Some Best Bets in Residential Water Conservation

Results of Multivariate Regression Analysis, City of Phoenix, 1990-1996

FINAL REPORT

Presented to:
Arizona Department of Water Resources (ADWR)
In compliance with deliverable #4, ADWR Grant # CA96PHM40-00

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May 1999

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Acknowledgments

We gratefully acknowledge the assistance of members of the City of Phoenix, especially Tom Babcock and Shannon Autwell of the Water Services Department, and Jeff DeWitt and Scott Willett of the Finance Department. Without their willingness to share their data and help us in developing a dataset, this research would not have been possible. They deserve commendation as true public servants, continually seeking information that may help them do their jobs better in the future.

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Executive Summary

In a rapidly growing desert metropolis such as Phoenix, the question of which water conservation measures and factors actually save water and which do not is an obviously important one. The water-related decisions made today and in the years to come will have lasting impact on the future of this area, including upon its sustainability. Estimates from the City of Phoenix suggest that, in non-SRP-areas, water demand will exceed water supply by the year 2025 – absent droughts or intervention.

This report documents and analyzes the results of a multivariate regression analysis designed to estimate the effects on residential, single-family water consumption of a host of factors, particularly water conservation policies. In the analysis, five major categories of variables are analyzed, as follows:

1) City of Phoenix conservation measures and programs;
2) Water pricing;
3) Climate;
4) Attributes of persons living in the household; and,
5) Attributes of the physical infrastructure of the household.

Forty-one variables control for these five causal categories, and the analyzed dataset is comprised of over 200,000 monthly observations of over 19,000 individual accounts during the years 1990 through 1996. Thus, the size of the dataset and comprehensiveness of the model allow high confidence in the findings.

Major Findings

- Water price can be an even more effective conservation method than the most effective non-price method. A mere 10% increase in the price of water can save 0.54 units per month per household. Assuming roughly 278,000 single-family residences in the City of Phoenix, a 10% increase in real price could result in a water savings of over 1.8 million units (over 1 billion gallons) per year.[1]
    - In a related finding, including units of water (at zero volume price) in the mandatory service charge causes an increase in water use. This underlines the importance of pricing water for conservation.

- A citywide ordinance mandating water-saving devices for all new and replacement fixtures overall saved the most water of any non-price conservation policy. It is estimated to save on the order of 20 million gallons per year (about 0.008 units of water per household per month).

- Targeted retrofit programs are the next most promising category of policies and measures analyzed.
    - Seniors Helping Seniors, a program using trained seniors to assist the elderly, poor, or disabled to retrofit their homes with water-saving devices saved the

[1] A "unit" of water is equal to 748 gallons.

most water per participant (more per participant than the ordinance – about 0.012 units per month – but less overall).
    - Metrotech / Neighbors Helping Neighbors, a program similar to the Seniors program, but using trained high school kids to assist lower income householders, saved the next most water per participant. Audit Follow-up, a program that taught householders how to do their own audit and then gave them hardware if they sent back a card showing they needed it, saved as much as the Metrotech program.

- Retrofit programs not based on some indication of need are not good bets.

Secondary Findings

- *Poor residents are estimated to use more water than wealthier residents do.*
    - This was expected by some local water experts and implies that conservation policies should be targeted toward those who are poor.

- *Young adults (those 17-24 years old) use more water than any other age group. A 1% increase in the census tract percentage of 17-24-year-olds is predicted to increase water use by 0.18%.*
    - This was expected by some local water experts and implies that perhaps water conservation programs specifically designed for young adults should be developed.

- *There is some evidence that water conservation education programs targeted toward children are effective.*
    - For the purpose of testing this hypothesis, we included a measure of the presence of children in the household, and found that, as the likelihood that a household has children increases, the household use of water declines significantly. Though an imperfect measure, this is encouraging.

- *There is some evidence that general education efforts (e.g., billboards and public service announcements) are effective.*
    - In order to test this hypothesis, we included a measure of having lived in Phoenix for a long time, and found a decrease in water use. Again, this is encouraging, though it is not a very good measure.

Cost data were not available, so we could not estimate water savings per dollar spent, which would be the next step in determining how a water provider should want to spend its resources. Further, since we were only able to analyze City of Phoenix data, not all types of programs in use in the Phoenix AMA have been analyzed, meaning that there may be more best bets still to be found. Nonetheless, the large dataset and comprehensive model allow confidence in the estimates of which programs save water, how much they save, and identifies which of these analyzed are among the best bets.

Introduction

Beginning in 1996 and continuing into 1997, a team of ASU researchers (including a group of researchers from the Morrison Institute for Public Policy and Professor Heather Campbell from the School of Public Affairs) collected data for the Arizona Department of Water Resources (ADWR) regarding the wide variety of programs and policies used to conserve residential water by municipalities and other water providers in the Phoenix Active Management Area (AMA).

Upon the completion of this grant (Phase I), ADWR initiated a second grant with the ASU team (Phase II) with the goal of developing a multivariate regression model that would allow estimation of "best bets" – policies and programs which, of all those identified, had been the most effective water conservation measures for residential, single family dwellings in the Phoenix AMA.

Multivariate analysis is superior to other analysis techniques (Kieffer, 1996) because it allows direct comparison among conservation measures while controlling for other factors known to be important. In other words, multivariate regression enables the isolation of the effect of the different conservation measures, and most directly answers the question of which actually save residential water. It also allows quantification of the amount of water savings to be expected, holding constant the effect of other factors that effect water use.

In pursuit of this goal, the ASU team designed a multivariate regression model to analyze a series of datasets provided by the one local provider (the City of Phoenix) who was willing and able to provide sufficient data. This report provides a brief overview of the method used to obtain estimates of water conservation best bets, and overviews the findings. Appendices describing the methodology in more detail and providing tables describing the data and estimates follow the main report.

A Brief Overview of the Method

Using knowledge garnered during Phase I and Phase II from literature review and interviews with Phoenix AMA water conservation experts, the ASU team developed a theoretical model of the causes of residential water consumption, the dependent variable to be explained. The following broad areas are expected to effect residential water consumption:

1. non-price conservation measures and programs;
2. water pricing;
3. climate factors;
4. attributes of persons living in the household; and,
5. physical infrastructure of the household.

Working with the City of Phoenix, a dataset was developed that allowed for the measurement of over 40 variables within those five categories. The dataset included more than 19,000 City of Phoenix water accounts observed during the period from January of 1990 through December of 1996. For each account, at least 12 months of data were observed, resulting in over 200,000 observations in this pooled cross-sectional model. Some conservation policies were citywide and varied with time, while others varied with household. Of the 19,000 accounts sampled, nearly 12,000 had participated in a household-specific conservation program.

Due to the large size of the dataset and the large number of residential water-use factors controlled for by it and the model, confidence in the results should be high. Organized by the five broad categories given above, the next sections describe the estimation results and their implications.

Note: Throughout the following discussions, please remember that the estimates given are for the independent effect of each variable on the dependent variable. That is, it is the effect of that variable holding constant all other variables. Thus, if we discuss the effect of poverty, it is the effect of poverty independent of household size and race – in short, independent of the effect of all other variables included in the model.

Throughout the discussions that follow, this is only mentioned when it seems likely to be especially confusing, but it is always true.

Discussion of
Variables Related to City of Phoenix Conservation Programs and Measures

During the period under study, the City of Phoenix had in operation a number of water conservation programs, some targeted to specific households, and some delivered citywide. This section briefly describes each of the conservation programs for which we could observe sufficient variation (either across accounts or across time) to allow estimation of effects. Next, results and their implications are given. At the end of this section, some overall interpretation is provided. Programs are generally listed in descending order of effectiveness in saving residential water.

Ideally, each conservation measure would result in water savings, leading to hypotheses that the signs of the estimated coefficients will be negative.[2]

Seniors Helping Seniors Program

From 1989 through 1995, the City of Phoenix initiated a program in which persons who were elderly, at 125% of poverty or below, or disabled were provided with hardware retrofit assistance in their homes by trained senior citizens. A total of 4,941 households had retrofit devices installed through this program. *Program Caveats*: Though we know that these retrofits were actually conducted in the homes, we cannot know whether the devices were removed, either immediately or later.

For these households, the regression estimates monthly water savings of 0.06%. The average residential monthly household water use in the data was about 20 units. A "unit" of water is 748 gallons. Thus, Seniors Helping Seniors is expected to have saved 0.012 units per month – about 9 gallons per month and about 108 gallons per year per household receiving this program. To put this amount of water into some more concrete terms, non-conserving toilets use 5.5 gallons per flush, while those in compliance with the 1990 Low-Flow Fixtures and Devices Ordinance use 1.6 gallons per flush; non-conserving shower heads put out 5 gallons per minute, while those in compliance put out 2.5 gallons per minute.[3]

Of City of Phoenix water conservation programs and measures, Seniors Helping Seniors saves the most water per program recipient.

Low-Flow Fixtures and Devices Ordinance (phase II and phase III)

The Phoenix City Council passed a low-flow fixtures and devices ordinance, to be implemented in three phases from January of 1990 through January of 1992. The ordinance required that all new and replacement fixtures meet low-flow requirements. *Program Caveats*: In 1992, a similar Federal Law was promulgated. The effect of this law is unclear since it was never funded or enforced.

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[2] For almost every variable included in the model, a sign prediction (hypothesis of the direction of effect) was made. All sign predictions are shown in Table 2.

[3] Data on water use rates were provided by the City via the table "Allocation of Indoor Water in Phoenix Homes, Gallons Per Capita Per Day (gpcd)."

The results indicate that the second phase of the ordinance saved roughly 0.04% per month per residence over the whole city, and phase III of the ordinance saved an additional 0.001% per residence across the city. This estimate implies 0.008 units saved per household per month or 0.096 units per household per year (for the average household of 20 units per year).

The Low-Flow Fixtures and Devices Ordinance phase II saved the second most water per participant among the programs studied. However, in this case "participants" are all single-family residences in the city. In 1998, there were roughly 278,000 single-family residential accounts in the City of Phoenix. Thus, according to the regression estimate, the city's Low-Flow Fixtures and Devices Ordinance has saved over 26,000 units per year since it's phase-in (roughly 20 million gallons of water per year). All told, between the ordinance's phase-in in January 1991 and the end of 1996 (the end of the study period for this analysis) an estimated 130,000 units of water have been saved.

Metrotech/Neighbors Helping Neighbors Program

In 1994, the City of Phoenix initiated a program similar to Seniors Helping Seniors whereby students from Metrotech High School helped to install retrofit devices into low-income homes. A total of 278 households had retrofit devices installed through this program. *Program Caveats*: Similarly to the Seniors Helping Seniors program, we are confident that the Neighbors Helping Neighbors retrofits were actually conducted in the homes; however we do not know if the devices were removed either immediately or later.

Among these households, the regression revealed monthly water savings of 0.02%.

Unsolicited Audit Kits

In 1993 through 1995, kits for self-administered water audits were sent to households (this program could only be measured as to whether it was or was not in effect citywide). After conducting a brief self-audit, the household could fill-out a card and reply to the city. In return, the household could receive water-conserving fixtures and devices. Alternatively, households could simply use the information on their own.

The regression estimated the sending out of these kits and the cumulative action taken in response by individual households to yield a 0.002% per month water savings over all households.

Audit Kit Follow Up

For those households that followed up and returned the reply card following their self-audit, hardware was sent. *Program Caveats*: It should be noted that while the City of Phoenix was able to indicate which households were sent the follow-up hardware, it is virtually unknown which households actually installed the hardware.

The regression revealed that these households which were sent water-saving devices saw an additional water savings of 0.02% per month (over the amount estimated for unsolicited audit kits noted above). This program ties with the Metrotech program for third most effective per program participant.

Retrofit Device Canvassing

In 1989 through 1991, the City of Phoenix dropped off around 8,000 hardware retrofit kits at residential water customers' households. *Program Caveats*: It should be noted that – as with the audit kit follow-up noted above – it is unknown how many households actually installed the devices which were dropped off.

The regression revealed that this program yielded a very modest savings of 0.001% in monthly residential water use per recipient.

Other Programs and Measures

We should also mention those programs that do not seem to be good bets for single-family residential water conservation. Phase I of the Water Ordinance, the Brochure Program, Water Waste Ordinance, Book of Seeds, Union Hills Plumbing Products Drop-Off, and Depot Plumbing Products Pick-Up were not estimated to save water (brief descriptions of these programs can be found in Appendix B).

Distressingly, the Union Hills and Depot programs were actually estimated to cause additional water usage on the same order of magnitude as the savings of several of the best programs. The Union Hills drop-off program was estimated to have caused 0.04% monthly increase in water use. Similarly, the Depot pick-up program was estimated to have caused a 0.05% monthly increase.

How could this be? Though the fact that several of the City's water conservation programs seemed to cause water use is discouraging, it is consistent with some literature, including some research specific to water use. Some policy literature suggests that people engage in off-setting behavior when asked to consume more of a good – such as safety – than they normally would (Chirinko and Harper, 1993). Further, Geller, Erickson, and Buttram (1983) note that water-conserving hardware can have differential effects, suggesting that water savings occur when people didn't know they had conserving hardware, but may not when they know they do. It appeared that people took longer showers when they knew their showerheads were water saving, an example of offsetting behavior. Also, though there has been much improvement in the function of water saving hardware, people often feel the need to "flush twice" with low-flow toilets and other water conserving devices, thus negating the possible savings yielded by these products. The size of the positive magnitudes revealed in this analysis for the City's Union Hills Drop-Off and Depot Pick-Up programs tends to support the idea that, for these programs, people must have initiated some off-setting (water-consuming) behaviors when they installed these devices. Though these positive magnitude findings seem discouraging, they are exactly the types of findings that led ADWR to fund this research in the first place. We know these devices save water in the laboratory, but the ultimate question is whether or not they save any water given aggregate human behavior.

An Overview of Findings Regarding These Programs

For virtually all of the City of Phoenix programs and measures which were estimated to save water, the magnitudes of saving are small, ranging from a low of –0.001% per month per household to a high of –0.06% per month per household.

The two greatest water savers in magnitude – the two “best bets” – are the Seniors Helping Seniors program (water savings of 0.06% per month, per household in the program), and the second phase of the Low-Flow Fixtures and Devices Ordinance (water savings of 0.04% per month per household, citywide). Tying for third are the Metrotech / Neighbors Helping Neighbors program and sending devices in response to self-audits (Audit Kit Follow Up).

In contrast, worst bets were the Union Hill Drop-Off and the Depot Pick-up.

In some sense, the Union Hills Drop-Off, Depot Pick-Up, Seniors Helping Seniors, and Neighbors Helping Neighbors programs are all similar – namely, plumbing hardware retrofit programs. How, then, should we interpret the opposite water savings results? Due to the large size of the sample and the high level of control for factors known to affect water consumption, we have good confidence in the estimates produced by the model. Therefore, we need to consider what other elements might be causing the effects of these programs to be different.

Union Hills Drop-Off was a government-initiated blanket program, distributing hardware virtually on every doorstep, while the Depot Pick-Up program required an act by some member of the household. Both are estimated to cause additional water usage Therefore, it does not seem that the difference is government behavior versus individual volunteer behavior (self-selection is not the issue).

The Seniors Helping Seniors and Neighbors Helping Neighbors programs – both of which caused water savings – had an individualized touch, however. Someone actually physically came into the household and helped install the water-saving fixtures. In addition, both programs targeted those who were likely to be on lower or fixed incomes (as discussed later, the regression estimated that households at or below the poverty level use more water than middle- and upper-income households, perhaps because they are less able to afford to save water). The Audit Kit Follow-up program also had an individualized touch since it required individuals to perform their own need assessment and then provide that to the City to receive water-saving hardware.

Overall, this portion of the analysis indicates that the city-wide ordinance saved the most water city-wide, but that hardware retrofits targeted based on some assessment of need are also best bets among residential water conservation programs and measures. Untargeted hardware programs – whether voluntary or not – should be avoided.

Discussion of
Variables Related to Water Pricing

Water prices and pricing structures have obvious policy relevance. Simple economics suggests that, as the price of a resource such as water increases, consumption should decrease. This makes it possible to use price itself as a conservation measure.

Indeed, many policy analysts and economists argue that the most efficient and effective technique for conservation would be to price water appropriately; that is, at a rate which reflects the true opportunity cost of the water used, including costs associated with future lack of water as a region continues to grow. And, the City of Phoenix considers its most recent water pricing structure – which seasonally adjusts water price to reflect seasonal City costs – to be a conservation structure.

For its analysis of City of Phoenix residential water use, the ASU team measured water pricing through the use of four variables: a measure of water included in the mandatory service charge; the real water volume charge (the price charged for units of water above and beyond the minimum included in the service charge); the real environmental charge (a small environmental fee charged for all water used); and the real sewer charge (explained below).

Water Included in the Service Charge

Early in the study period (1990-1996), the City of Phoenix charged for all water used by residential customers. This policy was changed, however, in mid-1990. Starting on June 1, 1990, the mandatory monthly service charge included up to 6 units of water during the months of October through May, and up to 10 units of water during June through September (before, the mandatory service charge included no water). Under the new policy, only units of water above those included in the mandatory service charge were priced (again, a unit of water is 748 gallons).

The ASU team hypothesized that – holding volume charges constant – the change from the old system to the new system should have increased water use because the effective price of the units included in the mandatory monthly service charge was reduced to zero.

As expected, the number of gallons included in the mandatory service charge was estimated to have a fairly large and positive effect on water consumption (i.e., it seems to cause more water use). Here, a 1% increase in the amount of water included in the service charge is expected to increase water use by about 0.2%.

The increase from 6 units (non-summer) to 10 units (summer) included in the service charge is a 66% increase. The regression estimate implies that this increase in what might be considered "free" water results in a 13.2% increase in water consumption. Please note that the climate variables of precipitation and evapotranspiration (which includes a measure of heat degrees) are controlled for, so this estimate should be close the effect from the change in water included in the service fee only.

Real Water Volume Charge

The real water volume charge measures the price of the water used above and beyond the water included in the minimum service charge. The ASU team hypothesized that increases in this variable (i.e., price) would decrease water usage.

Even given the very low prices for water charged by the City of Phoenix during our time period (even in nominal dollars, the variable only ranges from a low of 74 cents per unit to a high of $1.45; in real dollars, it ranges from 44 to 89 cents per unit), a 1% increase in the price of water over the amount included in the service charge was estimated by the regression to cause a 0.27% decline in water usage (the price elasticity of demand is - 0.27).

Thus, according to the estimate, a modest 10% increase in the price of water could save 2.7% of each household's monthly water use. For the household average of 20 units per month, this is 0.54 units saved per month, or 6.48 units saved per year per household (4,847 gallons). Assuming approximately 278,000 single-family residences in Phoenix, a 10% increase in the price of water could result in a saving of over 1.8 million units per year. It should be noted that these estimated savings are more than an order of magnitude greater than the savings estimated for the best water conservation program in this analysis.

Real Environmental Charge

During a portion of the period studied, the City of Phoenix charged an "environmental" fee on all units of water (including those included in the service charge). This charge is very small, in nominal terms varying between 4 and 8 cents per unit during the study period. As with all price variables, the ASU team expected that increases in this charge would result in a decrease in water usage.

The regression, however, revealed an estimated positive sign of the coefficient for the real water environmental charge (in other words, the fee actually seemed to cause water consumption). Obviously, it does not make sense that an increase in the environmental charge could cause an increase in water consumption. Therefore, we interpret this result as indicating that the environmental charge was not visible to residential consumers; either they did not notice it, or did not respond to it, or both. With such a small charge – per 748 gallons – this is plausible.

Real Sewer Charge

In the City of Phoenix, the residential sewer fee for the whole year is based on average water usage during a three-month period. Thus, during those three months, it may simply seem to the consumer as if an additional water charge is added. The ASU team expected that increases in this variable would decrease water usage.

The actual additional price of water implied by the sewer charge is very small, but it is also estimated to have a negative impact on water use (price elasticity of demand = -0.04), giving further credence to the idea that price can be an effective water conservation tactic.

Overall Discussion of Pricing

Given the order of magnitude of the estimated effects relative to those of other water conservation measures, water pricing should certainly be considered a best bet. Modest increases in price can cause citywide decreases in water consumption that are larger than effects estimated for any specific water conservation program analyzed here. Including non-volume-priced water in the mandatory service charge, however, is not a best bet.

Discussion of
Variables Related to Climate

Climate factors are expected to influence the outdoor component of residential water use. Though most City of Phoenix programs analyzed here target indoor water use, outdoor water use is a significant portion of overall household consumption.

The two factors included in this analysis were evapotranspiration (a variable related to the amount of heat and evaporation occurring in the local environment) and precipitation, or rainfall. Evapotranspiration is a measure of consumptive use of water by vegetation, and is measured as a function of solar radiation, temperature, and dryness (AZMET).

Evapotranspiration

Based on a review of literature and interviews with water expert, the ASU team hypothesized that – controlling for all other factors – higher levels of evapotranspiration will cause residential water use to rise. To control for this climate factor, monthly evapotranspiration data (ET) from the weather station closest to each water account's location was included in the regression.

The coefficient revealed by the regression for evapotranspiration data was, as expected, positive and relatively large (0.464), meaning that – true to the hypothesis – people use more water when hotter and dryer conditions exist. A 1% increase in measured ET is predicted to cause a 0.46% increase in monthly water use.

Precipitation

Higher levels of precipitation (i.e., rainfall) are expected to decrease water use among residential customers because of a perceived lesser need to irrigate the landscape. To control for this climate factor, monthly precipitation data from the weather station closest to each water account's location was included in the regression.

As hypothesized, the model produced a negative coefficient (-0.001) for the precipitation variable. However, the coefficient is quite small , implying that a 1% increase in the amount of rainfall in a month will decrease monthly water use by 0.001%. Of course, in our region some months may have no rain, while other months may have a couple of inches. Going from a month with one inch to a month with two inches would be a 100% increase, implying a 0.1% decline in water use. One possible factor in the small size of the estimate is the effect of irrigation timers – some experts expect that that people often do not alter or turn off their automatic irrigation timers in response to natural precipitation.[4]

Overall, these estimates can be seen as checks on the model and estimates. At the least, we should expect these coefficients to be estimated with the theoretically correct signs, and they are. This should give us additional confidence in the study.

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[4] This hypothesis is proposed by Bill Mee, based on analysis he did while working for the City of Phoenix Water Services Department.

Discussion of
Variables Related to the Persons Living in the Household

During phase I of the ASU teams study of water conservation in the Phoenix AMA, interviews with dozens of local water experts and a comprehensive literature review were undertaken. These information sources suggested a number of household-specific factors that are expected to effect household water use. In some cases, these factors have policy relevance; in others, they do not, but they need to be included as controls so that the estimates of policy interest are unbiased.

This section provides commentary on factors related to the persons living in the household, and the next section discusses how the physical attributes of the household might affect water consumption.

Household-level variables pertaining to persons are measured at the census tract level using 1990 Census data.[5] Therefore, these variables are proxies that can be though of as measuring the probability that the account under study has the attributes in question. For example, if the tract percent of households with children rises, then the likelihood that the particular household analyzed has children present rises.

Households With and Without Children Present – Possibly Policy Relevant

Many conservation experts interviewed during Phase I felt that youth education efforts are among the most effective conservation programs. Though the ASU team wanted to measure this effect to the extent possible, youth education programs were not specific City of Phoenix programs during the period. The best measure we could come up with a measure of the percent of households in the tract with children present. If youth-oriented water-conservation messages are learned, children may conserve and encourage conservation at home. We realized that this measure is tenuous, and also that another reason households with children might use less water is that parents of children may be more conservation-minded either to 1) be good role-models for their children, or 2) because they are concerned about the future in which their children will have to live someday. However, because we included this measure in order to estimate the effectiveness of youth-oriented conservation measures, we felt that a negative coefficient would provide cautious support for the hypothesis that youth-oriented water-conservation messages are effective.

The coefficient for percent of households with children is negative and fairly large compared to those for other water conservation programs: a 1% increase in households with children is estimated to cause a 0.31% decrease in water consumption. Thus, if the tract percentage went from 70% to 77% (interpreted as the likelihood that the actual account we observe has children), it is expected that the household would consume 3.1% less water. In the case of the average household use of 20 units per month, this results in yearly savings of about 7 units per household.

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[5] The City, of course, does not keep private information on its account holders. They do keep tract-level data, which they provided to us matched to accounts.

Though we cannot be sure of the exact cause of the water saving in households with children, the findings support cautious optimism that child-targeted programs involving water conservation are effective in saving water at home.

Those Who Have Lived In Phoenix for a Long Duration Vs. Those Who Have Not– Possibly Policy Relevant

General education messages sponsored by local municipalities and water companies (billboards, public service announcements, etc.) might be considered "unmeasurable" water conservation programs because of the obvious difficulty in quantifying how such messages affect individuals who are exposed to them. However, to the extent that these messages are effective, it is reasonable to assume that those who have been exposed to them longer (i.e., those who have lived in Phoenix longer) should be more conservation-minded, all else being equal.

To test this hypothesis, the ASU team used US Census data to match water account information with data related to the percentage in the census tract who lived in the same residence in 1985 (this is a proxy, the best available to us, for having lived in Phoenix for a long duration).

The coefficient related to percent having lived in Phoenix during the previous five years is negative (-0.056), providing some evidence that general education efforts such as billboards and public service announcements have a beneficial effect.

Those Who Have Lived in the West (but not the same house) Vs. Those Who Have Not

Some water experts and literature suggest that, in general, those who have lived in the arid Western US states have had a "conservation ethic" instilled in them regarding the scarce resource of water. Because of this ethic, it is hypothesized that people who have lived in the West prior to moving to Phoenix will be more conservation-minded than persons from other, generally less-arid, regions of the US

To control for this variable, the ASU team used US Census data to match water account information with data related to the percentage of households in the tract that indicated they had lived in another house but in a Western state (including in Arizona). We consider this a proxy for living in the West, but not in Phoenix (though there may be some few people who lived in Phoenix, but not in the same house).

Percent having lived in a Western US state is also negative and fairly large (0.16), implying – as the hypothesis suggests – that Westerners are more conservation-minded than others are. Taken in conjunction with the earlier (longer-term resident of Phoenix) variable, this indicates that Westerners are more conservation minded but, even holding that effect constant, longer-term residents of Phoenix conserve additional water. Again, this provides cautious optimism for general City of Phoenix conservation messages.

Race/Ethnicity of Household Members – Possibly Policy Relevant

Racial and ethnic factors may affect water use for a variety of reasons. Some researchers expect that minorities are more alienated from government, and thus are less willing to accept governmental messages (i.e., to conserve water). Further, some believe that cultural differences may cause differential water use between different cultural groups. Therefore, to the extent that some households in our area – particularly Hispanic– do not speak English as a primary language in the home, it is possible that those households may be receiving fewer conservation messages (i.e., water bills in English, fewer public service announcements and billboards in Spanish, etc.).

To control for this individual household factor, the ASU team used US Census data to match water account information with data related to the percentage in the census tract who identify their race as "Black," the percentage in each census tract who identify their ethnicity as "Hispanic," and the percent in each tract who identify their race as "Other (non-White)." This makes "White" the omitted, reference, group.

The regression revealed that for our region, it can be assumed that Blacks use the same amount of water as non-minorities (i.e., White / Caucasian). However, Hispanics are estimated to use more (coefficient estimated at +0.1) water than White / Caucasians, as are those who identified their race as "Other (non-White)" (coefficient estimate = +0.01).

Considering how different the Hispanic effect is from effects for other minorities, and considering this in tandem with the education effect (below), it may be that these two variables are picking up the effect of non-English speaking households. Ideally, one would measure this directly.[6]

With the possible exception of Hispanics, this analysis does not support the idea that minorities in general are more alienated and thus less responsive to governmental messages. It does suggest the possibility that either Hispanics are more alienated, that there are cultural differences in water use, or, possibly, that more Spanish water-conservation messages would be useful. This suggests that it may be worthwhile to study Hispanic water use in order to understand what factors are causing it to be higher. This would allow the development of Hispanic-targeted water conservation measures.

Household Income and Poverty – Possibly Policy Relevant

It has been suggested that – holding all other factors constant – poor families may use more water because they lack the resources necessary to fix leaks and pay for upgraded, lower-water-consuming, fixtures and devices. The idea here is that it takes money to effectively save money.[7]

[6] The City of Phoenix was unable to provide these data.

[7] Tom Babcock, Water Resource Specialist, Water Service Department, City of Phoenix is a proponent of this expectation.

To test this hypothesis, the ASU team used US Census data on the percentage in the census tract that reported an income below the poverty level, and also a separate measure of tract average income.

Holding constant the tract average income, as tract percent in poverty increases, the amount of water used is estimated to increase, with a 1% increase in those below the poverty level expected to lead to a 0.01% increase in the amount of water used by the household. This supports the idea that poorer household cannot afford to conserve water, and supports the concept from the first section that targeted retrofit programs can save water.

In accord with this finding, holding constant other attributes of wealth (such as value of the house, discussed in the next section), increases in tract average income is estimated to decrease water use per household.

Taken together, the estimates for these two variables plus those for the Seniors and Metrotech program imply that targeted programs may best target those with lesser incomes.

Average Household Size

Number of persons living in the household is expected to be an important indicator of household water use, with more persons using more water.

As hypothesized, the estimated coefficient was positive and fairly large (0.35), implying that a 1% increase in the number of persons expected to be in the household (expected based on tract percent) increases water consumption by 0.35%.

Here again, the sign of the coefficient being as expected should increase confidence in the model.

Ages of Household Members

A supposition among several Phoenix-area water experts is that people use different amounts of water at different times of their lives. In particular, it is thought that young adults (those aged 17-24) use more water than other age groups.[8]

To control for this individual household factor, the ASU team used US Census data to match water account information with data related to the percentage in the census tract aged 17-24, the percent of the tract aged 25-64, and the percent of the tract aged 65 or older. It was expected that young children under age 17 would use the least water, which is why that group is omitted, and is thereby the reference group.

The results of the regression imply that – true to the hypothesis – young adults use the most water of any age group. The model estimated that a 1% increase in the tract percent of persons aged 17-24 increases water use in that tract by 0.18%. Persons aged 65 and older use roughly the same amount of water as children under age 17, while adults between 25 and 64 used the least water (estimated coefficient –0.1).

[8] In particular, Ann Testa, City of Mesa, expects this effect to be important.

Female- Vs. Male-Headed Households

According to some researchers, females are more conservation-minded than males. In dual-headed households, this hypothesis cannot be tested. If the hypothesis is supported, female-headed households should use less water than dual-headed households (the reference group) should and also less than male-headed households. The coefficient produced by the regression for female headed households (-0.046) suggests that the hypothesis is correct, that female-headed households use less water than dual-headed households do. However, it should also be noted that male-headed households also use less water (-0.032) than dual-headed households, according to the estimates. The reason for this single-headed effect is unclear; variables controlling for numbers of persons in the household, ages of persons in the household, and household income are included, so the water-conserving effect of single-headed households are estimated holding constant those other explanations.

The coefficients do suggest that female-headed households are the least water-consuming households among the following three types: dual-headed, male-headed, and female-headed.

Educational Attainment

During the phase I grant, some of the literature and several local water experts suggested that – all else being equal – those who are more educated are more conservation-minded. To control for this individual household factor, the ASU team used US Census data to match water account information with data related to the percentage of heads of households in the tract with a high school diploma but less than a bachelors degree, and the percentage of heads of households in the tract with a bachelors degree or more.

The coefficients revealed by the model indicate – consistent with the hypothesis – that those with more education are predicted to use less water than those with less education. It is interesting to note, however, that most of the effect is for those with an education greater than a high school diploma but less than a bachelor's degree (-0.1). Increasing the incidence of those with a BA or more is predicted to lead to a lesser decrease (-0.04).

Renters Vs. Owners

There are several thoughts on the differences between renters and owners and their water use. If renters pay the water bill, they may be likely to neglect watering the landscaping to save money, while those who own their home may be more concerned with preserving the external look and value of their home. Conversely, if water is "included" in the monthly rent paid by a renter, that person may be inclined to use water freely (perceiving the price as zero). Because it was not possible to differentiate among renters who pay for their water and those who have their water "included" in their rent payment, coefficient estimates for this variable are not particularly interesting, but a measure needed to be included as a control.

The results imply that persons who own their home use slightly more water than renters (+0.009).

Discussion of
Variables Related to the Physical Infrastructure of the Household

Many attributes of the physical infrastructure should effect water consumption. For example, the size of the yard, the presence of water-using features, or the age of the fixtures inside the house. To measure physical attributes, we used four variables.

Number of Bedrooms/Bathrooms

It is reasonable to assume – all else being equal – that those households with more bathrooms will consume more residential water. Because the US Census collects data on the number of bedrooms in a household, but not the number of bathrooms, the ASU team chose to use US Census data concerning the tract average number of bedrooms as a proxy for the number of bathrooms.

As expected, the model estimated that, as the number of bedrooms (again, a proxy for bathrooms) is expected to increase, the amount of water used increases, with a 1% increase in the number of bedrooms predicted to lead to a 0.35% increase in water.

House Value

It is reasonable to assume that more valuable homes will have more water using features than will lower-value homes. Indeed, more expensive homes often have more land (and thus larger landscape areas), more bathrooms, and more frequently have a feature such as a swimming pool, or even a fountain. Thus, the ASU team used US Census data on tract average home value.

All else being equal, houses with higher expected value were estimated to use more water to the following extent: each 1% increase in the average home value in the census tract is predicted to increase water use by 0.57%.

Age of House

During the last decade, Greater Phoenix has seen a trend toward smaller lots for new single family homes. Because of this trend – and the concurrent increase in the desirability and use of low-water use xeriscape landscaping – it is assumed that newer homes have less landscape, and thus require less water. In addition to smaller lot size, it is believed that newer homes are generally more water conserving because of technology; plumbing codes now require the installation of "state of the art" water efficient fixtures and devices such as low-flow faucets and toilets in new construction.

But the "newer is more efficient" idea does not hold across the board, for it should also be assumed that as older homes age, their fixtures will wear out and will be replaced by the same "state of the art" water-efficient devices installed in new construction.

To test these ideas about new and old homes, the ASU research team created a composite variable for home age: the actual age of the home when available, otherwise an average age for the census tract was used. The team also used home age squared in the model. This allows the effect of newness to be positive up to a point, with the effect of age replacement eventually catching up (for additional explanation of this point, see The Model section of Appendix A, particularly the subsection “Functional Form”).

The estimated coefficient for home age was positive, and the estimate for home age squared was negative. These findings do support the idea that newer homes are more systematically water efficient than older homes, but that this effect is – as hypothesized – mitigated by replacements in older homes.

Landscape Flood Irrigation

A number of neighborhoods in the City of Phoenix have maintained the availability of flood irrigation. As the name implies, flood irrigation enables a household to periodically flood the landscape (i.e., grass) with water during the hot summer months. This service is available at a fixed annual price from SRP, and the water used is not metered to the individual account. Therefore, it is hypothesized that, for households that take advantage of flood irrigation, the amount of measured City water used – as reflected by the water meter – will be lower. It should be noted, however, that although the household water use may appear to be lower on the meter, it may not actually be lower due to the amount of unmeasured water used to periodically conduct the flood.

We were able to measure the availability of flood irrigation by account, and the estimates did indicate that those households with available flood irrigation are measured as using less water through their meter (flood irrigation water is not metered).

Conclusions

For virtually all of the City of Phoenix non-price programs and measures which were estimated to save water, the magnitudes of saving are small, ranging from a low of –0.001% per month per household to a high of –0.06% per month per household. Real Volume Price is estimated to be the most effective conservation technique, since a 10% increase in price can reduce water use by 2.7% per month per household.

Certain, city-wide policies – such as pricing policies or plumbing ordinances – saved the most water overall, but targeted programs competed successfully on a per-recipient basis.

Certain elements of the findings supported the idea of offsetting behavior. For example, both the Depot Pick-up and Union Hills Drop-Off programs were estimated to induce water use.

Although the Plumbing Products Ordinance phase I was not estimated to save water, this may be because there is a lag before actual savings could be expected. These ordinances only affected new and replacement fixtures, and we were able to measure only the start dates for ordinances. In fact, the estimated coefficient for Phase I is small but positive (again, indicating an increase in water use). This positive reading might be measuring a certain type of off-setting behavior where, at the beginning of the phase-in, people made earlier-than-usual fixture purchases in order to be able to buy non-conserving fixtures in anticipation of not being able to get them in the future. Given the probable lag and the possibility of strategic early purchasing, it may be more prudent to interpret the Phase II and Phase III results as measures of savings from the Ordinance overall (rather than from specific phases) during the analyzed time period.

Because of the data requirements and choices made by the City of Phoenix, not all types of conservation programs tried in the Phoenix AMA could be evaluated in this study. For example, some providers have experimented with xeriscaping rebates, but the City of Phoenix did not have this program during the period analyzed. Therefore, not all best bets are identified. But the analysis provided here provides a basis for understanding which programs are worth spending resources on, some that are not, and points the way for other providers to begin analyzing their own programs.

Appendix A: Methodology

This section discusses two important elements of the methodology of estimation. The first is the development of the dataset and measures. The second is the actual method of estimation.

Development of the Dataset

The ASU team developed the dataset analyzed here with major assistance from the City of Phoenix, which provided all data that were combined into the analysis dataset. Data were combined from several independent datasets: separate individual-level datasets on various conservation programs, account-level water billing datasets, tract-level US Census data, sub-City-level weather station data, and index datasets that allowed matching tract- and weather-station-level data to account-level data. In addition, we created datasets on pricing and citywide conservation programs from written information provided by the City (via rate sheets, etc.).

The Dependent Variable

The dependent variable is measured monthly at the single-family account level in units of water. A "unit" is 748 gallons. The average in the data is about 20 units per month. This variable has a high variance.

Multi-family housing units represent unique challenges in estimating the effect of water conservation programs and measures. Usually, households in multi-family units are not charged for their water, and their water use is not individually metered. Therefore, this study intentionally excluded all cases where we had an indicator, such as an apartment or unit number, that the household was part of a multi-family unit. Nonetheless, a small number of accounts have very high values for consumption and may indeed represent multi-family units rather than individual households.

Accounts were also excluded if they had zero water consumption for an entire year. In such cases, houses must be empty, and the independent variables will not explain consumption.

The Sample

The sample for the analysis includes both households that participated in conservation programs and those that did not. First, a sample of study (treatment) households were chosen at random from a rolling pool of accounts that participated in conservation programs from 1989 through 1995. Thus, consumption data are for the year after the household received the conservation intervention (the City found it too difficult to pull the conservation data based on the month, as well as year, of participation). Because of the durability of the conservation hardware provided, participants in hardware programs were put into the data to be sampled from for three years following receiving the hardware. For small programs, the "sample" was the entire pool of participants. For larger programs, the sample size was based on a percent of the pool (using information on sampling from small universes found in Folz, 1996).

Due to the size of the dataset, a decision was made not to include individually delivered conservation measures for which fewer than 100 accounts could be observed during the study period. It was felt that the level of variation in the variable would be too small for robust estimation.

Then, about 1200 per year non-participating households were chosen at random from the remaining (excluding those that had received some conservation measure within three years) active accounts in the study years. A sample of size 1200 is large enough to estimate population variables at a high level of confidence for a population the size of the City of Phoenix.

The years of the analysis were chosen to allow for sufficient cross-time variation in the citywide conservation measures studied.

Accounts were excluded if they lacked census tract, weather, or irrigation data. This may have excluded some of the newer areas of the City – areas that did not have sufficient population for census in 1990.

After screening, the total number of monthly records analyzed was 233,928.

Independent Variables

When using multivariate regression analysis to understand the effect of conservation measures on water consumption, it is necessary to control for other factors known to affect water consumption (independent variables). Strictly, for estimates to be unbiased, all other factors that affect water consumption should be measured, though measures may be proxies –measures of variables known to be highly correlated with the actual variable of interest.

The research team sought to measure each of the independent variables at their smallest, most individualized level (i.e., the household or account level). However, in some cases, the smallest level of measure possible was citywide, regional, or at the census tract level. This subsection discusses the different variables and their level of measurement.

<u>Conservation Program Variables</u>
The following conservation variables are measured at the account level: Seniors Helping Seniors, Metrotech / Neighbors Helping Neighbors, Audit Kit Follow Up, Retrofit Device Canvassing, Union Hills Plumbing Products Drop-Off, and Depot Plumbing Products Pick-Up. Table 1 displays the number of accounts sampled for each of these programs (please see next page).

Table 1: Total observations by individually measured conservation policies

Year Studied	Seniors	Metro-tech	Audit Follow-up	Canvas Drop	Depot Pick-up	Union Hills	Brochure
1990	141	0	0	518	373	0	0
1991	204	0	0	522	527	525	0
1992	289	0	0	548	580	531	0
1993	326	0	0	556	591	527	0
1994	252	0	2	467	597	555	0
1995	538	1	3	465	594	0	0
1996	529	227	101	13	572	0	290

Accounts receiving individually measured programs: 11,964
Total accounts used in analysis: 19,494

The following conservation variables are measured at the city level (they are time-varying): Low-Flow Fixtures and Devices Ordinance, phases I-III; Unsolicited Audit Kits; Water Waste Ordinance Enforcement; and Book of Seeds.

All conservation program variables are measured as dummies with 1 indicating the presence of the program, and 0 its absence.

Certain conservation programs and measures could not be measured with sufficient variation to include them in the analysis. These include participation in Xeriscaping seminars, a program targeting low-income customers (Utility Assistance Customers), and the publication of evapotranspiration data via newspaper, email, and telephone recording.

Pricing Variables
Pricing variables are measured citywide and vary across time. Water included in the mandatory service charge is measured in units, taking on 0, 6, or 10 in the data. Other price variables were converted to real dollars since real dollars are the theoretically correct behavioral concept.[9]

Weather Variables
These variables are measured at a sub-city level, based on the nearest weather station to the account. This technique allows for citywide variation in weather that occurs in our area.

Variable Related to the Persons Living in the Household
The City of Phoenix does not generally keep information about people living in account households. Therefore, these data were measured at the 1990 US Census tract level. Some

[9] Price data are adjusted using a Metropolitan Phoenix Consumer Price Index, base year 1982-1984, provided by the Center for Business Research, William Seidman Research Institute, College of Business, Arizona State University.

variables are tract percents or averages, while others are tract medians. Obviously, this measurement level introduces error from two sources.

First, these variables can only be interpreted in relation to the likelihood that the particular water account being observed had the attribute because a high percentage of accounts in the census tract had the attribute. For example, if a high percentage of households in a certain census tract were at or below the poverty level, we assumed—on a comparative basis—it would be more likely that the water accounts in that census tract were in poverty than the water accounts in a tract with a lower percentage of people at poverty or below. Thus, these variables are a sort of probability proxy for the actual variables of interest (the actual attributes of the account under analysis). It is definitely better to include some measure of these attributes than to exclude them entirely (exclusion would lead to bias), and these are the best measures available.[10] These data also have the virtue of being widely available to all water providers. With such a large dataset, it is likely that these probabilities will be highly correlated with the actual attributes of accounts.

The second source of error arises from the "aging" of the tract. As the date of the consumption data moves farther from the date of the census, the accuracy of the tract data will decline. Again, while this problem is clear, no better data are available.

<u>Variables Related to Household Infrastructure</u>
The number of bedrooms, itself a proxy for the number of bathrooms, and house value are also measured at the 1990 Census tract level. Home age is measured as a composite of data from the City of Phoenix and census tract data. The City has data on account start date (water accounts start in the year the house is built) for a certain number of years. For houses older than the City of Phoenix data go, census tract average home age is used. The availability of flood irrigation is measured by flood neighborhood (*?).

The Model

As discussed above, the dependent variable to be explained is single-family, monthly, account-level water consumption. Forty-one independent variables are measured in five broad categories of factors that should cause water consumption. The following subsections discuss issues of functional form, estimation and the error process, and provide coefficient estimates.

Functional Form

Water experts expect that the relationship between the dependent variable and most independent variables is curved, rather than strictly linear. In order to estimate such a curvilinear structure, variables can be first transformed by taking the logarithm of their values, and then linear regression can be performed upon the transformed variables. Because the log of zero is undefined, zero values must either be omitted—if they are not

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[10] For an analysis of current-year data, a survey (though expensive) could fill in these data. However, for a retrospective analysis such as this one, even a survey could not correct the data lack.

meaningful—or they must be converted to some non-zero value that the analyst is willing to consider zero for purposes of the analysis. In our case, zeros were meaningful values, so zeros were converted to small numbers for those variables to undergo log transformation. When both the dependent variable and a particular independent variable are measured in logs, then the estimated coefficient can be considered an elasticity: it tells the effect of a 1% change in the independent variable on the dependent variable.

However, dichotomous (dummy) variables were not converted to logarithmic form as this didn't make sense. Therefore, for these variables, the coefficient is not an elasticity, and instead gives the percent change in the dependent variable due to a one-unit change in the independent variables.

In addition to the standard expectation of curvilinearity for most relationships in the regression equation, an additional hypothesis regarding home age was made. In our area, it is expected that newer homes are generally more water-conserving than older homes. Thus, one can envision water consumption as a function of home age as starting as some relatively low level (holding all else constant) and rising with home age. However, it is expected that homes that are old enough will need to replace their fixtures with modern, more efficient fixtures. Therefore, it is expected that the increasing relationship between consumption and home age would crest and begin to decline after some time. This type of relationship can be allowed for by entering both home age and home-age-squared into the regression equation. This in essence allows a parabolic-shaped relationship between consumption and home age. When we tried this in the model with the logarithm of home age and home-age-squared, the two variables were too collinear for estimation to be possible. Therefore, these two variables were entered in the level, rather than in logs. Therefore, as for other variables not log-transformed, the estimated coefficients predict the percent change in the dependent variable caused by a one-unit change in home age and home-age-squared.

Income is also entered in the level, rather than in logs, making its relationship also semi-log. The reason for this is explained in the next subsection.

Estimation Procedure – the error process

One of the initial goals of ADWR in having this research performed is that other, smaller, local providers might be able to use the model and insight developed to produce their own analyses—or to begin to prepare to perform analysis. Therefore, the decision was made to perform the analysis on SPSS, a simple, inexpensive, and widely available program. This caused some limitation in the analysis, as explained here.

Generally, pooled cross-sectional data can be expected to exhibit both heteroskedasticity and autocorrelation. Heteroskedasticity is a situation in which the error term of the equation should be expected to have systematically different variance across observations. A classic cause of heteroskedasticity is observing household consumption over households with very different incomes, as here. Autocorrelation is a situation in which the error term in one time period is correlated with the error term in another time period. Here we would expect this to be present because we observe each household for 12 months in a row. Any attributes of each household that we cannot observe -- or cannot observe well -- will appear in the error term, making it likely that each month's error (holding constant account) will be correlated with the error for the previous month.

A simple correction for heteroskedasticity when it is caused by differences in income is to divide the entire dataset through by the income variable. We performed this transformation. A result of this transform is that the estimated "constant" (intercept) is actually the coefficient for the transforming variable. Since the constant is not entered in logs, but in the level (as 1, not the log of 1), this coefficient is also semi-log.

However, the correction for autocorrelation is far from simple to do "by hand," and SPSS lacks a standard autocorrelation correction (except for strictly time-series data, which wouldn't have worked for this dataset).[11] Therefore, we did not correct for the autocorrelation. We decided that it was better to retain the relative simplicity of the model and estimation procedure (rather than to use an advanced econometric statistical package, such as TSP, which is very unlikely to be available to smaller water providers), rather than to correct for the autocorrelation. Not correcting the autocorrelation of the errors has no unfortunate effects on the coefficient estimates (it does reduce efficiency, but that is not an issue with such a large dataset), but does render the estimated standard errors both biased and inconsistent (Pindyck and Rubinfeld, 1981).

Another possible error process to consider arises from the use of the census data. In general, it can be expected that the size of the error will grow over time as the census data contain more error (as measures of account factors) over time. Fortuitously, taking the logarithm of the data tend to correct for this type of error process (Pindyck and Rubinfeld, 1981).

Some Other Estimation Issues.
In general when estimating consumption, a simultaneous equations model should be used because price and quantity are determined simultaneously by the forces of supply and demand. In this case, however, the process is not simultaneous; the price is set by the City (it is an administered price), and households respond behaviorally to the price they face.

With certain types of conservation programs, a leaning process should be expected. This study does not attempt to estimate learning or learning decay effects. Further, it is sometimes the case that volunteers will behave differently than those who do not volunteer for citywide conservation measures this effect is irrelevant--we are estimating the effect over those who do and don't respond. For household-level conservation measures, if there is a voluntary component, it cannot be assumed that the same results would hold if people were forced to

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[11] Correcting for autocorrelation by hand involved creating additional and complicated transforms of each variable. We considered performing these transforms -- though it is unlikely smaller water providers could perform them -- but realized that we would exceed the capacity of our hardware. Another correction possibility would have been to estimate a "fixed effects" model. In this case, that would have involved creating over 19,000 dummy variables to control for each different account (since here the autocorrelation is really caused by the accounts, rather than by time itself), which would also present serious difficulty for smaller providers and also reduces the power of the estimation (though it increases the estimated R^2) because it uses up so many degrees of freedom.

have the program. Thus, if Seniors Helping Seniors were made mandatory, it should be expected that savings would decline. But, these results can be expected for those who are willing to participate in the program.

Estimates
The following table (see next page) provides hypothesized signs and actual estimates for all variables in the model. It also provides estimated standard errors, though they should not be used.

In order to obtain standard errors that could be used, we did estimate an annualized model -- a model in which all variables were measured yearly rather than monthly. This model performed poorly (and introduced many collinearity problems), but did indicate that Ordinance phase II and Seniors Helping Seniors are good bets even for those who will only bet on policies that are estimated as effective at the 95% statistical confidence level. Also, in this annualized model, the confidence interval is consistently positive (giving high statistical confidence of positive effects on consumption) for Union Hills Drop-Off, Depot Pick-Up, and Brochure, indicating that even a very conservative bettor should consider these poor bets.

Table 2: Regression Estimates

Dependent Variable: Account-level (household), monthly water consumption, in units.

Functional Forms: Log-log, except for all dichotomous variables and home age, (home age)^2, and income, measured in the level (resulting in a semi-log form for those variables).

Variables		**Hypothesized Signs**	**Coefficient Estimates**	**Inconsistent Standard Errors***
Seniors Helping Seniors	(0,1)	-	-0.064	.002
Ordinance Phase I	(0,1)	-	0.005	.004
Ordinance Phase II	(0,1)	-	-0.039	.003
Ordinance Phase III	(0,1)	-	-0.001	.003
Metrotech / Neighbors	(0,1)	-	-0.024	.009
Unsolicited Audit Kit	(0,1)	-	-0.002	.002
Audit Kit Follow Up	(0,1)	-	-0.018	.010
Retrofit Canvas	(0,1)	-	-0.001	.002
Union Hills Drop-Off	(0,1)	-	0.038	.003
Depot Pick-Up	(0,1)	-	0.046	.002
Water-waste Ord. Enforce.	(0,1)	-	0.029	.003
Book of Seeds	(0,1)	-	0.004	.003
Brochure	(0,1)	-	0.046	.006
"Free" Service Charge Water		+	0.198	.016
Real Volume Price		-	-0.271	.022
Real Environmental Charge		-	0.021	.002
Real Sewer Price		-	-0.044	.001
Evapotranspiration		+	0.464	.004
Precipitation		-	-0.001	.001
Percent HHs with children		-	-0.310	.044
Percent From Same City		-	-0.056	.012
Percent From the West		-	-0.160	.018
Percent Black		+	-0.001	.002
Percent Hispanic		+	0.097	.006
Percent Other, Non-White		+	0.010	.003
Percent Below Poverty		+	0.015	.006
Median HH Income		?	-2.146	.118
Avg. Persons per HH		+	0.353	.073
Percent 17-24		+	0.177	.011
Percent 25-64		?	-0.104	.049
Percent Older than 65		?	0.006	.009
Percent Female-head HHs		-	-0.046	.008
Percent Male-head HHs		+	-0.032	.004
Percent $\geq$ HS, < BA		-	-0.107	.017
Percent BA or Higher		-	-0.037	.006
Percent Owners		?	0.009	.016
Avg. Number of BedR (Bath)		+	0.491	.042
Median House Value		+	0.574	.017
Home Age		+	64.197	8.895
Home-Age-Squared		-	-1.043	.162
Irrigation	(0,1)	-	-0.027	.002

*In a pooled time-series analysis, both heteroskedasticity and autocorrelation are expected to be present. Here we corrected for heteroskedasticity, but not for autocorrelation (see Appendix).. Therefore, though coefficient estimates are reliable, Standard Errors (SEs) should be interpreted with extreme caution since the estimator used to calculate them is not consistent. Similarly, R^2 and Adj-R^2, functions of the SE, are inconsistent. For this equation, both are estimated as 0.27.

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