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**Household water use and conservation models using Monte Carlo techniques**

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# Household water use and conservation models using Monte Carlo techniques

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## Abstract

The increased availability of water end use measurement studies allows for more mechanistic and detailed approaches to estimating household water demand and conservation potential. This study uses, probability distributions for parameters affecting water use estimated from end use studies and randomly sampled in Monte Carlo iterations to simulate water use in a single-family residential neighborhood. This model represents existing conditions and is calibrated to metered data. A two-stage mixed integer optimization model is then developed to estimate the least-cost combination of long- and short-term conservation actions for each household. This least-cost conservation model provides an estimate of the upper bound of reasonable conservation potential for varying pricing and rebate conditions. The models were adapted from previous work in Jordan and are applied to a neighborhood in San Ramon, California in eastern San Francisco Bay Area. The existing conditions model produces seasonal use results very close to the metered data. The least-cost conservation model suggests clothes washer rebates are among most cost-effective rebate programs for indoor uses. Retrofit of faucets and toilets is also cost effective and holds the highest potential for water savings from indoor uses. This mechanistic modeling approach can improve understanding of water demand and estimate cost-effectiveness of water conservation programs.

## 1 Introduction

Models predicting residential water use and conservation potential based on empirically estimated parameters, device turnover rates, and regression analysis are quite common. Many water utilities develop regression relations for total single-family residential water use based on historical trends for planning purposes (Sacramento Department of Utilities, 2011; San Jose Environmental Services Department – SJ ESD, 2011). Such models may assume increasing levels of conservation in the future, but

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often give little indication of where this conservation will come from. Estimating realistic conservation potential requires an understanding of where water is currently being used in homes and savings potential for each end use under various drought, pricing, and demographic conditions. Measurement-based studies now provide reliable data on water consumption for each end use (e.g., toilets, showers, irrigation, etc.) (Mayer and De Oreo, 1999), yet these can be costly.

Case studies for Europe, Africa, America and Australia (Blokker et al., 2010; Gumbo et al., 2003; Kampragou et al., 2011; Sauri, 2003), highlight the use of modeling to assess the effectiveness of water conservation programs. Kampragou et al. (2011) summarize guiding principles of water demand management strategies and programs, presenting case studies for Canada, the US, Europe and Asia that employ both market and non-market incentives. While economically-driven strategies seem to be effective, the adequacy of their application is linked to the prevailing socio-economic conditions (Kampragou et al., 2011). Sauri (2003) presents a qualitative approach with historical information on water use and urban development patterns that discusses the role of pricing, water sources augmentation, technology and outreach for the Metropolitan Region of Barcelona in Spain.

Blokker et al. (2010) present a simulation model for water demand patterns in a region of the Netherlands using a very small time scale at the residential level. This method is presented as an alternative to metering, using data management programs which have proved to be useful in other areas (Gumbo et al., 2003). An end-use model was employed to estimate the distribution parameters and demand predictions. Compared to measured data, the model depicted good fit overall. The end-use model includes pulse intensity, time of use, and duration for each end-use type, user, and busy time per end use. However, this approach does not include outdoor uses, and whereas aggregate demand is close to the measured data, it relies on high quality appliance information and behavioral data, which is more suitable for regions with homogeneous demographics (Sauri, 2003).



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water consumption for each end use, with fewer empirical relationships. We employ a Monte Carlo approach to include variability in household physical characteristics and behavior when estimating distributions of household water use and conservation potential. This is a novel way to estimate household-based water demands for a study area and potential for conservation, differing substantially from more deductive (statistically-based) approaches. This modeling approach is applied to a neighborhood in the East Bay Municipal Utility District (EBMUD) service area, California.

After an overview of the modeling approach, a short summary of the case study area (San Ramon, California) is presented. Then, (1) existing conditions use, and (2) least-cost conservation models are described in detail. Third, calibration and modeling results are presented and discussed, with a cost-effective assessment of different short and long term conservation actions. Finally, the inherent limitations and desirable extensions of this modeling approach are discussed.

## 2 Modeling overview

The framework developed for this study can be thought of as two interrelated models: (1) “existing conditions” and (2) “least-cost conservation” (Fig. 1). The existing conditions component estimates water use rates based on uncertain physical parameters in each virtual household given by a Monte Carlo iteration. The results are calibrated using metered data, and this model can also be used directly to examine simple conservation alternatives, such as water use if all toilets were retrofitted with high efficiency toilets (“what if” scenarios). In essence, this is a simulation where households take particular actions to change their water use behaviors.

The “least-cost conservation” component is a companion optimization model builds on the existing conditions model, finding the least cost combination of long and short term household conservation actions. The least cost conservation output suggests an upper bound of conservation savings. The changes in household water use resulting



from policy changes (e.g., differing rebate strategies or pricing schemes) can be evaluated in the least-cost conservation model.

To make the distinction between each model clearer, a list of possible insights desired by utilities is presented along with the model that can provide the output. The list in Table 1 is not comprehensive, but it shows capabilities of each model.

Both models extend of a models developed to estimate household water use in Amman, Jordan (Rosenberg et al., 2007). Rosenberg’s model accurately reflected actual water use patterns in Jordan, but such an approach has not been attempted in the US. Other mechanistic models have been applied for developed regions and provide reasonable estimates of water demand probability distributions of indoor appliances (Blokker et al., 2010); yet these models are often unable to provide least cost-based water use estimates, which are more useful for assessing the cost-effectiveness of conservation programs.

## 2.1 Metered data

EBMUD provided metered data for 151 households in a neighborhood in San Ramon, CA which was employed to calibrate the model. San Ramon is east of the Oakland Hills, where there is less precipitation, warmer temperatures, and more sunny days than areas west of the hills. Therefore, the metered homes should have more outdoor water use than the average EBMUD household. Furthermore, the houses are in an affluent neighborhood near a golf course, where the median selling price of homes was approximately \$900 000 as of 2011 (Zillow, 2011). Since many of the homes were built around 2000, the “standard new homes” end use study from Aquacraft (DeOreo, 2011) is particularly applicable to the neighborhood for obtaining parameter distributions on appliances and water use in the study area.

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### 2.1.1 “Existing conditions” water use model

The “existing conditions” model estimates household water use by end use, calibrating to metered data. This model is analogous to the model developed by Blokker et al. (2010). In this model, conservation devices such as low flow showerheads are present in their assumed market penetration rates, and the households make no behavioral changes. As a simulation model, it allows evaluation of specific alternatives for their effect on total water use (e.g., what would the water use be if all households installed warm-season turf?). The basic modeling process is:

1. develop parameter probability distributions
2. sample distributions to create a “house”
3. calculate water use from sampled parameters
4. repeat steps 2–3 until convergence (Monte Carlo iterations)
5. calibrate results to metered data.

### 2.1.2 Parameter probability distributions

Many parameters affect household water use (e.g., type of toilets, household size, lot size, etc.). Instead of assuming average numbers for each parameter, probability distributions are used to capture uncertainty. In the model, 69 parameters are used to define the water use of each house. The distributions of these parameters were taken from end use studies or other literature, when available; otherwise, engineering estimates were used. For a full list of the parameters and their distributions (see Cahill, 2011).

### 2.1.3 Distribution sampling

After the distributions have been developed, each Monte Carlo iteration randomly samples these distributions independently to create a modeled “house”. Each sampled

“house” does not line up with a physical house, but the whole sample of houses should approximate the neighborhood’s water use. Covariance between parameters was not included in the sampling process, although such relations do exist (DeOreo et al., 2011).

#### 2.1.4 Calculation of water use from parameters

After the parameters have been randomly sampled for a household, relations between the parameters are used to estimate the water demand by end use. For example, water used for laundry can be estimated using Eq. (1) below:

$$Q = \left( \frac{\text{liters}}{\text{cycle}} \right) \left( \frac{\text{cycles}}{\text{week} \cdot \text{person}} \right) \left( \frac{\text{persons}}{\text{house}} \right) \left[ \frac{1 \text{ week}}{7 \text{ days}} \right]. \quad (1)$$

Each factor in the equation is randomly sampled for each household (except physical constants). Equations have been developed for each end use, and the full list of relations can be found in Cahill (2011). For each end use and household, water use is calculated within the Monte Carlo loop. The model used two seasons (wet winter and dry summer) to further disaggregate the water use, as precipitation and evapotranspiration values are quite different in the dry and wet seasons (CIMIS, 2011).

#### 2.1.5 Calibration to metered data

The results from the existing conditions model are compared to metered data to ensure that reasonable ranges of results are being produced. Only one parameter was set to match the metered data – the percent of landscaped area that is lawn. It was set to a value of 65%, which is close to the average lawn proportion of landscape in the study area (EBMUD, 2002).

Goodness of fit of the Existing Conditions model was formally tested using the Kolmogorov–Smirnov 2 variable test (Smirnov, 1948), resulting in a  $p$  value of 0.36, suggesting modeled and observed results may come from the same underlying distribution. This is also illustrated in Fig. 2.



A summary of the modeled results for each end use is compared to the findings from other end use studies in Fig. 3. The Existing Conditions simulated water use fits well with the standard new homes dataset with the exception of outdoor water use in winter. This is not surprising, since these metered houses are located near a golf course with a drier climate than the standard new homes dataset.

## 2.2 “Least-cost conservation” model

The “least-cost conservation” component incorporates household behavior into the “existing conditions” component. In the least-cost model, each household has several available long-term and short-term conservation actions. Each conservation action has a house-specific effectiveness in reducing water use and an associated cost. For each household, a combination of these long-term and short-term conservation decisions exists that will minimize cost; the least-cost conservation model finds this mix of actions. This two-stage optimization approach has been used by Garcia-Alcubilla (2006) and Lund (1995). Each household is aware of the probabilities of future shortages and the price increases that will occur during each shortage event. As a stochastic optimization model with recourse decisions, the model may not actually predict what real homeowners will do, as it assumes cost-minimizing, rational behavior of all homeowners. However, the model results do provide a likely upper-bound (from an economic perspective) of the conservation potential for the neighborhood. Viewed in this light, the model is a helpful complement to the existing conditions model. The steps to develop the model are as follows:

1. define conservation actions and effectivenesses (how much water is saved)
2. define event probabilities and corresponding water bill increases
3. define costs of actions
4. define and solve the optimization equations mixed linear programming.

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This model also is solved in Monte Carlo fashion to create statistical results for a set of households.

### 2.2.1 Conservation actions and effectiveness

A list of the short-term and long-term conservation actions and the end use available to households appears in Table 2. Short-term actions may or may not be activated during each event, while long-term actions apply to all events. Both short-term and long term actions are expected to decrease water use.

Each conservation action saves a given amount of water (effectiveness), depending on the initial state of the household. For example, the relationship estimating the amount of water saved by installing a water-conserving laundry machine is shown in Eq. (2) below:

$$Q_s = \left( \left( \frac{\text{liters}}{\text{cycle}} \text{Std.} \right) - \left( \frac{\text{liters}}{\text{cycle}} \text{Efficient} \right) \right) \left( \frac{\text{cycles}}{\text{week} \cdot \text{person}} \right) \left( \frac{\text{persons}}{\text{house}} \right) \left[ \frac{1 \text{ week}}{7 \text{ days}} \right]. \quad (2)$$

From Eq. (2), households that already have a water efficiency laundry machine will have an effectiveness value of zero for  $Q_s$ . Since each house in the Monte Carlo iterations has a different value for each randomly sampled parameter in the Eq. (2), the amount of water saved by replacing a laundry machine will vary by household. The full set of equations can be found in Cahill (2011).

### 2.2.2 Water shortage event descriptions

Six different water shortage events are considered in the Least Cost model – three events in the winter and the same three corresponding events in the summer to account for seasonality in water supply. These events were based on the EBMUD water shortage contingency plan and are presented in Table 3.

In this study, water shortage events are characterized by the price paid for water by the homeowners. In other words, a household may use as much water as desired during a shortage event, but the price paid for water use will be higher.

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most people, while more difficult tasks like installing xeriscape have more restrictive handiness cutoffs.

### 2.2.5 Short-term actions

The financial costs of nearly all short-term actions are zero, as they are behavioral changes rather than retrofits. There is no concept of a “handiness” factor for the short-term actions, as it is assumed that everyone can carry out these actions. If hassle costs are omitted, nearly all short-term actions are implemented in every event because they save water and cost nothing to the household.

Hassle costs are additions to financial costs to reflect inconvenience costs to households beyond financial costs of conservation actions. Often, households do not reduce consumption due to the hassle costs of conservation (Dolinicar and Hurlimann, 2010). As such models of conservation should include hassle costs, as financial costs alone do not explain homeowner behavior. Unfortunately, little has been written on estimating hassle costs of conservation activities. Contingent valuation studies are the preferred method of estimating hassle costs, but such studies do not exist for the water conservation activities considered in the model. In the absence of contingent valuation studies, economic literature relating to opportunity costs is the most appropriate. When hassle costs are included, the conservation actions are assumed to take a given amount of time, which can then be translated into a dollar amount based on the value of time to a particular household (Narasimhan, 1984). To introduce uncertainty, the annual household income was converted to an hourly amount and used as the value of time for a household. Such an approach reflects a higher opportunity cost of time for higher income-earners, a common assumption in economics literature (Anderson and Song, 2004; Narasimhan, 1984). These assumed hassle costs produce more realistic behavior than assuming no hassle costs.

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### 3 Model formulation

A two-stage mixed-integer linear program was used to formulate the optimization problem. The first stage consists of long-term actions and costs, and the second stage includes actions and costs for each short-term shortage event. For a complete description of all inputs to the optimization model (see Cahill, 2011).

#### 3.1 Decision variables

The decision variables are listed below:

$S_{s,e}$  = short term actions, a binary variable defined over the set  $s$  of short term actions (third column in Table 2), and for the set  $e$  of all six water shortage events.

$L_l$  = long term actions, a binary variable defined over the set  $l$  of long term actions (second column in in Table 2).

$B_e$  = water bill (\$/billing period) for each water shortage event  $e$ .

$U_e$  = water use (liters/day) for each water shortage event  $e$ .

$E_{u,e}$  = end use saved (liters/day) for each end use  $u$  and each water shortage event  $e$ .

$W_e$  = water saved (liters/day), for each water shortage event  $e$ .

Decision variables for the water bill, water use, etc. are not really “decisions” that the household has direct control over, but they are defined as decision variables to incorporate complexities, such as piecewise-linear representation of water bills and interactions between conservation actions.

#### 3.2 Objective function

The objective function (Eq. 3) is to minimize the total expected economic cost of all water conservation decisions, including permanent conservation  $L_l$ , short-term conservation decisions for each shortage event  $S_{s,e}$ , and the household water bill for each shortage event  $B_e$ :

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$$\text{Minimize } Z = \sum_l c_l L_l + j \sum_e \left[ p_e \left( i \sum_s (c_s S_{s,e}) + B_e \right) \right] \quad (3)$$

where:

$c_l$  = annualized long-term action costs (\$/year)

$c_s$  = short-term action costs (\$/day)

$p_e$  = probability of event  $e$

$i$  = number of events per billing period (60 days/billing period)

$j$  = number billing periods per year (6 billing periods/year).

### 3.3 Constraints

A summary of the constraints to the model is given below:

- 10 1. *Non-negativity*: no conservation action increases the water use of households as shown in the inequality (Eq. 4):

$$U_e \leq O_e, \quad \forall e \quad (4)$$

where:

$O_e$  = original water use of the household in a water shortage event  $e$ .

- 15 2. *Discrete choices*: no conservation action can be partially implemented (Eqs. 5 and 6):

$$S_{s,e} = 0 \text{ or } 1, \quad \forall s, e \quad (5)$$

$$L_l = 0 \text{ or } 1, \quad \forall l. \quad (6)$$

- 20 3. *Maximum effectiveness*: the water saved cannot exceed the initial water use (inequality Eq. 7):

$$W_e \leq O_e, \quad \forall e. \quad (7)$$

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4. *Mutually exclusive actions*: some actions cannot be implemented simultaneously (inequalities Eqs. 8 and 9):

$$\sum_{I2} L_{I2} L X_{I, I2} \leq 1, \quad \forall I \quad (8)$$

$$\sum_{S2} S_{S2, e} S X_{S2, S} \leq 1, \quad \forall s, e \quad (9)$$

where:  $L X_{I, I2}$  equals 0 or 1 for each possible combination of long term actions and set  $I2$  is same as set  $I$ . A value of 1 corresponds to mutually exclusive actions. Likewise,  $S X_{S2, S}$  contains all possible combinations of short term actions with 1 for mutually exclusive long term actions and  $s2$  is same as set  $s$ .

5. *Mutually dependent actions*: some actions (inequalities Eqs. 10 and 11) depend on implementation of other actions.

$$\sum_{I2} L_{I2} L R_{I, I2} = 0, \quad \forall I \quad (10)$$

$$\sum_{S2} S_{S2, e} S X_{S2, S} \leq 0, \quad \forall s, e \quad (11)$$

where:  $L R_{I, I2}$  equals 0 or 1 for each possible combination of long term actions (same as inequality Eq. 8). A value of 0 corresponds to mutually dependent actions. Likewise,  $S X_{S2, S}$  contains all possible combinations of short term actions (same as inequality Eq. 9) with 0 for mutually requiring short term actions.

6. *Increasing block water bills*: unit water price increases with increasing use (inequality Eq. 12).

$$B_e \geq F + i V_1 U_e, \quad \forall e \quad (12)$$





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5 levels. Two separate base condition runs were computed – one with financial costs only and one including hassle costs. The average household use after adopting least-cost conservation actions is 1820 lphd (480 gphd) with financial costs only and 1930 lphd (510 gphd) with hassle costs, while the average household use under the existing conditions model was 2040 lphd (540 gphd). This reduction of 12 % with financial costs only (6 % with hassle costs) means it would be unrealistic to achieve conservation beyond this amount under current water price rate structures and no rebates, as more conservation would not be cost-effective for the neighborhood and each home individually. Figure 4 shows water use after least-cost conservation compared to existing conditions. Many large water users reduce consumption by large amounts, while the low water users can save less.

10 All future results are extracted from runs with hassle costs, as these runs are expected to be more realistic. The modeled adoption rates and ranges of effectiveness of conservation actions for the base conditions are shown in Fig. 5.

15 For permanent conservation actions, installing smart irrigation controllers has a 45 % adoption rate. The relatively low implementation rates most other outdoor conservation activities indicate that these conservation actions are not cost-effective for most households, but the households that implement them save large amounts of water. With current water price structures, no household finds it worthwhile to install xeriscape or warm-season turf (not shown in Fig. 5). The indoor actions are implemented more often, but their savings are usually less than outdoor conservation.

20 The relative frequency of adoption of short-term conservation actions by season and drought event appear in Fig. 6. The short-term actions are adopted with highest frequency during severe shortages in the summer, which is when adopting these actions saves the most water and money. However, it is financially worthwhile for some homes to adopt short-term actions even when there is no shortage. Stress irrigation shows the greatest seasonal variation, as the water saved by stress irrigation in the winter is much lower than in the summer. As a preliminary model, the results also indicate

where additional calibration and study seems desirable, such as for the seemingly high percentage of households flushing only when necessary.

## 4.2 Indoor device rebates

While the least-cost conservation model can be applied in many ways, the effectiveness of indoor rebates will be focused on here, which is of interest to a utility. The ratio of water saved to total rebates disbursed indicates cost-effectiveness. Rebate strategies with high ratios provide more “bang for buck”. Figure 7 shows this relation for varying rebate levels. As nominal rebate levels increase, the cost-effectiveness decreases due to free riders (who would have conserved even with a lower rebate). The plot suggests that rebates for efficient clothes washers are the most cost-effective, saving the most water per rebate dollar invested.

## 4.3 Limitations of the model

While the least-cost conservation model has many capabilities, its limitations also are important.

1. Rebate aspects of the model do not account for “free riders”, people who intend to replace their devices anyway and reap the benefit of a rebate without being enticed by it (Sovocool, 2005). However, such households can be identified by comparing results with and without rebates.
2. The model assumes that all households behave rationally to minimize the cost to themselves, which is not always the case. Many decisions on conservation are not affected strongly by the actual savings gained or the reduction in cost to the household (Komor and Wiggins, 1988). Calibration of hassle costs can help in this regard. Furthermore, a payback period measure would be a good addition to the model as the life span of some appliances may exceed the planned occupancy period of some homeowner.

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3. The optimization model is built from a homeowner's perspective, so it cannot calculate the best suite of rebates from the utility's perspective directly. However, a similar model from a utility's perspective might be formulated and used (Wilchfort and Lund, 1997), and calibrated based on household model results.
- 5 4. Although the model provides a more mechanistic framework for water conservation studies, requires estimation of many parameters. Much of this information is now available from recent end use studies. Outdoor water use data remains the greatest uncertainty.
- 10 5. While household water conservation reduces water costs at the household level, this also reduces revenues for the utility that depend on the proportion of households employing conservation measures. Some pricing mechanisms be needed to cover operation costs of the utility, however, quantification of these are beyond the scope of this paper.

## 5 Conclusions

15 The approach taken here produces reasonable "existing conditions" water use estimates and provides insights on household conservation potential for the metered homes in a San Ramon, California neighborhood. Since the modeled results were comparable to measurements from other end use studies and were calibrated with little difficulty to the metered data, the existing conditions use model appears to be

20 robust.

The least-cost conservation model can provide useful insights. Indoor conservation is more widespread, but the savings are lower than outdoor conservation. The most cost-effective widely adopted indoor conservation actions are retrofitting bathroom faucets and showerheads, but retrofitting toilets with HETs holds the greater potential of water savings. The rebates for high-efficiency laundry machines give EBMUD the highest

25 water saving per unit cost of conservation. Other insights, such as the effectiveness of



reduced landscape water requirement rebates (cash for grass) or price increase effects can also be produced by the model, and are presented in Cahill (2011).

This type of modeling approach, after further testing, has the potential to be applied to any neighborhood or city after adjusting the parameter distributions. The existing conditions model can be easily adapted to other communities or service areas using reasonable market penetration assumptions and adjusting for geographical factors. Both modeling approaches provide a more detailed and mechanistic understanding of household water use and conservation decisions.

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**Table 1.** Example capabilities of existing conditions and least-cost conservation models.

Result desired by utility	Existing conditions	Least-cost conservation
Water use by end use in 2010	x	
Expected water use after price increase of 10 %		x
Savings after penetration of HETs increases to 40 %	x	
Cost-effectiveness of payment for less-grass area (Cash for grass)		x
Budget for showerhead replacement rebate program		x
Water consumption of proposed new subdivision	x	
Outdoor water consumption with climate change		x
Water use with water rationing policy		x

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**Table 2.** Actions available to households in the least cost conservation model.

End use affected	Long-term actions	Short-term actions
Shower	Retrofit showerheads	Reduce shower length Reduce shower-taking frequency
Toilet	Retrofit all standard toilets with High Efficiency Toilets (HET) Retrofit all standard toilets with Ultra Low Flush Toilets (ULFT) Retrofit all ULFTs with HETs	Flush only when necessary
Faucet	Retrofit bathroom faucets	Turn off faucets while washing
Laundry	Install conserving laundry machine	Reduce laundry-washing frequency
Leaks		Find and fix leaks
Lawn	Install xeriscape Install warm-season turf Install smart irrigation controller	Stress irrigate
Garden/landscape	Install xeriscape Install drip irrigation system Install smart irrigation controller	Stress irrigate
Car wash		Wash car with buckets Wash car at gas station
Pool		Stop filling swimming pool

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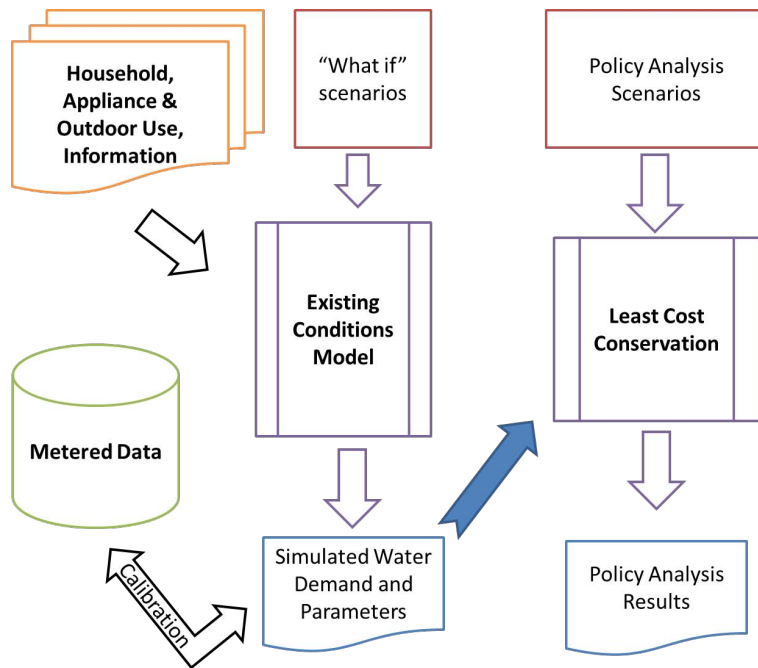
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**Table 3.** Description of water shortage events.

Event	Description	Probability	Volumetric use price increase (%)	Freeport source surcharge (14 % increase)	Ration amount (% reduction in original use)	Penalty for exceeding rationed amount (\$/2.83 m <sup>3</sup> )
Summer						
1	Regular delivery	0.35	0 %	no	0 %	\$0
2	Shortage	0.1	10 %	no	20 %	\$2
3	Severe shortage	0.05	10 %	yes	30 %	\$2
Winter						
4	Regular delivery	0.35	0 %	no	0 %	\$0
5	Shortage	0.1	10 %	no	20 %	\$2
6	Severe shortage	0.05	10 %	yes	30 %	\$2

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**Fig. 1.** Modeling framework for economic analysis of water conservation.

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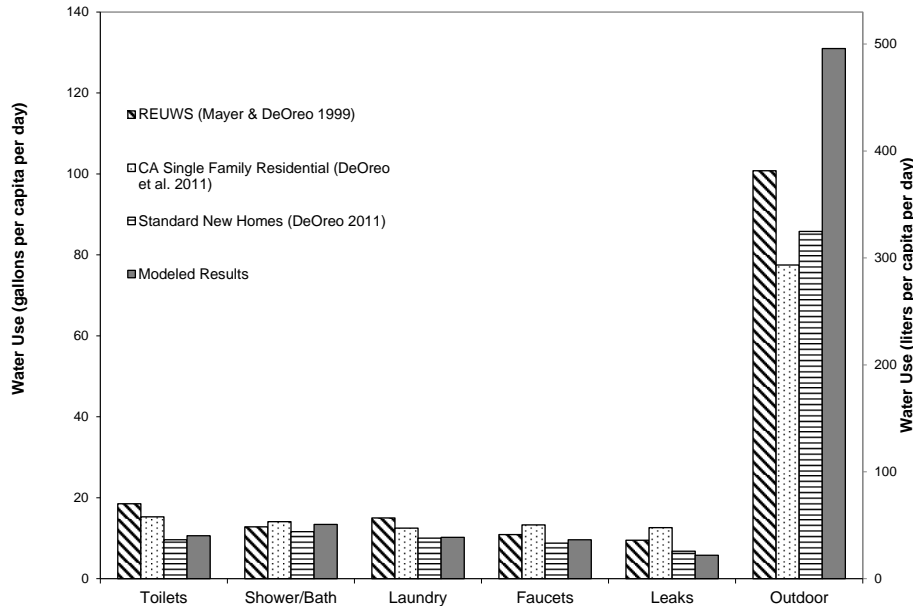
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**Fig. 3.** Average modeled end uses of water compared to end use studies.

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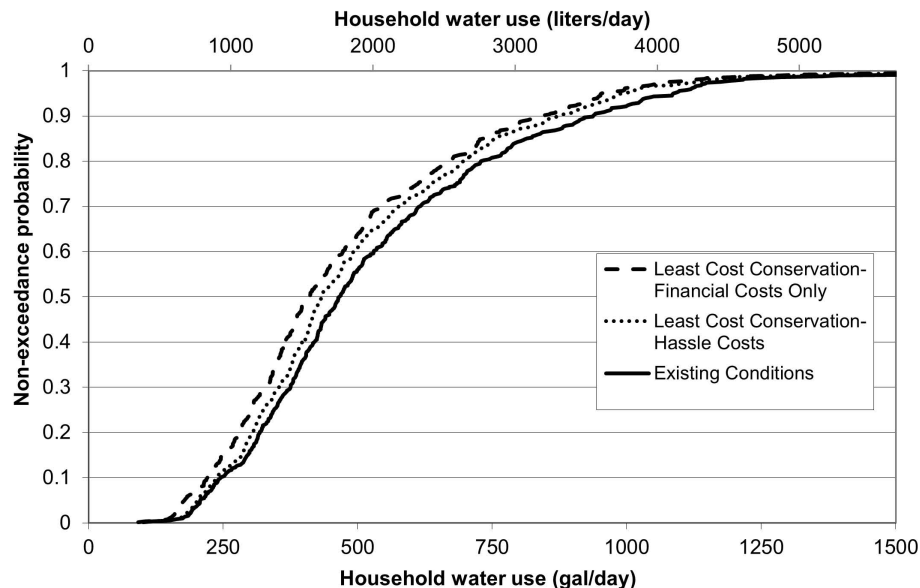


Fig. 4. CDF of water use under existing conditions and least-cost conservation.

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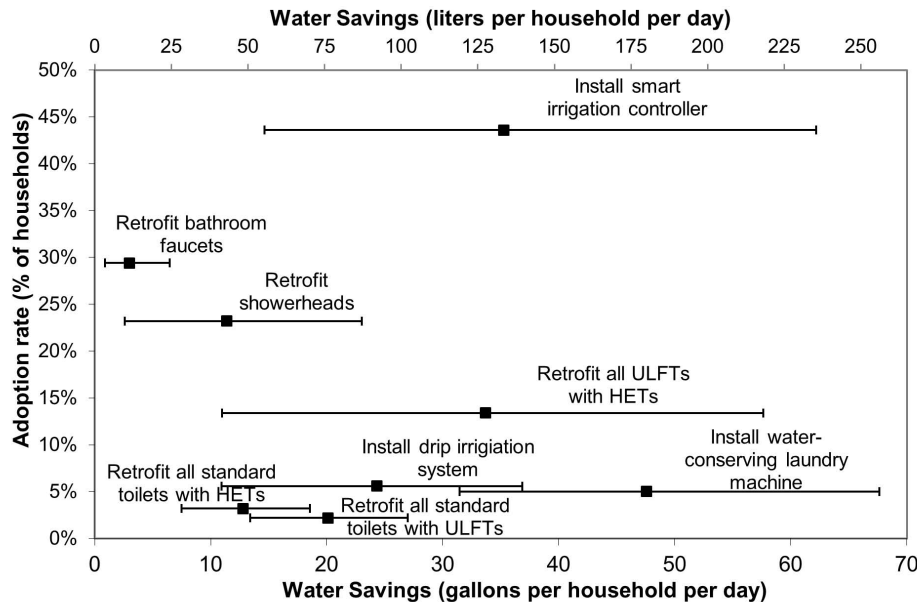


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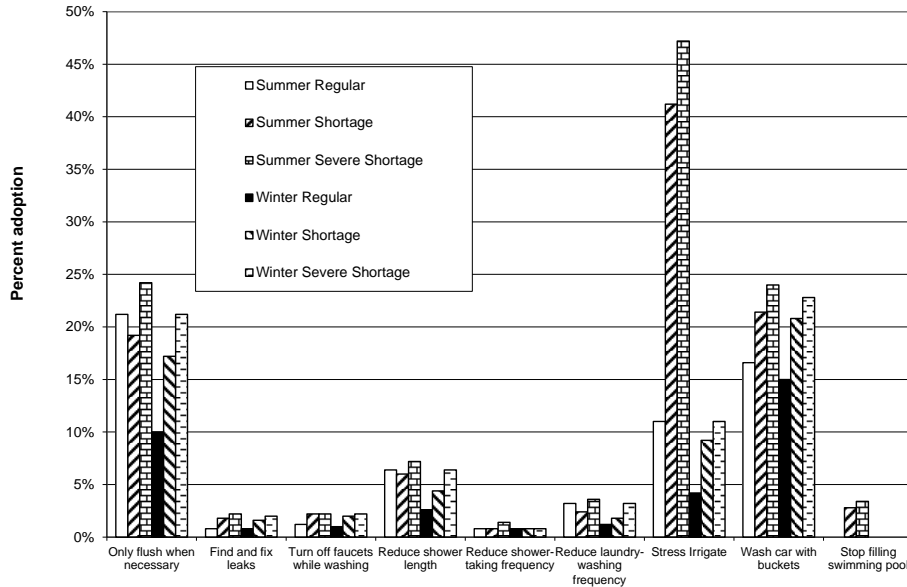
**Fig. 5.** Modeled market penetration and average water savings for long-term conservation actions, base conditions run with hassle costs (error bars are 10th and 90th percentiles).

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**Fig. 6.** Modeled average market penetration for short-term conservation actions by season and drought event, base conditions with hassle costs.

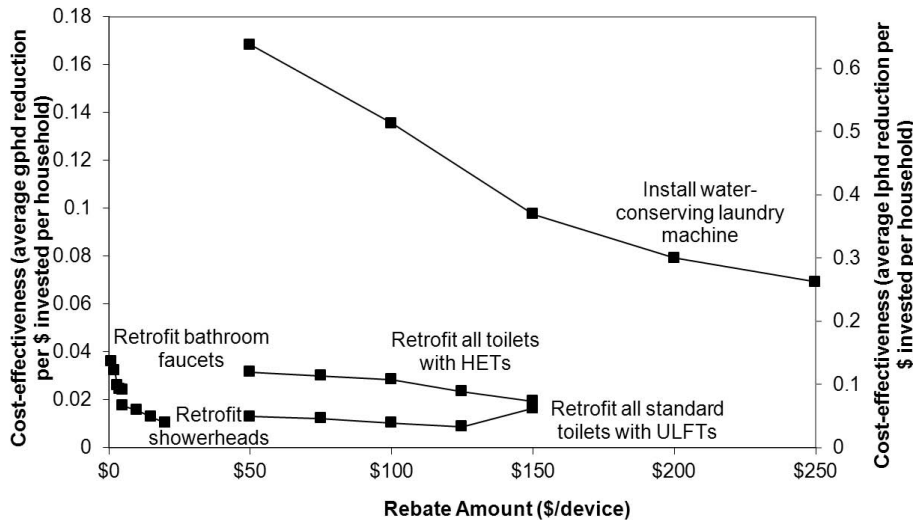
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**Fig. 7.** Cost-effectiveness of rebate programs, average use reduction per rebate dollar invested per household.

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