

- installation of the devices. In general, the random assignment of subjects as in this study helps to produce equivalence between study groups. But more complete equivalence between experimentals and controls sometimes requires controlling statistically for the effects of certain variables.

In order to determine equivalence between study groups, experimental and control subjects were compared with respect to variables found or hypothesized in previous investigations to affect water use (see Chapter 2). Such variables included personal demographic characteristics (education, income, income change during the study) as well as residential ones (number of persons in the household by age category, length of residence, owning versus renting one's home). They also included attitudinal predispositions regarding water and energy savings.

The results of this comparison are shown in Table 3.1. As is evident from the table, experimentals and controls did not differ from each other at statistically significant levels (p=.05) with regard to education, income, number of household residents by age, length of residence, or owning versus renting. They also did not differ at statistically significant levels with respect to attitudes about water and energy savings. However, they were found to differ in reports of income change -- increases or decreases combined -- during the study period: controls were more likely than experimentals to report such change (p=.05). Accordingly, particular care was taken during data analysis to control statistically for this difference.

Analytical Methods: the Single Family Study

All billing and survey information gathered for the single-family study were data-entered in a computer-readable format and verified for accuracy. Once in a computer-readable format, a single survey-billing data file was created, organized by individual subject. Then, the information was analyzed using principally the Statistical Package for the Social Sciences ("SPSSX").

Standard statistical models appropriate to the level of variable measurement and to the number of variables in an analytical problem were utilized in the data analysis. Such statistical models included univariate ones (e.g., standard deviation), bivariate ones (e.g, analysis of variance), and multivariate ones (e.g., least-squares, multiple regression).

Thoughout the analysis, appropriate tests of statistical significance were conducted. Such tests included calculations of Chi-square, Student's t, and F ratios. The level of type I error utilized thoughout the study was that of .05 (p=.05).

The Methodology of the Apartment Study

In addition to single family residences, the study also investigated the impacts of retrofit devices on water and on energy savings in multifamily apartment complexes. In October of 1991 the managers of the two large apartment complexes located in Harris County Municipal Utility District #55 were approached about participating in this evaluation. For reasons unrelated to the study or to its schedule, agreement could not be obtained until the spring of 1992.

During the period from mid-May until mid-June, 1992, the three retrofit devices were installed in all of the apartments in one of the two complexes (designated the "experimental group of apartments"). The other complex was selected to serve as the "control" or "comparison" group of apartments. Although the "experimental" complex had considerably more apartment units (776 vs. 320 units), the two complexes were rather ideally matched. Both complexes were built in about the same year; the two complexes were designed alike with identical floor plans; they compete in the same rental market; and they are located in close geographic proximity.

Despite their obvious similarities, however, it is possible that they differed in important but unknown ways during the study period. For example, they might have differed in occupancy rates. Unfortunately, several factors, including the lack of managers' approval, study resources, and available study time, precluded the gathering of such important, additional information. Thus, the apartment study is not as well-controlled as is the single-family residence investigation. This conclusion needs to be kept in mind in interpreting results. Nonetheless, the apartment investigation offers further, important evidence concerning retrofit devices and water savings.

Evidence on water usage was obtained from actual billing records for the experimental and control complexes. Such evidence was obtained for the months of August and September of 1992, a period beginning about two months after device installation in the experimental complex. In addition water data for both complexes were also obtained for the same months of the previous year -- August and September of 1991 -- a period about 8 to 9 months prior to installation.

The impact of the retrofit plumbing devices on water savings was calculated by comparing changes in water use pre- to post-installation between the experimental and control complexes. Unlike the single-family study, tests of statistical significance were not appropriate. No samples were involved; the "subjects" were two complete populations of apartments, one with retrofit devices, the other without.

In order to study possible energy savings, data on natural gas consumption were obtained from actual billing records for the experimental and for the control apartment complexes. Data on natural gas consumption were obtained because both complexes utilized natural gas as the source for water heating. Unfortunately, two problems arose concerning data availability. First, billing records were available for all twelve months of 1992 for the control complex, but could only be obtained for the months of January through October of 1992 for the experimental group of apartments. Second, errors appeared in two billing records for the control complex: The initial meter readings for the months of January and September did not correspond to the final meter readings for the previous months. Accordingly, these two months could not be used for comparison purposes.

The impact of the retrofit devices on energy savings was calculated by comparing changes in natural gas consumption for the pre-installation months of February and March, 1992, with the post-installation months of August and October, 1992. Again, tests of statistical significance were not appropriate for this comparison. The "subjects" were two populations -- not samples -- of subjects, one with retrofit devices, the other without.

Finally, at the conclusion of the study period, an interview was conducted with the manager of the experimental apartment complex. During the interview, the manager was asked about any comments that she received from residents about the devices as well as about her own evaluation of costs or savings.

The Methodology of the Flow-Tests

As noted above, upon receipt of a water conservation kit and low-flow showerhead, each experimental subject was asked to return his/her present showerhead in a postage-paid envelope to a test site. Subjects were advised that as part of the over all study flow-tests on the existing showerheads would be conducted.

In total 141 showerheads were received by mail at the test site, located in Modesto, California, from the subjects. Out of that total, 100 showerheads were randomly selected for testing. In addition to the flow-tests, information about the construction and the design of the selected showerheads was recorded at the site. The results of the tests and the information recorded are discussed below in Chapter 8.

Chapter Summary

This chapter has discussed the methodology of the single family residence study, of the apartment study, and of flow-testing showerheads that were replaced during the study with new, water-conserving ones.

The single family residence study utilized an experimental design with random assignment of subjects. Enough subjects (192 controls and 288 experimentals) were included in the study to achieve more than adequate statistical power. The principal dependent variables were changes in water and energy consumption, changes measured by means of billing data. The principal independent variable, installation of retrofit plumbing devices, as well as important control variables were measured by means of telephone surveys. Standard univariate, bivariate, and multivariate statistical models were used to analyze the data.

The apartment study was of a "quasi-experimental," equivalent groups design. Retrofit devices were installed in all apartments located in one large complex. A second set of apartments, equivalent to the first in date of construction, design and floor plan, rental market, and geographic location, was selected as the control or comparison group. The impact of the devices was assessed by comparing changes in water and in energy use, measured by actual billing data, before and after device installation.

Flow-tests were conducted and observations recorded on 100 showerheads that were randomly selected from 141 returned by mail from experimental subjects during the study. The showerheads returned were ones that were installed in residences prior to the study and prior to installation of the new, low-flow head included in the study's kit.

Chapter 4
Results from the Single Family Study: Water

This chapter reports results from the single family study that concern water savings and consumption. That is, it discusses those findings with respect to single family residences that directly pertain to the question, "Does the use of the three retrofit devices result in water savings?" Initially, the effects of the retrofit devices on water consumption are described. Then, the influences of variables other than the retrofit devices on water consumption, variables which might lead to spurious or otherwise erroneous conclusions, are considered.

The Effects of the Retrofit Devices on Water Consumption

Does the use of the retrofit devices produce water savings? In order to consider this question, changes in water consumption on the part of control and of experimental subjects were compared. Such changes were calculated over the study period for both groups. Initial measurement of water usage was conducted both for control and for experimental subjects prior to the time of device installation (October-November 1991). (Of course, only the experimental subjects installed the devices.) The second measurement was taken in the post-installation period (February-March 1992) for both study groups.

Before reporting the results of the comparison, an important caveat about device installation must be discussed. At the conclusion of the second measurment period (April 1992), a follow-up survey of all subjects -- controls and experimentals -- was conducted. The purposes of this survey were to verify retrofit device installation; to learn whether devices had been removed for any reason; and to discover any other matters (e.g., changes in household size, extended vacations, installation of swimming pools) that might have affected water consumption during the study period.

The results of this follow-up survey revealed that only 196 of the subjects had actually installed all three retrofit devices. An additional 56 persons reported having installed two devices while 27 experimental subjects reported having installed just one of the devices. Furthermore, some of the subjects reported removing permanently one or more of the devices during the study period. (In total 11 subjects reported removing permanently the showerhead; 8 the kitchen aerator; and 9 the bathroom aerator.) Finally, a comparison of these results with those from an initial survey of all subjects (conducted in January of 1992) revealed that apparently not all experimental subjects had installed the devices for the complete study period. At least, it was not possible to verify installation for the complete study period for a number of subjects.

Since the true impact of the three retrofit devices could only be estimated through the water consumption of those experimental subjects who had installed the devices for the entire study period, the decision was made to truncate the sample of experimental subjects. Through a careful comparison of the follow-up and the initial survey results, those experimental subjects who had installed all three devices by the initial survey and who had not removed any one of them by the follow-up survey were identified.
Such subjects numbered 111 in all. Changes in water consumption from October-November, 1991, to February-March, 1992, were calculated for this set of experimental subjects and compared to those calculated for control subjects. The results are shown in Table 4.1.

As the results in the table reveal, the difference in monthly water savings between control and experimental subjects was dramatic. While the control households actually displayed an increased water consumption of about 122 gallons per month (or a decline in water savings), the experimental subjects who had installed all three devices throughout the period experienced a substantial water savings -- on the order of over 1,300 gallons per month. (This difference was found to be statistically significant at the .05 level; F=6.6246, p=.0105) That is, installation of the retrofit devices was found to be associated with an average water savings of approximately 1,471 gallons per month, an amount equal to about 18% of the average monthly consumption of a single family residence. As the table also shows, on an average daily per capita basis ("Average Daily Per Person Water Consumption") the savings associated with installation of the retrofit devices was approximately 14.13 gallons per person per day.

The Effects of Other Variables on Water Consumption and Savings

It may be, however, that this water savings is spurious, not a result of the retrofit devices but of other differences between control and experimental subjects. For example, experimental subjects may have been away from home for more extended periods during the study period than control subjects or they may have been less inclined to install new swimming pools or hot tubs. Morever, truncating the experimental subjects sample for analysis may have resulted in demographic differences (e.g., number of persons in the household) between study groups that are the real source of the observed water savings.

The consideration of such other influences on water consumption and savings amounts to testing hypotheses alternative to that of a "retrofit device effect." Alternative hypotheses can be tested through the introduction of suitable control variables. Such introduction and alternative hypothesis testing was next conducted.

Out of the ordinary but differential water use between study groups unrelated to installation of retrofit devices is certainly one hypothesis alternative to that of a device effect on water savings. For example, if experimental subjects more often took extended vacations during the study period or if control subjects were more likely to have installed hot tubs, then this might help to account for the water savings reported above. In order to test for this alternative hypothesis, questions concerning unusual water use were included on the follow-up survey conducted in early April 1992. Both experimental and control subjects were asked the following two questions:

"In the last 2 months has there been any major increase in the amount of water your household has used -- for example, have you installed a new hot tub or swimming pool, any broken water pipes, anything like that?"

"In the last 2 months has there been any major decrease in the amount of water your household has used -- for example, have you been away on an extended vacation, have there been fewer persons in your household, anything like that?"

Both of these questions were followed by an open-ended probe of those responding "yes" that asked why or what caused the increase or decrease.

The responses of both control and experimental subjects with respect to major increases in water usage were first examined. While about 9% of the controls reported major increases, so also did about 8% of the experimentals. These percentages were not found to differ at statistically significant levels (Chi-square = .004, 1 d.f., p= .948).

On the other hand, differences with respect to major decreases in water usage were found at statistically significant levels. While only about 9% of the control subjects reported such decreases, about 20% of the experimental subjects did so (Chi-square=6.046, 1 d.f., p=.0139). Moreover, only two of the experimental subjects reported in response to the open-ended probes that the decrease was a consequence of their having installed the retrofit devices.

But did these experimental-control differences with respect to reported decreases in water usage result in actual water savings? Can the water savings between the study groups observed above (Table 4.1) be attributed to such matters as extended vacations or fewer persons in the house rather than to the retrofit devices? In order to consider these questions, two separate analyses were conducted. In the first, multiple regression analysis was employed. Changes in water consumption over the study period were regressed on study group status (being an "experimental" or a "control") after controlling for the effects of reported decreases in water use. In the second, analysis of variance was employed to compare changes in water use between those experimental subjects who reported decreases in household water use and those that did not. The results are reported in Table 4.2 and Table 4.3, respectively.

If the water savings observed above are really attributable to factors other than the retrofit devices (vacations, fewer persons in the household, etc.), then controlling for reported decreases in water use should eliminate any differences in water savings between experimental and control subjects. In other words, experimental group (or control group) status should no longer be related to water savings. But as the results in Table 4.2 reveal, controlling for the effects of reported decreases in water use made no difference. The original association, that experimental subjects who had installed and not removed the retrofit devices saved water while controls did not, was unaffected by a control for reported declines in water use. As shown in Table 4.2, the original coefficient of simple correlation between "Group" (experimentals vs. control) and change in water use over the study period was a statistically significant -.147. After the effects of reported decrease were introduced into the regression model, the correlation was hardly altered. It was -.142 and statistically significant after controlling for reported decrease.

The second analysis performed was to examine differences in actual water savings among experimental subjects according to reported decreases in water use. If other factors (extended vacations, fewer persons in the household, etc.) made a difference in actual water savings, then this should be evident among experimental subjects. Specifically, one should expect those experimentals who reported a major decrease to have saved more water during the study period than those experimentals who did not. This is especially so because those respondents (n=2) who indicated that the reported decrease was a consequence of having installed the retrofit devices were removed from the analysis.

Table 4.3 shows that the average change in water consumption among experimentals was unrelated at statistically significant levels to reported major decreases in household use that followed from an extended vacation, fewer persons, or the like (F=.4619, 1 d.f., p=.4982). In fact those experimentals who did not report major decreases in household water use attributable to factors other than the retrofit devices actually saved more water than did those experimentals who cited "decreases" as a consequence of these "other factors."

In brief, these several findings fail to support the "alternative hypothesis" that the water savings reported above might be attributable to unusual, differential water use during the study period -- water use unrelated to the retrofit devices. No differences were found at statistically significant levels between control and experimental subjects in reported water increases attributable to having installed a new hot tub or pool, broken water pipes, or the like. On the other hand, experimental subjects compared to control subjects did report more decreases in household water use resulting from extended vacations, fewer persons in the household, and the like. But such reported decreases proved unrelated to actual water savings at statistically significant levels.

It may well be that the experimental subjects were unduly sensitized to the experimental arrangements and to the water savings information that they were provided through their participation in the study. Such sensitization or "reactivity," in turn, may have increased the likelihood of misperceiving water reductions or of overestimating the impact of changes within their households.

On the other hand, experimental sensitization or reactivity may have induced changes in more subtle ways -- changes in normal, even daily behavior with respect to water. A test of this possibility was permitted by means of the analysis of responses to the following question asked both of experimental and control subjects on the follow-up or second survey: "In the last two months have you become more conscious about saving water?" In response to this question, 72% of the experimental subjects, but only 48% of the control subjects answered this question in the affirmative, a difference found to be statistically significant (Chi-square = 17.58, 2 d.f., p= .00015).

As a test of the effect of such elevated consciousness, the influence of retro device installation on water savings was studied with a control introduced for greater consciousness about saving water. The results, presented in Table 4.4, show that installation (represented in the analysis by the variable "Group") continued to be related to water savings at statistically significant levels even with increased consciousness ("Conscious" in the table) controlled. Indeed, the correlation between device installation and water savings was about -.14 with and without the control. Therefore, despite more reports from experimental subjects than from controls about becoming increasingly conscious about water savings, evidently such elevated concern was not a source of actual water savings.

If not unusual, differential water use during the study period, perhaps the water savings reported above (in Table 4.1) are really attributable to abnormal consumption during the period in which initial measurements were taken. Suppose, for example, that the experimental subjects had consumed abnormally large amounts of water and control subjects abnormally small amounts during the months of October and November 1991. Even the random assignment of subjects cannot fully obviate such a possibility. Then, the change observed during the study may merely be the "law of averages" reasserting itself: a reversion to more normal consumption on the part of both study groups that had little to do with retrofit devices. Such "regression effects," as they are called, are problems common to a number of research settings (Campbell and Stanley, 1965, p. 5). ("Regression effects" should not be confused with a statistical model known as "regression" or "multivariate regression.")

In order to test for regression effects, analysis of variance tests were employed. The mean October-November 1991 water use for both control and experimental subjects was calculated and compared. The average <u>monthly</u> October-November water use for experimental subjects was found to be somewhat higher than for control subjects (7846 gallons versus 7279 gallons), but the difference was not found to be statistically significant ($F=1.0415$, 1 d.f., $p=.3083$). Consequently, abnormal consumption during the initial period and associated regression effects cannot explain the water savings observed previously.

If not unusual water use either during or at the outset of the study period, perhaps more normal water use can qualify as an "alternative hypothesis." That is, the water savings reported above (Table 4.1) may be attributable to background or demographic variations between experimental and control subjects rather than to the retrofit devices. Since it was necessary to truncate so severely the sample of experimental subjects in order to estimate the impact of the devices (see the preceding section), important demographic differences may have been introduced incidentally into the analysis. In other words, perhaps experimental and control subjects were not identical in social characteristics that are related in important ways to normal household water consumption.

As discussed in Chapter 2 of this report, previous studies of household water use or of retrofit devices have hypothesized the importance of the following demographic characteristics: the total number of persons in the household by age category (12 and under; 13 to 21; adults over age 21); length of household residence; renting versus owning one's residence; total family income; and education. Each of these characteristics represents a potential confounding influence with respect to retrofit devices and a possible source of spuriousness. In addition the authors of this study hypothesized that one's feeling about the importance of saving water may have had an important influence on household water use. For example, even though subjects were randomly assigned to the experimental and to the control group, it is possible that subjects who feel that saving water is important may have been inadvertantly assigned to the experimental group. Similarly, those not so predisposed might have been assigned randomly to the control group. Accordingly, the water savings observed above may be only an artifact of retrofit devices, but truly a result of consumption behavior based upon predispositions.

In order to test these hypotheses, control subjects were compared against those experimental subjects who had installed the three retrofit devices by the time of the first survey and who had not removed them by the time of the second survey. The comparison, which involved the demographic characteristics and feelings just noted, is shown in Table 4.5. As the table reveals, control and experimental subjects failed to differ from each other at statistically significant levels ($p=.05$) in length of residence, education, total family income, income change during the study period, and in total persons in the household by age category (age 12 and under; ages 13-21; and over 21). However, controls and experimentals were found to differ in owning versus renting one's home (p= .04) and in the importance of water savings (p=.019) at statistically significant levels. In particular, experimentals were found to more often own or be purchasing their homes than were controls and were more inclined to feel that saving water was important.

Are the actual water savings reported above (Table 4.1) really attributable to home owning versus renting or to attitudes about water savings rather than to the retrofit devices? To consider further these alternative hypotheses, multiple regression statistical procedures were employed. Actual changes in water consumption during the study period were regressed on "Group" (experimental versus control group status) after controlling for the effects of either homeownership ("Owning Home" in Table 4.6) or attitudes about water savings ("Attitudes" in Table 4.7). If, say, attitudes are the true source of water savings, then "Group" should not bear a statistically significant relationship to water consumption after attitudes are controlled. The same is true with respect to home owning versus renting.

The results reported in Tables 4.6 and 4.7 reveal that the water savings (presented in Figure 4.1 above) cannot be accounted for by differences between experimental and control subjects either in home owning (or renting) or in attitudes regarding the importance of saving water. The original relationship between "Group" (i.e., being an experimental subject) and change in water consumption during the study was a -.147. This relationship was affected scarcely at all by controlling either for "Owning Home" (Table 4.6) or for "Attitudes" (Table 4.7). After controlling, the relationship was -.141 and -.145, respectively. Moreover, "Group" continued to bear a statistically significant relationship to change in water consumption even after controls were introduced for "Owning Home" or for "Attitudes" (p=.023 and p=.0355, respectively). In other words, experimentals who had installed and not removed the retrofit devices showed a decline in water consumption -- an increase in water savings -- relative to controls, even after differences in home owning versus renting and differences in attitudes were taken into account.

Chapter Summary

This chapter has reported the results of the single family study with respect to water consumption and savings. The findings reported here indicate that installation of the three retrofit devices was associated with a monthly water savings of approximately 1,471 gallons or about 18% of the average consumption for a single family residence. Expressed differently, the savings were amounted to approximately 14.13 gallons per person per day. In addition, the study findings indicate that these water savings could not be attributed to unusual water consumption unrelated to the devices either during the study period or during the period of initial water measurment (October-November 1991). Further, the findings also reveal that these water savings could not be attributed to differences among study subjects in length of residence, education, total family income, changes in income, number of persons in a household by age, owning versus renting one's home or by attitudinal predispositions regarding the importance of saving water. The only hypothesis supported by the data examined in this chapter is that the three retrofit devices resulted in water savings.

Chapter 5
Results from the Single Family Study: Energy Savings

In addition to water savings, the study also investigated the effects of installing retrofit plumbing devices on energy savings. Energy savings in the form of reduced electricity consumption were expected to derive directly from lower water consumption. Installation of the three retrofit devices was predicted to reduce water consumption and, in turn, to reduce energy needed for water heating. This chapter reports the results of testing these predictions.

The Effects of Retrofit Devices on Energy Savings

In order to test whether energy savings were associated with the retrofit devices, data on electricity consumption in the form of kilowatt hours or KWH were obtained for each single family residence in the study. Such data were obtained for the same initial period, October-November 1991, and for the same follow-up period, February-March 1992, for which water consumption data were gathered. These initial and follow-up periods were, respectively, the months immediately prior to the time of device installation and 3 and 4 months following that time. The study team is grateful to Houston Lighting and Power for providing these data.

Only electrical and not other forms of energy savings (e.g., natural gas) were investigated in this study for two important reasons. First, it was felt that energy savings would be more readily discerned given the relatively greater costs of heating water with electricity rather than with natural gas.
Second, the residential area included in the study permitted restricting the subjects -- both control and experimental subjects -- to just those who heated their household water with electricity. By restricting the subjects to those heating water with electricity, one possible confounding variable -- manner of heating water -- was controlled. Restriction of subjects was accomplished by means of a mail postcard, returned by study participants, which asked whether gas or electricity was used to heat water. Only a very few of those volunteering to participate in the study, all of whom were screened out, reported the use of a gas water heater.

As an initial test of electrical energy savings associated with installation of the retrofit devices, an analysis of variance was performed. Mean changes in energy consumption among experimental and control subjects over the study period were compared. The results, reported in Table 5.1, showed a lower average change -- greater energy savings -- among experimental as opposed to control subjects. However, these mean changes were not found to differ at statistically significant levels ($p=.05$). Thus, while changes in electricity consumption over the study period were in a direction consistent with the hypothesis of energy savings, such changes were not sufficiently different to support a claim of statistical significance.

Perhaps more substantial differences in energy consumption among experimentals and controls are concealed or "suppressed" as a consequence of the influence of other, confounding variables. A variable antecedent to both device installation and to energy consumption (e.g., family income) that is directly related to, say, energy consumption but inversely related to device installation would serve to conceal a true device-energy relationship. Relationship-suppressing variables and true device-energy associations can only be identified by means of controlling for the influence of likely variables.

Such "likely variables" were already discussed in Chapter 4. They are variables or characteristics that distinguish control subjects from experimental subjects. Specifically, control and experimental subjects were found to differ at statistically significant levels in reported decreased water use during the study period; in elevated consciousness about water savings; in home owning as opposed to renting; and in attitudes regarding the importance of saving water (see above). Each of these variables or characteristics may be suppressing an association between installation of the retrofit devices and energy savings. In addition, experimental and control subjects may have differed in initial energy consumption with attendant "law of average" or "regression" effects (see above). Finally, energy savings may have been more important either to experimentals and controls with important consequences for energy consumption.

Consideration of the influence of these several "likely variables" will parallel the discussion presented previously in Chapter 4. Initially, "law of average" or "regression" effects were considered. If either controls or experimentals had abnormal levels of electricity consumption in October-November 1991 and the other group normal ones, the "law of averages" simply may have
overwhelmed any energy changes resulting from installation of the retrofit devices.

Table 5.2 reports the results of testing for differences in electricity consumption for the initial measurement period, i.e., October through November 1991. The table reports mean <u>monthly</u> electricity consumption for this period. As the data reveal, experimentals did have somewhat lower levels of electricity consumption than controls. However, the difference is not statistically significant (p=.05). Accordingly, different initial consumption levels and "law of average" or "regression" effects cannot explain the absence of energy savings revealed in Table 5.1.

If not differential initial energy levels, perhaps the absence of a device-savings relationship is attributable to decreased water use unrelated to the retrofit devices. As discussed in Chapter 4, experimentals were more likely than controls to report decreased water use during the study period, decreased use that could not be accounted for by installation of the retrofit devices. Even though such reported decreases proved unassociated with <u>actual</u> water savings, it is possible -- even if unlikely -- for such decreases to influence energy savings. The data reported in Table 5.3, however, disconfirm this expectation. Experimentals were not more likely than controls to save energy at statistically significant levels after differences in reported decreased water use were taken into account.

In addition to reported decreases in water use, experimentals were found more likely than controls to report having become more conscious of water savings during the study period. (See Chapter 4) This type of experimental "reactivity" could lead to greater energy sensitivity as well and result in important behavioral changes. In consideration of such a possibility, multiple regression analysis was again employed. In the absence of direct survey evidence bearing on energy behavior, changes in energy consumption were regressed on "Group," the surrogate for device installation, with reported consciousness about water savings controlled. The regression results and associated correlational analysis, summarized in Table 5.4, show, however, that device installation and energy savings remained unrelated at statistically significant levels.

Another variable that was found (in Chapter 4) to distinguish experimental and control subjects in the study was that of owning as opposed to renting one's home. Experimentals were much more likely to own or to be purchasing their homes than were controls. Accordingly, home ownership may serve to suppress or conceal an energy savings relationship.

In order to better understand the influence of home ownership on energy savings, several different statistical tests were conducted. First, multiple regression techniques were employed to examine the relationship between device installation ("Group") and changes in electricity consumption during the study with home ownership controlled. The results reported in the top portion of Table 5.5 show, however, that device installation remained unrelated to changes in electricity consumption at statistically significant levels even after home owning was taken into consideration. Second, possible "statistical interaction" between home ownership and device installation was considered. Statistical interaction refers to the influence of a control variable being different between categories of an independent variable. For example, energy savings may be substantial just for those home owners who had installed the retrofit devices. The data presented in the bottom portion of Table 5.5, however, shows no evidence of such statistical interaction.

Home ownership was related to changes in electricity consumption (Table 5.5), though evidently it was not a "suppressor variable." Consequently, two other tests involving home ownership were conducted. Separate multiple regression analyses were conducted of the relationship between device-installation and energy savings <u>among</u> homeowners and <u>among</u> those renting. Such analysis revealed that having installed the retrofit devices and changes in energy consumption were unrelated <u>among</u> owners as well as <u>among</u> renters at statistically significant levels. (These data are not shown).

In brief, then, home owning was found related to energy savings. But controlling for home owning failed to show any effect on savings attributable to having installed the retrofit devices.

Besides owning as opposed to renting, attitudes regarding the importance of saving water were found in Chapter 4 to distinguish experimental and control subjects. Compared to controls, experimental subjects were found more likely to believe water savings to be important at statistically significant levels. Controlling for the influence of such beliefs on the relationship between device-installation and changes in energy consumption, however, failed to provide evidence of a device-effect. As shown in Table 5.6, "Group" -- the indicator of device-installation -- remained unrelated to changes in electricity consumption at statistically significant levels ($p=.05$) with attitudes about water savings controlled.

In addition to querying about the importance of saving water, each subject was also asked his/her beliefs concerning the importance of energy savings. The question posed to each experimental and each control subject on the initial survey was the following: "On a scale of 1 to 5 with 5 being most important, how important are energy savings to you personally?" In order to determine whether predispositions regarding energy savings might be responsible for the absence of a relationship between installation of the devices and energy savings, an analysis of variance was conducted. Mean differences in attitudes about energy savings between experimental and control subjects were calculated. As shown in Table 5.7 the difference in attitudes between the groups of subjects was slight and not statistically significant (p=.05). Thus, attitudinal predispositions regarding energy could not account for the finding (in Table 5.1) of an absence of an effect of retrofit devices on energy savings.

An Estimation of Energy Savings

Although controlling for "likely variables" showed no evidence of a concealed effect of retrofit devices on energy savings at statistically significant levels, it is still possible for the devices to have yielded some savings. It may be that energy savings did result, but that the savings were so modest in magnitude that they were undetected by the sample sizes of subjects that were available in this study. Given such a possibility, an altogether different method of studying energy savings was utilized.

The method utilized involved, first, combining the experimental and control groups and, then, computing an equation relating water savings and energy savings for the combined groups. With such an equation and with knowledge of water savings associated with the retrofit devices, knowledge reported above in Chapter 4, it was possible to estimate energy savings associated with device installation. In effect, this method amounted to treating the groups not as samples of control and experimental subjects but as a combined population of subjects.

Table 5.8 reports the equation which related changes in electricity consumption (in kilowatt hours) with changes in water consumption (in thousands of gallons). This equation was obtained by fitting observations to data by means of ordinary-least squares regression procedures. The equation itself describes the linear relationship for the population of subjects that included the control and experimental subjects studied in Chapters 4 and 5. Such subjects included all control subjects for which complete data were available (n=192) and all experimental subjects that had installed all three retrofit devices at the time of the initial survey and had not removed them by the time of the second (n=111). This population of subjects was employed in the analysis because this is the set of subjects for which an estimate of water savings was obtained (in Chapter 4).

Table 5.8 also presents inferential statistics that are appropriate to obtaining sampling estimates. These statistics (e.g., t, significance of t, etc.) are reported only for reasons of completeness -- many statisticians prefer that they always be reported. However, since the subjects were treated in this analysis as a population and not as samples, these sampling statistics will not be interpreted here.

In addition to the inferential statistics, the table also reports a diagnostic statistic known as the "Durbin-Watson." A particularly important mathematical problem that can attend the regression analysis of time series data -- data (e.g., water and energy consumption) in which the time ordering of observations is important -- is known as the serial correlation of residuals. (This problem is discussed in Hoel, 1964). This problem may result in a misestimation of the reliability of the coefficients in a regression model. The value of the Durbin-Watson reported in Table 5.8 shows that serial correlation of residuals is not a problem with the data here.

The "Water Consumption" coefficient in the equation in Table 5.8 indicates that on a per month basis each 1,000 gallon increase in water consumption is associated with an increase of 13.61 kilowatt hours of electricity ("13.61 x Water Consumption" in the table). Since the three retrofit devices were earlier (in Chapter 4) estimated to result in a monthly water savings of 1,400 gallons, the amount of monthly energy savings associated with the devices should be approximately 18.6 kilowatt hours (13.61 x 1.4 thousand gallons). Eighteen and six-tenths kilowatt hours amounts to approximately 1.25% (18.6/1482.93) of the monthly average October-November 1991 electricity consumption for the single family residences in this study and approximately 1.05% (18.6/1766.49) of the monthly average consumption for February-March 1992.

Chapter Summary

Experimental and control subjects were not found to differ at statistically significant levels (p=.05) with respect to electricity consumption or savings even after differences in reported decreases in water use, in consciousness about water savings, in home owning versus renting, and in attitudes about water savings were taken into account. Also, subject groups were not found to differ at statistically significant levels with respect to other possible confounding variables including initial (October-November 1991) electricity consumption and feelings about the importance of saving energy. Finally, by means of pooling subject groups and using least-squares regression techniques, it was possible to estimate that installation of the three retrofit devices was associated with an electricity savings of approximately 18.6 kilowatt hours per month.

Chapter 6
Results from the Single Family Study: User Satisfaction and User Perceptions

This chapter presents the results of an analysis from the single family study of user satisfaction with the retrofit devices and of user perceptions of water savings. Initially, findings which pertain to who installed the devices and who did not are presented followed by a discussion of reasons for not installing the devices. Then, reported problems with each device are discussed as well as reasons for removal of the devices. Finally, user satisfaction with each device and perceptions of water savings for the experimental group and the control group are reported.

Who Installed the Devices and Who Did Not

The number of persons installing each of the devices is reported in Table 6.1. As noted in the table, 81% of the experimental group installed the showerhead; 88% installed the kitchen aerator; and 84% installed the bath aerator. The remainder said they had not installed the device or were "unsure."

Those persons who did install a particular device were compared with those persons who did not install that device to determine if the two groups were significantly different. As noted in Table 6.2 and in Table 6.4 (Characteristics of Experimental Group Participants Who Did/Did Not Install the Showerhead and Bathroom Aerator), there were no differences at statistically significant levels (p=.05) between those who did or did not install the showerhead or the bath aerator with respect to owning/renting a home, family income, education, importance of water saving, length of residence and total number of persons in the household. For those who did or did not install the kitchen aerator (Table 6.3), there were no statistically significant differences between the groups except for the total number of persons in the household. In that instance the families which had installed the kitchen aerator were larger on average than the families which had not installed the aerator (3.41 v. 2.71). It could be that those participants from the larger families were more interested in saving money or saving water.

Reasons for Not Installing the Devices

Even though most participants installed at least one device, knowing why a device was not installed is important for marketing and educational purposes. Those who did not install a device reported most commonly the following reasons for not doing so (see Table 6.5).

The most common reasons for not installing a device were mechanical ones (it did not fit/there was no adaptor, the old fixture would not come off, a plumber would have to do it). Another reason for non-installation was a lack of time to do the job (especially for the showerhead and the bath aerator). Only two respondents did not like the devices and only one respondent believed that the aerators would not work.

These findings suggest a need to perhaps include adapters with the kit. In addition, installation instructions could state that it "only takes 30 minutes to install" (or whatever is the average time) so that users would not feel that the installation would take an inordinate amount of time.

Problems in Installing Each Device

Subjects in the experimental group were asked if they had experienced any problems in the installation of the devices. As indicated in Table 6.6 below, 29% of those installing the showerhead had problems in its installation while 3% of those installing the kitchen aerator and 6% of those installing the bath aerator had problems. This supports the finding presented above (reasons for not installing the devices) that more problems were encountered with the installation of the showerhead than with the other two devices.

Reasons for Removing the Devices

Subjects were also asked if any of the devices had been removed permanently after they had been installed. A total of 11 subjects reported permanently removing the showerhead; 8 removed the kitchen aerator; and 9 removed the bath aerator. The reasons for the removal of the devices are reported in Table 6.7.

As noted in the table, "Not enough pressure" was the major reason for the removal of the showerhead and the bath aerator. "Made the faucet leak" was the next most frequently mentioned reason for removal both of the showerhead and of the bath aerator. Again it should be noted that more problems were associated with the showerhead than with the kitchen aerator or bath aerator.

User Satisfaction with Each Device

Participants in the study were then asked how satisfied they were with the performance of the showerhead, the kitchen aerator, and the bath aerator. The findings are reported in Table 6.8. The kitchen aerator produced the highest degree of satisfaction (86% very satisfied) while 73% of the respondents said they were very satisfied with the bath aerator and 62% very satisfied with the showerhead. When responses in the categories "very satisfied" and "somewhat satisfied" were combined, all three devices had a satisfaction level in excess of 90% (showerhead- 91%; kitchen aerator- 97%; bath aerator- 95%).

Perceptions of Water Savings

Experimental subjects who installed all three devices were asked if they believed they had saved money as a result of installing the retrofit devices. The findings are reported in Table 6.9. Approximately 58% of the subjects believed they had saved money while only 22% said they did not believe they had saved money. About 21% reportedly "did not know."

Participants in both the experimental and control groups were asked if they believed their home water use had increased, decreased, or stayed the same in the last two months. The findings are reported in Table 6.10. Statistically significant differences exist between the two groups (Chi-square = 44.92, $p <= .001$). About 53% of the experimental group believed their home water use had decreased; 7% believed it had increased; and 32% believed it had stayed the same. In comparison, 66% of the control group believed it had stayed the same; 23% believed water use had decreased; and 10% believed it had increased.

As reported above (Figure 4.1), data from actual water use indicate that the control group actually increased its water consumption by about 100 gallons/month while those in the experimental group who had installed all three devices for the duration of the study saved over 1300 gallons of water/month. Total water savings, then, for those who installed the retrofit devices was about 1400 gallons/month, or about 18% of the average water consumption for a single family residence. Users, then, believe they save water by using the devices, and, in reality, they do.

Experimental and control group subjects were asked if they had become more conscious of water savings in the last two months. The results are found in Table 6.11. The two groups are significantly different with respect to being more conscious about water saving. ($p = .05$) About 72% of the subjects in the experimental group responded "yes" to being more conscious of water savings while only 48% of the subjects in the control group responded in the same way. At the same time, 23% of the experimental group and 47% of the control group said "no," they were not more conscious of water savings.

Chapter Summary

In summary, this chapter has presented the results and discussed findings with respect to those subjects in the single family retrofit study who did and did not install the devices; reasons for non-installation of the devices; problems with the devices; why the devices may have been removed; user satisfaction with each device; and perceptions of water savings.

A particularly high percentage of respondents reported installing at least one device. The main reason for non-installation of a device was that it did not fit/there was no adaptor. More participants reported having problems installing the showerhead than the other two devices. The main reason for removing a device was "not enough pressure." Most experimental group subjects were very satisfied with the devices with the kitchen aerator receiving the highest reported level of satisfaction. A majority of participants believed they had saved money as a result of installing the retrofit devices. The experimental group believed their water use had decreased more than did the control group, a belief confirmed by actual water use data. Finally, experimental group subjects reported that they had become more conscious of water savings during the study period than did participants in the control group.

Chapter 7
Results from the Apartment Study

In addition to single family residences, the study also investigated the effects of installing the retrofit plumbing devices on water and energy savings in apartments. This chapter reports the results of that investigation. A review of the methodology of the apartment study, discussed previously in Chapter 3, is followed by a presentation of results.

Methodology of the Apartment Study

As discussed in detail in Chapter 3, the design of the apartment investigation was of a "quasi-experimental," equivalent groups design. Retrofit devices were installed in all apartments located in one large complex ("Experimental Apartments" or "Experimental Group"). The same devices from the same manufacturer utilized in the single family investigation were installed. A second set of apartments, equivalent to the first in date of construction, design and floor plan, rental market, and geographic location was selected as the "Control" or "Comparison Group." The principal difference between the two apartment complexes was that the former contained considerably more apartment units than did the latter (776 units vs. 320 units, respectively). However, other than there having been more experimental than control "subjects," this difference seems to have been without either practical or design effect.

Despite their obvious similarities, however, it is possible that the two complexes differed in important but unknown ways during the study period. For example, they might have differed in occupancy rates. Unfortunately, several factors, including the lack of managers' approval, study resources, and available study time, precluded the gathering of such important, additional information. Thus, the apartment study is not as well-controlled as is the single-family residence investigation. This conclusion needs to be kept in mind in interpreting results. Nonetheless, the results of the apartment investigation offer further, important evidence concerning retrofit devices.

The impact of the devices on water savings was assessed by comparing changes in water use, measured by actual billing data, before and after device installation. Such billing data were obtained for the months of August and September of 1992, a period beginning about two months after device installation in the experimental complex. In addition water data for both complexes were also obtained for the same months of the previous year -- August and September of 1991 -- a period of about 8 to 9 months prior to the installation of the devices.

Similarly, the effects of the retrofit devices on energy savings were assessed by comparing changes in natural gas consumption, measured by actual billing data, before and after device installation among the experimental and control apartment complexes. Natural gas was studied because it was the means employed for water heating in both apartment complexes. Such data were obtained for the pre-installation months of February and March of 1992 and for the post-installation months of August and October, 1992.

The Effects of the Retrofit Devices on Water Savings

The impact of the retrofit plumbing devices on water savings was calculated by comparing changes in water use pre- to post-installation between the experimental and control complexes. (Of course, devices were only installed in the experimental apartments.) Unlike the single-family study, tests of statistical significance were not appropriate. No samples were involved; the subjects were two complete populations of apartments, one with retrofit devices, the other without.

Table 7.1 displays actual water use for the experimental and control apartments, respectively, for the months of August and September 1991 (the pre-installation period) as well as for the months of August and September 1992 (the post-installation period).
The table also shows the differences in water use, computed as post-installation water consumption minus pre-installation consumption, separately for the experimental and control units.
Finally, it also displays the percentage change in consumption from pre- to post-installation.

As is evident from the table, the experimental apartments showed a decrease in water use from pre- (August-September 1991) to post-installation (August-September 1992) of approximately 1,424,000 gallons. This amounted to a water savings of about 18% over the study period. In comparison, the control apartments showed an increase in water use pre- to post- of approximately 244,600 gallons or about 9%. Thus, the installation of retrofit plumbing devices was found associated with a 27% (18% + 9%) water savings.

These results appear to be quite consistent with those from the single family investigation. Water savings of approximately 18% were found associated with the installation of the retrofit devices in single family residences (Chapter 4). The savings found here to be associated with device installation in apartments, 27%, are similar, only larger.

Quite likely, these larger savings for apartments are a result of an important difference in study methods. Each single family residence was sent a kit which contained devices sufficient to retrofit one kitchen and one bathroom (i.e., one bathroom sink and one showerhead). Yet, in general the single family residences included in the study had more than one bathroom. By way of contrast, each of the "experimental" apartments was completely retrofit with devices. Of the 776 apartments included in the experimental group, 249 had two bathrooms (not full bathrooms) both of which were retrofit. Thus, the differences in estimated water savings between single family residences and apartments are probably attributable to variations in the proportions of fixtures
retrofit with water-conserving devices.

The Effects of the Retrofit Devices on Energy Savings

Energy use and savings were studied in a manner analogous to water savings. Table 7.2 displays natural gas consumption for the experimental and control apartments, respectively, for the months of February and March 1992 (the pre-installation period) as well as for the months of August and October 1992 (the post-installation period). The table also shows the differences in gas use, computed as post-installation consumption minus pre-installation consumption, separately for the experimental and control units. Finally, it displays the percentage change in consumption from pre- to post-installation as well as energy savings associated with installation of the retrofit devices.

As the table indicates, the experimental apartments were found to use relatively less natural gas over the study period than were the control apartments. That is, installation of the retrofit devices was found associated with a natural gas savings of approximately 12% over the period studied.

However, energy consumption and savings are likely to be greater in some months of the year than in others. Indeed, the data in Table 7.2 provide confirming evidence of this. August, the first post-installation period, was the warmest of the months included in the apartment study. Less energy is required to heat water in warmer months and, accordingly, there is less energy to be saved. When August was removed from the analysis and comparisons drawn just to October, the second post-installation period and a cooler month, even greater energy savings were found associated with retrofit device installation. Calculations revealed that device installation was then associated with a 14% natural gas savings (percentage not shown in the table). Thus, it seems likely that had even colder months been compared, still greater energy savings would have resulted. Accordingly, a 12% to 14% natural gas savings should mostly likely be regarded as a conservative estimate of the annual energy savings associated with retrofit device installation.

But why were natural gas savings for the apartments so much greater than the electrical energy savings found for single family houses (Chapter 5)? Quite likely, some of these greater energy savings are attributable to the greater water savings realized for the experimental apartment complex relative to those realized for the experimental, single family dwellings (see above). That is, more water savings probably resulted in more energy savings.

Other possible reasons, however, can be suggested. Such possible reasons include differences in the study periods and in the variability of energy use. The study periods for the single family dwelling and apartment investigations were not the same. The single family study was conducted in months where there was likely to have been relatively greater variability in individuals' electricity consumption. For example, while air conditioning is likely to be used constantly throughout the summer months, it may be used more or less frequently during the months of October and March in the Houston region. Moreover, such relative variability in electricity consumption might have been substantial enough in one or another of the study groups (experimental or control) so as to obscure an effect of the retrofit devices. In contrast, natural gas consumption in the apartment complexes was not subject to the same possible individual or within-study group variability. All water heating in the control apartments was accomplished in a single boiler, decisions about which were made by the apartment's management; water heating in the experimental apartments was accomplished in just four boilers, not in individual apartment water heaters. Accordingly, less individual variability in consumption combined with different study months may help to explain the greater energy savings in the apartments compared with single family dwellings.

Still another possible reason, of course, concerns different energy sources. Contrary to the expectations of the study team, gas may be a less efficient water heating source than electricity in the Houston area. If so, then water savings would result in relatively greater gas than electricity savings. Unfortunately, the study design did not permit testing this possibility.

Results from Interviewing the Apartment Management

In addition to these calculated savings, the manager of the experimental apartments was interviewed concerning any comments she had received from residents as well as about her personal satisfaction with the devices. The manager reported only a very few comments from apartment residents, most of which were about decreased pressure resulting from device installation. On the other hand, she also reported to the study team how pleased she was with the cost-savings resulting from device installation.

Chapter Summary

This chapter has reported the results of studying the effects of installing the retrofit devices on water and energy savings in apartments. The findings reported here, based on a "quasi-experimental," equivalent groups design, revealed that installation was associated with water savings of approximately 27% for the study period. These savings are larger than those found for single family residences. This is probably attributable to differences in study methods: water-conserving devices were installed on a greater proportion of plumbing fixtures in apartments than in single family residences. In addition to water savings, the devices were also found associated with a natural gas savings of from 12% to 14%, percentages that are specific to the period of the study and that may be conservative with respect to annual energy savings. Finally, the manager of the apartments in which the retrofit devices were installed reported how pleased she was with the cost-savings.

Chapter 8
Results of the Flow Tests

As mentioned previously in Chapters 1 and 3 of this report, the retrofit study included testing and recording data on existing showerheads that were replaced with new, low-flow, water-conserving ones. Such testing and recording were deemed important because they provided important information on the condition of existing showerheads among the experimental subjects in the study. Additionally, they offered further evidence concerning the effects of retrofit devices on water savings. This chapter reports the results of the tests, summarizes the data recorded on the replaced showerheads, and discusses likely water savings.

Test Results and Data on Replaced Showerheads

The water conservation kit that was mailed in November 1991 to each experimental subject included a postage-paid envelope along with a request that the subject's existing showerhead, the showerhead that was to be replaced by the new, low-flow variety, be mailed back so that flow tests could be conducted. The postage-paid envelope was addressed to the testing site, Northwest Water and Energy Audit Systems in Modesto, California. The tests were conducted and the data recorded at Energy Technology Laboratories in Modesto.

In total 141 showerheads were received by mail at the test site from the subjects. Out of that total, 100 showerheads were randomly selected for testing. In addition to the flow-tests, information about the construction and the design of each selected showerhead was recorded at the site. This chapter is based upon the report provided by the testing laboratory.

Before reporting the data received from the laboratory, an important caveat is in order. Despite the request to do so, not all experimental subjects returned their existing showerhead. Those 141 who did so were a self-selected subset of the study's experimental subjects. Self-selected subjects always entail the possibility of bias. Simply put, those who returned their showerhead differ from those that did not, if only in whatever motivated their returning the showerhead. Accordingly, the returned showerheads -- and the data on those showerheads -- cannot be taken as representative of all experimental subjects. Rather, the data discussed below must only be interpreted as suggestive, not definitive or conclusive.

The vast majority of the returned showerheads (84%) were listed as metallic in the laboratory test report. Unfortunately, the test results did not indicate specifically whether the metal showerheads had internal plastic parts. Such information is important in assessing the test flow results since metal corrosion might have restricted water flow. However, the average weight of of the tested showerheads, 3.32 ounces, and a range of from 1.8 to 10.9 ounces, suggest that most were metallic with plastic internal parts.

Flow results were determined by measuring the rate of flow in gallons per minute (gpm) after the showerheads were attached to a water line under 65 pounds per square inch (p.s.i.) pressure. The average flow rate of all of the tested showerheads was found to be 5.9 gpm.

Many showerheads have some type of internal flow restrictor as part of their construction. Of the returned and tested showerheads, 14 were found to have internal flow restrictions. The average flow of such units was 2.16 gpm.

The report from the testing laboratory also showed that 79 of the showerheads returned for testing were of the unrestricted flow variety. Such showerheads were found to have an average flow rate of 6.71 gpm.

By way of comparison, the retrofit, water-conserving showerheads sent to the study's experimental subjects had a flow rate of 2.5 gpm at 65 p.s.i.

The Effects of Retrofit Devices on Water Savings

These laboratory data tend to support the principal hypothesis of this study: retrofit, water-conserving devices result in water savings. This is so despite the caveat about self-selection bias and representativeness just noted. The vast majority of the returned showerheads (79%) were of the unrestricted flow variety. These showerheads had an average flow rate that was considerably higher than the low-flow, water-conserving ones that replaced them. Of course, this is what one would expect if the retrofit devices used in the study were truly the source of the observed (in Chapter 4) water savings.

If these laboratory data tend to support the hypothesis, however, they do not allow the easy calculation of water savings attributable directly to the retrofit showerhead. First, the problem of self-selection bias and representativeness precludes such calculation for experimental subjects in general. Second, the flow tests were conducted at 65 p.s.i. If this pressure level is not typical of that throughout the MUD #55 distribution system, then direct calculations of water savings are difficult to compute.

Finally, note should be made of the prospects for additional water savings. The water-conserving showerheads used in this study had a flow rate of 2.5 gpm (at 65 p.s.i.), however the manufacturer of the devices has developed one with a flow rate of 2.0 gpm (again at 65 p.s.i.). Given the findings of the present investigation, this lower-flow showerhead is likely to lead to even greater savings.

Chapter Summary

This chapter has reported the results of laboratory flow tests and observations recorded on showerheads that were replaced with retrofit, water-conserving ones during the study. One hundred (100) randomly selected showerheads out of a total of 141 returned ones were tested and observations on them recorded. Most of the returned showerheads were metallic in construction, but probably had plastic internal parts. The average flow rate of these showerheads was higher than that of the low-flow, water conserving ones that replaced them during the study. The laboratory data tend to support the hypothesis that the water savings observed in the study (Chapter 4) resulted from the installation of the water-conserving retrofit devices. However, the laboratory data do not allow the easy calculation of water savings attributable directly to the retrofit showerhead.

Chapter 9
Summary and Conclusions

This chapter summarizes the principal findings of the study. It also presents the conclusions of the investigation and discusses implications of them.

Summary of Principal Findings

Installation of the three retrofit plumbing devices in single family residences was found associated with an average monthly water savings of approximately 1,400 gallons. This savings amounted to about 18% of the average consumption for a single family dwelling. Moreover, statistical controls for unusual water consumption unrelated to the devices; for differences among study subjects in length of residence, education, family income, number of household residents by age, home owning (vs. renting); and for variations in attitudinal predispositions regarding the importance of saving water did not alter the findings. That is, device installation alone, and not any of these other influences, accounted for the monthly water savings.

Installation of the devices in single family residences also was found related to energy savings. Water savings appear to have resulted in average electrical energy savings of about 18.6 kilowatt hours per month, a result that is likely attributable to a reduction in hot water heating.

In multifamily apartment residences, device installation was found associated with a water savings of approximately 27%. This larger savings in apartments relative to those for single family residences seems to be an artifact of the study's methods. Each single family participant in the study received only one bathroom aerator and only one showerhead regardless of the number of household bathrooms. In contrast, all bathrooms in the apartments were retrofit with water-conserving devices.

Device installation was also found related to natural gas savings in multifamily apartment residences. For the period studied, the retrofit devices appear to have resulted in a 12% to 14% savings in gas consumption. Since the period studied was from cooler (February and March) to warmer months (August and October) in the Houston area, it is possible that these energy savings estimates are conservative.

Telephone surveys of study subjects revealed that sizeable majorities were "very satisfied" with all three water-conserving devices. Among the devices, the kitchen aerator received the highest reported level of satisfaction. Further, a majority of the study's participants believed that they had saved money as a result of device installation. And the experimental subjects -- those who installed the devices -- were more likely to perceive that their water use had decreased in preceding months than were their control counterparts (who did not install the devices). Of course, these perceptions were confirmed by actual water use data. Interestingly, the experimental subjects who installed the devices were also much more likely than other subjects to report increased concern about saving water.

Telephone survey results were also revealing about the installation and removal of the devices. Specifically, when a device was not installed, the main reason cited was that the device did not fit existing plumbing fixtures and required an adapter to install it. More subjects reported having problems installing the water-conserving showerhead than the other two devices. Finally, very few subjects reported removing devices after installing them; the principal reported reason provided for removal was "not enough water pressure."

Lastly, flow tests conducted on existing showerheads that were replaced during the study indicated an average flow-rate that was higher than that for the retrofit, water-conserving ones. These test results further supported the hypothesis that the savings observed in the study resulted from the installation of the retrofit, water-conserving devices.

Conclusions

Taken together, these several findings suggest three important conclusions. First, installation of water-conserving plumbing devices of the quality considered here is quite cost-effective. For example, consider costs and savings from the viewpoint of the individual, single family residence. At existing rates in the Houston-Galveston area for electricity and in Municipal Utility District #55 for water and sewer, the ETL water-conservation kit used in this study will pay for itself in savings in about a year at full, single-kit, retail price and in less than 6 months at prices available to utilities for quantity purchase. Since the devices are engineered and manufactured to last for many years, this is, indeed, an excellent investment.

From the viewpoint of apartment managers, installation of retrofit devices of the quality studied here is again quite cost-effective. For example, for the 720 unit "experimental" apartment complex used in this study, the devices would have paid for themselves in less than 2 years <u>in natural gas savings alone</u>. When savings from lower water consumption and reduced sewer charges are taken into consideration, retrofit devices are an even better investment for multifamily apartments.

Second, from a regional or community-wide viewpoint, i.e., aggregating the savings from a number of individual households and apartments, the widespread installation of "good quality" retrofit devices will result in major water and energy conservation. For example, data from this study suggest that the installation of a water-conserving showerhead, bathroom aerator, and kitchen aerator in each of 10,000 homes with electric water heaters would result in a savings of 14,000,000 gallons of water and 186,000 kilowatt hours of electricity per month. Similarly, completely retrofitting 10,000 apartment units would result in an estimated community-wide savings of 14,000,000 gallons of water and nearly 45 million cubic feet of natural gas per month. And these numbers do not include any additional water or energy savings resulting from a reduction of sewage treatment.

Finally, prospective users can expect to be highly satisfied with the performance of retrofit, plumbing devices as well as to perceive readily the resulting savings -- provided, of course, that the devices are equal in quality to those considered here.

Implications

These conclusions together with the findings of this study have important, action-oriented implications. One such implication is that water and energy officials would do well to consider an educational campaign or promotional effort aimed at community-wide, retrofit device installation. The costs of such a campaign or effort are likely to be more than offset by the resulting savings. This is especially so when communities are facing water, sewer, or energy facilities in need of expansion. For many utilities, the cost of purchasing devices in quantity (presently, ETL's price to utilities is less than $23.00 per kit) is likely to be a rather modest investment that will yield considerable water and energy dividends. Moreover, there is an additional bonus: those subjects who installed the devices in this study tended to report becoming more generally conscious of the importance of saving water.

Findings concerning who did and who not install the retrofit devices offer another implication. Among those who were provided the water conservation kit in this study, households of all sizes, ages, incomes, lengths of residence, educational backgrounds, and owner (vs. renter) status reported having installed the devices. (There was only a minor, single exception. See Chapter 6.) That is, the devices generally appealed to all socioeconomic groups. Thus, anyone contemplating a community-wide educational or promotional effort need not be concerned about the special targeting of particular groups -- at least of the groups studied here.

On the other hand, given the reasons cited by study subjects for not installing a device when it was provided, any educational or promotional campaign does need to be concerned about possibly making available plumbing, especially showerhead, adapters. The need for an adapter because a device failed to fit a fixture was the principal reason for noninstallation.

Finally, any water or energy official contemplating a community-wide campaign or educational effort will want to approach apartment managers about installing retrofit plumbing devices in their units. Substantial, community-wide savings will be realized quickly at a lower per unit cost (relative to single, retail purchase). At the same time, managers can expect to receive lower water and energy bills accompanied by few complaints from renters.

Table 3.1
Characteristics of Control and Experimental Subjects

	Controls (n=192)	Experimentals (n=288)
Characteristic:		
Length of household residence	5.74 years	5.24 years
Education		
Grade school	0%	0%
High school	11	9
Some college	28	32
College degree	41	37
Tech/Voc school	2	4
Prof/graduate school	18	17
Total family income before taxes		
Under $15,000	1%	1%
$15,000 to $30,000	10	11
$30,001 to $55,000	54	54
Over $55,000	35	34
Reported income change during study period**		
Yes	16%	9%
No	84	91
Number of persons in household		
Over age 21	2.05	2.00
Ages 13-21	.32	.32
Ages 12 and under	.86	.88
Owning/renting home		
Own/buying	79%	80%
Renting	21	20
Importance of saving water (5-point scale)	4.27	4.36
Importance of saving energy (5-point scale)	4.75	4.72

Notes: ** denotes a difference between control and experimental subjects that is statistically significant at p=.05.

Table 4.1
Water Savings Resulting from Installation of Retrofit Devices
(in gallons)

Average Monthly Household Water Consumption

	Pre-installation Period (Oct - Nov 1991)	Post-installation Period (Feb - March 1992)	Difference (Post-Pre)
Controls (n=191)	7,317	7,439	+122
Experimentals (n=111)	7,890	6,541	-1349
		Total Savings	1471 *

Average Daily Per Person Water Consumption

	Pre-installation Period (Oct - Nov 1991)	Post-installation Period (Feb - March 1992)	Difference (Post-Pre)
Controls (n=191)	71.19	73.58	+2.39
Experimentals (n=111)	75.31	63.57	-11.74
		Total Savings	1471 *

Notes: * "Total savings" are calculated as the post-pre difference in water consumption for controls minus that for experimentals.

Table 4.2
Multiple Regression Results:
Effect of "Group" with Reported Decreases in Water Use Controlled

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Equation:

Change in Water Consumption =	.0511	+ .1137x	Reported Decrease	- 1.3786x Group
Standard error	.346	.8026		.5603
t (sign.)	.148	.142		- 2.461*

Correlations:

Simple r (Change in Water Consumption with Group) = -.147*
Partial r (Change in Consumption with Group controlling for Reported Decrease) = -.142*

Notes: "Group" is a dichotomous "dummy variable" that denotes being a member of the experimental as opposed to the control group. "Reported decrease" refers to responses to a survey question, discussed in the text, that concerned perceived major decreases in water use during the study period.

* denotes different from zero at the .05 level of statistical significance.

Table 4.3
Analysis of Variance Results:
Comparison of Actual Water Use between Experimentals Reporting a Major Water Decrease and Those Not So Reporting

	Experimentals Not Reporting Decreased Water Use (n=89)	Experimentals Reporting Decreased Water Use (n=20)
Mean actual water savings (gallons per month)	1499	465

F ratio = .4619 with 1 d.f.

Significance level = .4982 (not statistically significant)

Table 4.4
Results of Regression Analysis:
Group-Water Savings Relationship with Consciousness Controlled

Equation:

Change in Water Consumption =	.072 -	.005 x Consciousness -	.144 x Group
Standard Error	.044	.056	.058
t (sign.)	1.647	-.88	-2.489*

Correlations:

Simple r (Change in Water Consumption with Group) = -.148*
Partial r (Change in Water Consumption with Group Controlling for Consciousness) = -.143*

Notes: "Group" is a dichotomous "dummy variable" that denotes being a member of the experimental as opposed to the control group. "Consciousness" refers to responses to a survey question, discussed in the text, that asked whether one became more conscious of water savings over the last two months.

* denotes different from zero at the .05 level of statistical significance.

Table 4.5
Demographic Characteristics of Control Subjects and of Experimental Subjects Who Installed and Did Not Remove Devices

Characteristic:	Controls (n=192)	Experimentals (n=111)
Length of household residence	5.66 years	5.34 years
Education		
Grade school	0%	0%
High school	11	10
Some college	28	36
College degree	41	33
Tech/Voc school	2	4
Prof/graduate school	18	16
Total family income before taxes (first survey)		
Under $15,000	1%	1%
$15,000 to $30,000	12	10
$30,001 to $55,000	52	55
Over $55,000	36	34
Reported income change during study period		
Yes	16%	9%
No	84	91
Number of persons in household		
Over age 21	2.06	1.99
Ages 13-21	.30	.40
Ages 12 and under	1.01	1.04
Owning/renting home**		
Own/buying	79%	89%
Renting	21	11
Importance of saving water (5-point scale)**	4.25	4.50

Notes: ** denotes a difference between control and experimental subjects that is statistically significant at p=.05.

Table 4.6
Results of Multiple Regression Analysis of
Actual Water Savings on Group with Owning One's Home Controlled

Equation:

Change in Water Consumption =	.7854	- .802x Owning Home	- 1.375x Group
Standard Error	.693	.7495	.5757
t (sign.)	1.134	-1.070	-2.389*

Correlations:

Simple r (Change in Water Consumption with Group) = -.147*
Partial r (Change in Water Consumption with Group controlling for Owning Home) = -.141*

Notes: "Group" is a dichotomous "dummy variable" that denotes being a member of the experimental as opposed to the control group.

* denotes different from zero at the .05 level of statistical significance.

Table 4.7
Results of Multiple Regression Analysis of Actual Water Savings on Group with Attitudes Toward Water Savings Controlled

Equation:

Change in Water Consumption =	.8668 -	.1684x Attitudes -	1.4131x Group
Standard Error	1.4113	.3209	.5773
t (sign.)	.614	-.525	-2.448*

Correlations:

Simple r (Change in Water Consumption with Group) = -.147*
Partial r (Change in Water Consumption with Group controlling for Attitudes Toward Water Savings) = -.144*

Notes: "Group" is a dichotomous "dummy variable" that denotes being a member of the experimental as opposed to the control group.

* denotes different from zero at the .05 level of statistical significance.

Table 5.1
Analysis of Variance Results: Changes in Energy Consumption among Experimental and Control Subjects

	Controls (n=191)	Experimentals (n=111)
Mean Change in Electricity Consumption	301.93	257.07
Standard Deviation	399.53	381.07

F = .9045, 1 d.f.

p = .3423

Note: Tabular entries are in KWH

Table 5.2
Analysis of Variance:
Electricity Consumption in October-November 1991

	Controls (n=192)	Experimentals (n=111)
Mean Electricity Consumption	1510.37	1434.60
Standard Deviation	447.21	423.28

F = 2.0739, 1 d.f.

p = .1509

Note: Tabular entries are in KWH

Table 5.3
Multiple Regression Results:
Effects of Group Controlling for Reported Decreased Water Use

Equation:

Change in Electricity Consumption =	299.16 -	51.46x Water Use	- 31.7x Group
Standard Error	29.19	67.54	47.5
t (sign.)	10.248*	-.762	-.668

Correlations

Simple r (Change in Electricity Consumption with Group) = -.047
Partial r (Change in Electricity Consumption with Group Controlling for Reported Water Use) = -.039

Notes: "Group" is a dichotomous dummy variable that denotes a member of the experimental as opposed to the control group.
"Water use" refers to a reported decrease in water use during the study period in response to a survey question.

* denotes different from zero at statistically significant levels (p=.05).

Table 5.4
Regression Results: Effects of Device Installation on Energy Savings with Consciousness about Water Savings Controlled

Equation:

$$\text{Change in Electricity Consumption} = .224 + .01\text{x More Conscious} - .029\text{x Group}$$

Standard Error	.029	.037	.038
t (sign.)	7.723*	.279	-.759

Correlations:

Simple r (Change in Electricity Consumption with Group) = -.041
Partial r (Change in Electricity Consumption with Group Controlling for Consciousness of Water Savings) = -.044

Notes: "Group" is a dichotomous dummy variable that denotes a member of the experimental as opposed to the control group.
"More Conscious" refers to a reported increase in consciousness about water use during the study period.

* denotes different from zero at statistically significant levels (p=.05).

Table 5.5
Regression Results Concerning Home Owning versus Renting

Equation 1:

Change in Electricity Consumption =	430.1 -	138.6x	Owning Home -	49.71xGroup
Standard Error	57.28	61.82		47.35
t (sign.)	7.51*	-2.24*		-1.05

Correlations:

Simple r (Change in Electricity Consumption with Group) = -.079
Partial r (Change in Electricity Consumption with Group Controlling for Home Owning versus Renting) = -.062

Equation 2:

Change in Electricity Consumption =	457.8 -	173.4x	Owning Home -	158.4xGroup +	125.8xInt
Standard Error	64.9	72.72		124.44	138.18
t (sign.)	7.054*	-2.38*		-1.233	.91

Correlations:

Simple r (Change in Electricity Consumption with Group) = -.079
Partial r (Change in Electricity Consumption with Group Controlling for Other Variables in Equation) = -.074
Simple r (Change in Electricity Consumption with Int) = -.08
Partial r (Change in Electricity Consumption with Int Controlling for Other Variables in Equation) = -.05

Notes: "Group" denotes a dichotomous "dummy variable" that represents being an experimental as opposed to a control subject. "Int" is an interaction term formed by multiplying "Owning Home" and "Group."

* denotes different from zero at statistically significant levels (p= .05).

Table 5.6
Regression Results:
Effects of Group Controlling for Importance of Saving Water

Equation:

Change in Electricity Consumption =	167.87 +	35.73x	Water Saving - 72.08xGroup
Standard Error	116.08	26.42	47.77
t (sign.)	1.45	1.35	-1.51

Correlations:

Simple r (Change in Electricity Consumption with Group) = -.079
Partial r (Change in Electricity with Group Controlling for Importance of Saving Water) = -.090

Notes: "Group" denotes a dichotomous dummy variable that represents being a member of the experimental as opposed to the control group. "Water Saving" refers to the felt importance of saving water; it was measured by a survey question on a 1-5 scale with 5 being most important.

Table 5.7
Analysis of Variance Results:
Controls versus Experimentals Feelings about Energy Savings

	Controls (n=171)	Experimentals (n=110)
Mean Attitudes About Importance of Energy Savings (1-5 Scale)	4.76	4.84
Standard Deviation	.55	.66

F = 1.102, 1 d.f.

p = .2947

Note: The attitude scale was encoded in such a way that a "5" indicated that saving energy was "very important."

Table 5.8
Regression of Change in Electricity Consumption with Change in Water Consumption

Equation:

Change in Electricity Consumption =	290.93	+ 13.61 x	Water Consumption
Standard Error	22.51	4.85	
t (sign.)	12.93*	2.81*	

Multiple R = .16046, F = 7.87579, 1 d.f., p= .0053

Durbin-Watson = 1.9547

Note: * denotes different from zero at statistically significant levels (p=.05).

Table 6.1
Percentages of Experimental Subjects Who Installed Each Device
(n=280)

	Showerhead	Kitchen Aerator	Bathroom Aerator
% Installing	81%	88%	84%

Note: Tabular entries indicate the percentage of experimental subjects who reported on the follow-up survey that they had installed each device.

Table 6.2
Characteristics of Experimental Subjects Who Did/Did Not Install the Showerhead

Characteristic:	Did Install	Did Not Install
Owning/Renting Home		
Own/buying	81%	75 %
Renting	19	25
	(n=248)	(n=40)
Family Income		
Less than $15,000	1%	0 %
$15-$30,000	12	3
$30,001-$55,000	53	60
More than $55,000	33	37
	(n=228)	(n=35)
Education		
High School	10%	7 %
Some College	31	38
College Degree	37	38
Tech/Voc School	5	0
Prof/Graduate School	18	16
	(n=223)	(n=55)
Importance of Saving Water (1-5 Scale)	4.36	4.35
Length of Household Residence	5.29 years	4.88 years
Total Number of Persons in Household	3.31	3.53

Table 6.3
Characteristics of Experimental Subjects Who Did/Did Not Install the Kitchen Aerator

Characteristic:	Did Install	Did Not Install
Owning/Renting Home		
Own/buying	80%	88%
Renting	20	12
	(n=264)	(n=24)
Family Income		
Less than $15,000	1%	5%
$15-$30,000	11	9
$30,001-$55,000	53	68
More than $55,000	35	18
	(n=241)	(n=22)
Education		
High School	10%	3%
Some College	32	38
College Degree	36	41
Tech/Voc School	4	0
Prof/Graduate School	17	18
	(n=244)	(n=34)
Importance of Saving Water (1-5 Scale)	4.37	4.21
Length of Household Residence	5.19 years	5.71 years
Total Number of Persons in Household**	3.41	2.71

Note: ** denotes a difference that is statistically significant at p=.05.

Table 6.4
Characteristics of Experimental Subjects Who Did/Did Not Install the Bathroom Aerator

Characteristic:	Did Install	Did Not Install
Owning/Renting Home		
Own/buying	80%	85%
Renting	20	15
	(n=255)	(n=33)
Family Income		
Less than $15,000	1%	0%
$15-$30,000	11	12
$30,001-$55,000	53	59
More than $55,000	35	28
	(n=231)	(n=32)
Education		
High School	11%	2%
Some College	32	37
College Degree	37	35
Tech/Voc School	4	2
Prof/Graduate School	16	23
	(n=235)	(n=43)
Importance of Saving Water (1-5 Scale)	4.37	4.26
Length of Household Residence	5.34 years	4.44 years
Total Number of Persons in Household	3.38	3.12

Table 6.5
Reasons for Not Installing a Device**

Reason:	Showerhead	Kitchen Aer.	Bath Aer.
Did not fit/no adapter	20	7	13
Did not like it	2	2	2
Did not think it would help	0	1	1
No time	7	1	8
Could not remove old fixture	4	0	0
Did not receive it	2	2	3
Have a water filter or fixture	1	3	0
Plumber would have to do it/lack tools	5	1	1
Did not work	0	0	2
Already had one	4	0	1
Inconvenient	3	0	1

Notes: table entries are numbers of responses. Multiple answers per subject are possible.

Table 6.6
Percentages of Subjects Reporting Problems in Device Installation

Problem?	Showerhead	Kitchen Aer.	Bath Aer.
Yes	29%	3%	6%
No	71	97	94
n of cases	237	239	237

Table 6.7
Major Reasons for Removal of Devices

Reason:	Showerhead	Kitchen Aer.	Bath Aer.
Not enough water pressure	8	0	11
Did not like it	3	0	1
Did not fit	4	0	0
Made faucet leak	5	1	4

Note: Tabular entries are number of responses.

Table 6.8
Satisfaction with Each of the Retrofit Devices

	Showerhead	Kitchen Aer.	Bath Aer.
Very Satisfied	62%	86%	73%
Somewhat Satisfied	29	11	22
Not Satisfied	8	3	4
Unsure	1	0	1
n of cases	228	245	236

Table 6.9
Reported Beliefs that Family Has Saved Money as a Result of Installating the Retrofit Devices

Question: "In the last 2 months do you believe that your family has saved money as a result of installing the retrofit devices?

Yes	58%
No	22
Unsure	21

n of cases = 111

Note: Percentages are based on experimental subjects who installed all three devices at the start of the study period and who did not remove them.

Table 6.10
Beliefs among Experimentals and Controls about Changes in Water Use

Question (Second or Follow-up Survey): "In the last two months do you think that your home water use has increased, decreased or stayed the same?"

	Experimentals (n=111)	Controls (n=190)
Increased	7%	10%
Decreased	53	23
Stayed the same	32	66
Unsure/Not answered	8	0

Notes: Experimentals are those who installed all three devices at the outset of the study and did not remove them. The differences between experimentals and controls are statistically significant: Chi-square=44.92, p,=.001.

Table 6.11
Reported Feelings of Becoming More Conscious of Water Savings

Question (second or follow-up survey): "In the last two months have you become more conscious about saving water?"

	Experimentals (n=111)	Controls (n=190)
Yes	72%	48%
No	23	47
Don't know	5	5

Notes: Experimentals are those who installed all three devices at the outset of the study and who did not remove them. The differences between experimentals and controls are statistically significant: Chi-square = 16.99, p=.0002.

Table 7.1
Water Use in Experimental and Control Apartments: Pre- and Post- Device Installation

	Pre-installation		Post-installation	
	Aug 1991	Sept 1991	Aug 1992	Sept 1992
Experimentals (n=776)	4230.4*	3730.3	3165.7	3371.0
Controls (n=320)	1498.0	1225.9	1385.1	1583.4

Differences (Post-Pre):

Experimentals	-1424.0
Controls	+ 244.6

Percentage Change (Difference/Pre-installation Amount):

Experimentals	-18% (or Water Savings=18%)
Controls	+ 9% (or Water Savings=-9%)

Note: * pre-installation and post-installation numbers are in thousand (i.e., 000) gallons.

Table 7.2
Natural Gas Consumption in Experimental and Control Apartments: Pre- and Post-Installation
(in 000 cubic feet)

	Pre-installation Feb 1992	Pre-installation Mar 1992	Post-installation Aug 1992	Post-installation Oct 1992
Experimentals (n=776)	1802.0	1688.0	1022.0	1176.0
Controls (n=320)	642.0	606.0	432.0	506.0

Differences (Post-Pre):

Experimentals	-1292.0
Controls	-310.0

Percentage Change (Difference/Pre-installation Amount):

Experimentals	-37% (or Energy Savings=37%)
Controls	-25% (or Energy Savings=25%)

Percentage Difference in Energy Savings Associated with Retrofit Device Installation = 12%