Water Utilities Objectives Evaluation of Single Family Residence Greywater Systems

by

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Abstract

Meeting the potable water demand for cities across the world is becoming increasingly difficult considering 54% of the world's population currently live in urban areas. Public water providers have considered a variety of programs to promote potable water conservation including the reuse of greywater, untreated wastewater that is not contaminated by toilet or kitchen discharge. Through interviews with water conservation specialists at public water utilities and analysis of water conservation progress reports, this study develops a decision framework for public water utilities in California to determine whether to promote the installation of residential greywater reuse systems. The framework evaluates the feasibility and relative success of two greywater promotion strategies, as well as five alternative commonly implemented water conservation strategies. The framework evaluates each water conservation strategy's ability to reduce potable water consumption. Results show that the ideal combination of water conservation programs supported by a public water utility is influenced by the reliability and source of potable water, as well as the conservation maturity and water use of habits of rate payers.

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1.0 Introduction

Meeting the potable water demand for cities across the world is becoming increasingly difficult considering 54% of the world's population currently live in urban areas; a figure that is expected to climb to 66% by the year 2050 (United Nations, 2014). Increased industrial activity, urban migration and the development of additional power plants have strained the existing water supplies and infrastructure of water conveyance systems in several nations (Reyes et al., 2017, Bardsley, Hugo 2010).

Water has become an increasingly precious commodity for the southwestern United States, one of the fastest growing regions of North America. The Colorado River Basin, the major catchment of the region, spanning portions of Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming, has seen a 14% increase in water use over the course of the last 40 years as a result of continued population growth and stable-to-decreasing agricultural water use (Bureau of Reclamation, 2012). In Arizona's Upper Santa Cruz alluvial basin, increased groundwater extractions and periods of severe drought have lowered groundwater tables causing subsidence, the sinking of land as the saturated zone is reduced. The subsidence has occurred at rates rapid enough to reduce the permanent storage volume of subsurface soils (Miller et al, 2017).

An even more dire situation exists in South Africa. In 2017, city officials from Cape Town announced the Western Cape Water Supply System expects to shut off taps to homes and businesses at some point in 2018. After "Day Zero", Cape Town residents would be issued rations of potable water distributed from hundreds of water stations across the city (Welch, 2018). In spite of progress made by the city to reduce per-capita consumption over the course of the last 20 years, the reservoirs that supply the city were measured in 2018 at 26% capacity (NASA, 2018).

Urban density is generally perceived to be a strain on a region's water supply; however, the concentration of people in metropolitan regions can provide opportunities for economy of scale. The complex inter-dependent systems of cities can be leveraged to use resources, including water, more efficiently through multi-level government collaboration (Revi et al, 2014). Implementing targeted water conservation campaigns can be most effective in metropolitan regions where the reduction of per capita water consumption can have the greatest impact on overall water demand. The reuse of wastewater utilizing a regional treatment facility provides opportunities for recovery of water, energy and nutrients in urban water systems (Larsen et al., 2016). Installing such non-potable water conveyance systems have the greatest feasibility in densely populated regions.

Increasingly, water providers have turned to water recycling programs that reuse wastewater to reduce potable water demand. In addition to reducing demand, these systems can be seen as an opportunity to diversify water supply portfolio depending on the degree to which wastewater is treated. Water reuse strategies are generally divided into three categories:

1. Municipal wastewater reuse- The treatment and reuse of wastewater generated by commercial and residential properties and discharged to municipal wastewater systems.
2. Industrial wastewater reuse - The treatment and reuse of industrial wastewater that is not discharged to the municipal system due to contaminants in the wastewater or the facilities location outside of municipal limits.

3. Greywater reuse - The reuse of water for on-site non-potable purposes instead of discharging to municipal wastewater systems.

Greywater is defined as untreated wastewater generated at residential and commercial properties that is separated from kitchen, septic or manufacturing waste (California Water Code, 2010). Most commonly, residential greywater sources are limited to bathroom sinks, laundry and bathing. Greywater systems include two broad categories: (1) systems using greywater for toilet flushing, and (2) systems using greywater for landscape irrigation. Installing decentralized greywater systems, systems which reuse greywater at the same location where it is generated, require some of the least initial investment and can reduce potable water consumption more so than rainwater systems (Ghisi & Ferreira, 2007).

Considering indoor water use by residential occupants is relatively constant on a per capita basis [approximately 59 gallons per capita per day (GPCD)], the greywater produced in a typical household exceeds the toilet flushing demand in a residential setting (14 GPCD) (National Academies of Sciences & Medicine, 2016). A typical single-family home, containing 2.6 persons produces approximately 90 gallons of greywater per day, which could address a significant portion of the irrigation needs of a 0.25-acre lot landscaped with bedding plants and turf (Roesner, 2006).

The precise amount of the irrigation requirements that can be addressed by greywater is highly variable. The water savings potential of reusing greywater use is influenced by the amount and consistency of wastewater generated, the design of the system, the water demands of the irrigated flora, as well as the seasonal demand for water use.

To investigate the potable water and utility bill savings of greywater, the Alliance for Water Efficiency (A4WE) analyzed the water savings and return on investment of single-family package greywater systems, meaning systems which reuse greywater generated from a single-family residence. Although cost savings is not the only benefit of greywater systems, it can be an integral factor for homeowners considering water conservation strategies. If the total life-cycle cost of owning and operating a greywater system is greater than the savings achieved by reducing potable water consumption over the life of the system, the greywater system would not be considered cost-effective for the homeowner (Gauley, 2017).

The A4WE greywater system analysis found that the water and cost-savings of most shower-to-toilet systems are not worth the investment for homeowners, apart from situations where household occupancy is very high and/or water rates are extremely high. The cost savings and return on investment of landscape-based greywater systems were found to vary significantly depending on the type of system, the number of occupants in the home, water rates, and whether the system was installed by the homeowner or professionally (Gauley, 2017).

Cost effectiveness is not the only factor considered when making decisions on the support of single family greywater reuse systems. As water providers evaluate opportunities to maintain sufficient and reliable supplies, the reuse of greywater, municipal wastewater, and industrial wastewater represent an opportunity to diversify supplies. Greywater distinguishes itself from the other two reuse options due to its limited treatment requirements and minimal infrastructure investment.

Considering the installation of greywater reuse systems in new homes can be accomplished at a low marginal cost relative to retrofitting existing homes, widespread use of greywater systems can ease the burden of rapidly growing populations on water utilities (National Academies of Sciences & Medicine, 2016). Renewing and replacing aging water and wastewater infrastructure was identified as the most important issue facing water utilities (Association, 2015).

The regulatory incentives and impediments to reusing greywater vary greatly within the United States. In 41 states, a regulatory definition of "greywater" or "graywater" exists, and 26 states regulate greywater less stringently than reclaimed wastewater (Yu et al., 2013; National Academies of Sciences & Medicine, 2016). Promotion of safe greywater reuse is provided by 29 states; however, inconsistencies between state plumbing codes and other regulations impede the installation of greywater reuse systems (Yu et al., 2013). Regulations vary in their definition of greywater, as well as the permittable reuse applications (National Academy of Sciences & Medicine, 2016). Kitchen sinks and dish washers were found to be the most common wastewater sources excluded from the definition of greywater. Permitting is required for the storage and reuse of greywater in 30 states, and regulations vary depending on the daily quantity of greywater reused by the system in six states (Yu et al., 2013).

Due to the inconsistencies amongst states in what constitutes greywater and what applications are permissible, this report focuses on the regulatory framework of California, where legislation was adopted in 1992 to promote greywater reuse. The regulations established a framework distinguishing greywater from blackwater and have since been updated to allow for the safe application of greywater systems in residential and commercial buildings (Snodgross, 2010).

California has long prioritized water conservation, including passing the Urban Water Management Planning Act in 1983, to address long-term drought concerns. Since then, water utilities in the state have been mandated to develop effective water conservation programs to maintain reliable supplies and meet existing and potential regulations (California, 2017). It is critical that the conservation strategies implemented by public water utilities are effective for their unique climate, constituency, and budget.

This report attempts to better understand the extent to which greywater reuse is a component of conservation programs of public water utilities in California and establish a decision framework to help public water utilities in California decide whether to promote single-family greywater reuse systems. This framework is to be utilized by water providers considering a suite of strategies and programs with the goal of reducing potable water use by residential ratepayers.

2.0 Methods

Prior to developing a decision framework to be utilized by public water utilities in California, the water conservation strategies currently being implemented by water providers in the state were investigated. Publicly available conservation plans, and agency websites were reviewed to gain an understanding of the promotional campaigns and financial incentives currently implemented by water providers to encourage potable water conservation.

Water conservation programs currently implemented by California public water utilities consisted of portfolios of strategies aimed at reducing residential potable water consumption by augmenting indoor and outdoor water use behavior. As noted in Table 5, water conservation programs described by public utilities in their final 2015 urban water management plan included multiple promotional campaigns and financial incentive strategies. These strategies were the alternatives considered in the decision framework and were not considered mutually exclusive alternatives.

2.1 Interviews

Representatives from four public water utilities who are involved in developing water conservation strategies for their agency were interviewed by phone to gain an understanding of their considerations and decision making related to their current and proposed water conservation plan. The interviews were recorded for review. Interviewees were selected to represent a diversity of public water utility agencies including:

1. Pasadena Water & Power – A water retailer (an agency that sells water directly to customers) with an established greywater promotion program in a metropolitan area and water supplied by groundwater, imports and recycled water;
2. Big Bear Lake Department of Water & Power – A water retailer that does not currently promote greywater reuse located in a more sparsely populated area and water supplied exclusively by groundwater;
3. West Basin Municipal Water District – A water wholesaler (an agency that sells to water retailers) with a recently developed greywater promotion program in a metropolitan area and water supplied by imports, desalinated brackish water and recycled water;
4. Austin Water Utility – A water retailer with an established greywater promotion program located outside California with water supplied by groundwater and surface water

The water conservation specialists interviewed for this study were asked to provide their perspectives on water conservation strategies and single-family greywater reuse systems including:

- Criteria and processes used to determine water conservation strategies
- The perceived success and challenges of currently implemented conservation programs
- The perceived benefits and drawbacks of single family grey water reuse systems

2.2 Framework Development

Criteria used to evaluate each water conservation strategy alternative were determined through review of publicly available agency reports, review of previous potable water studies, and the utility representative interviews. Based on review of literature and interviews of water utility representatives, each alternative was assigned an integer score ranging from 0 to 5 for each criterion.

The benefits and drawbacks of the conservation alternatives were evaluated, and the tradeoffs identified. After which, the priorities of different water utilities were considered to recommend an optimal portfolio of water conservation strategy alternatives.

The decision framework methodology is summarized in Figure 1.

Topic key
Navy: Initial Question
Blue: Evaluation
Red: Proposed Solutions
Green: Greywater Alternatives
Orange: Conservation Alternatives
Purple: Evaluation

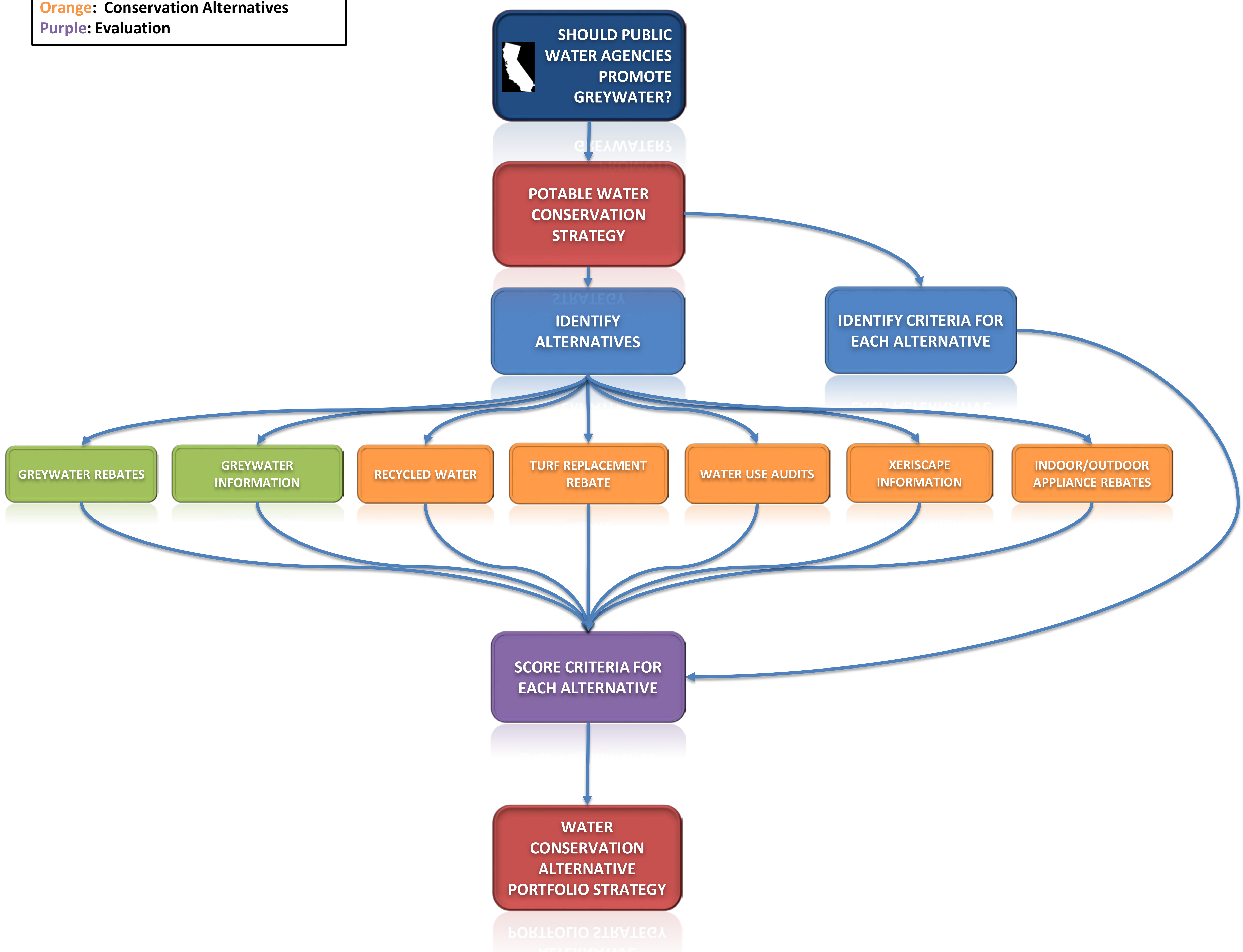

Figure 1: Overall Decision Framework Approach

2.3 Identifying Alternatives

To determine whether public utilities should support greywater systems, the existing regulatory landscape for greywater and alternative water conservation strategies currently being implemented in California must be considered. Following revisions to the state plumbing code in 1992, greywater reuse has been legal throughout California. Recent revisions to the California Plumbing Code allow single family homes to install systems that reuse clothes washer water without a permit provided systems comply with guidelines (Cal. Code Regs., Title 24). Levels of permitting and promotion vary amongst water suppliers in the state, and the California Department of Water Resources recommends consultation with local building departments to determine specific permitting (Yu et al., 2013; California DWR, 1995).

> **California Greywater Regulation -** Chapter 16 of the California Plumbing Code was updated in 2013 to ease regulations related to alternate water sources for non-potable applications. The revised code allows Laundry to Landscape (L2L) systems to be installed without a permit as long as they follow specific best management practices. L2L systems are relatively simple and use greywater generated from clothes washer systems for subsurface landscape irrigation (Cal. Code Regs., Title 24).

The water conservation programs currently being implemented by public water utilities in California (alternatives) were identified by reviewing publicly available information related to water utilities' existing conservation campaigns. Urban water management plans, prepared by water agencies and submitted to the California Department of Water Resources (DWR), were the primary document reviewed.

California water suppliers providing over 3,000 acre feet (AF) of water annually or serving more than 3,000 customers are required to prepare urban water management plans to DWR every five years. California State Senate Bill X 7-7 was enacted in November 2009 to address the shortfalls of the Urban Water Management Planning Act of 1983. The bill establishes water conservation targets for urban water suppliers and requires efficiency improvements for agricultural suppliers. The bill calls for urban water utilities to achieve a 20% reduction in urban per capita water use by 2020 and periodic evaluation of water reduction progress (California 2015). Required elements of the plan include:

- The calculated water use within their service area, expressed in gallons per capita per day (GPCD);
- Findings on the progress made to words meeting water use target's;
- Current and projected water demands and supplies;
- Water management actions taken to improve supply reliability;
- An evaluation of reliability to meet demands under both normal and drought conditions

The plans provide valuable insight into the conservation measures public utilities have implemented to meet the state-mandated water use reductions. Therefore, the urban water management plans represent a standardized articulation of the water conservation strategies currently being utilized by water providers.

The water conservation programs currently being implemented by public water utilities in California were found to consist of seven major strategy categories, two of which involved the promotion of greywater. The seven alternatives of water conservation strategies considered in this report for public water providers in California include:

1. Greywater Information/Workshops – Fact sheets, guidelines, or in-person workshops on greywater regulations, permitting, installation, and best practices;
2. Greywater Rebates – Rebates or reimbursements provided to residents to offset the cost of materials necessary for the installation of greywater reuse systems;
3. Xeriscape Information – Fact sheets, guidelines, or in-person workshops on landscape design that requires little or no irrigation or other maintenance;
4. Turf Replacement Rebate – Rebates or reimbursements provided to residents who replace traditional turf with landscape that requires little irrigation;
5. Recycled Water Supply – The production or availability of recycled water and associated conveyance infrastructure within the service area of the public water utility;
6. Water Use Audits – Review of an individual homes water uses and identification of opportunities for potable water use reduction;
7. Indoor/Outdoor Appliance Rebate – Giveaways or rebates provided to residents who replace indoor or outdoor appliances with higher efficiency models. Indoor appliances include low-flow showerheads, toilets, and faucets, as well as high efficiency clothes washers. Outdoor appliances include garden spray nozzles, irrigation controllers, rain sensors, and pool covers.

The above-mentioned strategies were the most commonly cited by California public water utilities in 2015 urban water management plans. These strategies are not expected to reduce potable water consumption uniformly amongst water users. The effectiveness of different approaches is largely dependent on building occupancy, a factor that is highly variable within a water supply region (Berhanu, et al., 2016). Each strategy has unique costs and savings for the users and the agency in terms of investment of time and money. Those costs can, in some cases, be offset by state and federal grant programs. Additionally, recycled water can be perceived as a water conservation strategy or a source of water supply, depending on the level of treatment and source of recycled water.

2.4 Criteria Identification

Identifying the possible criteria which will inform public water utilities decisions whether to support grey water systems is necessary to evaluate and compare the identified alternatives. To evaluate whether the two greywater promotion alternatives (greywater information/workshops and greywater rebates) should be selected by a public water utility, the most important criteria which would influence the water conservation strategy of a public water utility in California were considered. Two sources of previously established evaluation criteria were considered.

The Bureau of Reclamation (BOR) prepared a study to evaluate options and strategies for improving water supply and demand pressures on the Colorado River Basin. As part of the study, 17 evaluation criteria were used to characterize water demand reduction strategies. The evaluation criteria used in the study were consistent with the intentions of the BOR study, which included the legality and policy considerations of each option and the impacts to hydropower, recreation, and other environmental factors (U.S. Department of the Interior, 2012). Some of these factors are not expected to be pertinent to the decision framework established in this report.

Water conservation specialists with Big Bear Lake Department of Water & Power indicated they were evaluating their potable water demand reduction strategy. This evaluation included the development of a screening criteria document which describes five evaluation criteria used to characterize all available water conservation strategies. These five criteria are described below.

Criteria	Summary Description of Criteria
Water Savings Potential	Estimated reduction in potable water use as a factor of (1) the reduction in daily water use per account and (2) the ability to confidently quantify savings
Account Saturation	Approximation of the percentage of ratepayers able to implement/comply. Influenced by tangible barriers, economic barriers or perceived barriers
Community and Social Acceptance	Approximation of the popularity or opposition to the proposed strategy
Feasibility of Implementation - Cost	Estimated cost as expressed in price per acre foot of potable water saved
Feasibility of Implementation - Staff Time	Estimated time investment necessary for water utility representatives

Table 1: Criteria Used to Characterize Water Conservation Alternatives. Adapted from "Screening Criteria for Water Conservation Measures" Draft, Big Bear Lake Department of Water and Power (2018).

Based on the initial question proposed in this report and the relatively consistent regulatory framework under which public water utilities in California operate, the evaluation criteria presented by Big Bear Lake Department of Water & Power (BBLDWP) was utilized to score and compare alternatives for this study.

3.0 Alternative Scoring

3.1 Alternative Scoring System

Each of the seven water conservation alternatives was characterized by assigning alternatives integer value scores from 0 to 5 score for the five abovementioned criteria. For four of the five criteria considered (Account Saturation, Community and Social Acceptance, Feasibility of Implementation – Cost, and Feasibility of Implementation – Staff Time) were scored based on an evaluation of each alternatives characteristics. A “5” score would be assigned to alternatives that could be implemented by a vast majority of customers, alternatives considered highly popular, alternatives considered financially beneficial to customers, or alternatives that require little or no additional staff time to implement (BBLDWP, 2018). A "0" score is described in the BBLDWP screening criteria document as being assigned to alternatives considered unacceptable to rate payers, alternatives that rate payers were unwilling to implement or comply with, or alternatives infeasible due to fatal flaws; while, a "3" score would be assigned to alternatives with a "moderate ability to implement/comply", a neutral opinion by community, a neutral financial feasibility, or a manageable but difficult time commitment for existing staff (BBLDWP, 2018). For the purposes of this framework, the seven alternatives were evaluated relative to the six others.

The water savings potential score was determined using the following matrix. The qualitative scores "High, "Medium", and "Low" were assigned to the per account reduction in total daily water use, as well as the ability to confidently quantify savings. Considering the average per capita toilet flushing rate is 5.0 times per day, the replacement of an older 3.5 gallons per flush (GPF) with a high efficiency (1.28 GPF) toilet would be considered an alternative with high confidence for quantifiable water savings (BBLDWP, 2018; DeOreo et al., 2016). Whereas, an advertising campaign providing customers with xeriscape information would be considered an alternative with low confidence for quantifiable water savings due to the difficulty in attributing a homeowner's water-saving landscaping habits to an ad campaign. The three qualitative scores for daily reduction in total water use were assigned comparatively to the other six alternatives. Further detail regarding the characteristics that correlate to assigned scores can be found in the appended screening criteria document.

		Reduction in Total Daily Water Use by Account		
		High	**Medium**	**Low**
Ability to Confidently Quantify Savings	**High**	5	4	2
	Medium	4	3	1
	Low	2	1	0

Table 2: Matrix used for determining water savings potential. Adapted from "Screening Criteria for Water Conservation Measures" Draft, Big Bear Lake Department of Water and Power (2018).

When possible, the scores were determined using peer reviewed research on water conservation strategies or data collected by public organizations in California or other similar regions. The scoring is representative of a qualitative assessment of the alternatives, and in the case of account saturation and community and social acceptance may vary amongst water utility service area.

3.2 Alternative Scores

3.2.1 Greywater Information/Workshops

For the greywater information/workshop alternative, the ability to confidently quantify potable water savings is considered low. Quantifying the number of greywater reuse systems installed by residential ratepayers based on the information disseminated by an agency is difficult. The potential reduction in total daily water use by each account is considered moderate (**Water Savings Potential Score: 1**). Further, the lack of permitting requirements for the most common type of greywater reuse system (Laundry to Landscape) in California limits the ability to quantify the number of greywater systems installed.

The potential reduction in total daily water use by each account would be considered moderate, depending on the number of occupants in a residence and the potable water use being replaced by the greywater reuse system. Further, the theoretical water savings of an installed greywater system vary depending on the type of system installed with pumped systems providing greatest potable water savings potential (Gauley, 2017).

The account saturation score for greywater reuse information is considered low (**Account Saturation Score: 1**) due to the time and financial investment necessary to install greywater reuse system. The economic barrier is considered relatively high, with costs ranging from $2,000 to $4,5000 depending on a number of factors including the following (Gauley, 2017).

- Type of system installed
- Whether the system is newly installed versus a retro-fit system
- Do-it-yourself versus professionally installed

The community and social acceptance at this time would be described as limited acceptance (**Community and Social Acceptance Score: 2**). The current public perception of greywater reuse is not universally favorable, with some residents unaware that it is legal and safe to reuse greywater. However, proper greywater reuse requires less energy to treat and has more accepted perception than wastewater reuse (Larsen, et al., 2016).

The cost of providing greywater reuse information is relatively low; however, the overall cost of producing water through greywater recycling was estimated to be $4,200 per acre-foot (GreywaterAction, 2017). Therefore, providing greywater information/workshops is considered feasible due to the relatively low cost of informational campaigns compared to rebate programs or conveyance infrastructure (**Feasibility of Implementation – Cost Score: 4**).

The amount of water utility staff time required to successfully implement a greywater information/workshop program is variable depending on the time invested in developing original materials and the frequency of workshops **(Feasibility of Implementation – Staff Time Score: 3)**. Information/workshop strategies generally allow for manageable and variable time commitment.

3.2.2 Greywater System Rebate

For the greywater system rebate alternative, the ability to confidently quantify potable water savings would be considered high, considering the number of rebates provided would be easily quantified and the rebate program could be structured in a manner where savings pertinent information was provided in order to receive the rebate. The potential reduction in total daily water use by each account would be considered moderate, similar to the greywater information/workshop alternative (**Water Savings Potential Score: 4**).

The account saturation capacity for greywater rebates is considered limited (**Account Saturation Score: 2**) due to time and financial investment similar to Alternative 1; however, some of the costs would be offset by the reimbursement/rebate.

The community and social acceptance would be similar to that of the Greywater Information/Workshop alternative (**Community and Social Acceptance Score: 2**).

The cost of providing greywater system rebates is variable, with most existing rebates only offsetting a small portion of the cost of materials. Additionally, the overall cost of producing water through greywater recycling was relatively high, approximately $4,200 per acre foot of water (GreywaterAction, 2017). Therefore, greywater system rebates are considered an alternative with some limitations (**Feasibility of Implementation – Cost Score: 2**).

The amount of water utility staff time required to successfully implement a greywater information/workshop program can vary depending on whether the rebate is accompanied by an inspection of the system. The implementation of a greywater system rebate program exclusively would require little investment in time from staff. Specific materials at local stores could be designated reimbursable, and time spent confirming proper equipment could be passed along to customers and supply retailers **(Feasibility of Implementation – Staff Time Score: 4)**.

3.2.3 Xeriscape Information/Workshops

For the xeriscape information/workshop alternative, the ability to confidently quantify savings is considered low. Determining the potable water savings attributed to xeriscape information disseminated by a particular agency would be difficult, and the water savings could be extremely variable depending on the size of the landscaped area, as well as the irrigation practices of the ratepayer before and after converting outdoor areas. The potential reduction in total daily water use by each account is considered moderate, considering xeriscaped landscapes have been found to significantly impact water use with a mean predicted savings for single family residential accounts of 24.6 gallons per square foot per year (Price et al., 2012; Tull et al., 2016). (**Water Savings Potential Score: 4**).

Most residential ratepayers would be expected to be able to implement xeriscape practices (**Account Saturation Score: 4**) considering the existing prevalence of water-intensive plants, including turf, across California, and the relatively limited barriers to implementation. In some regions of California, xeriscaping may already be prevalent, limiting the potential for converting additional outdoor areas.

The community and social acceptance of xeriscape information/workshops is considered relatively high as compared to recycled water and greywater which have a level of public distrust (Larsen et al., 2016) (**Community and Social Acceptance Score: 4**). Despite the potential for water savings, agencies have reported negative perceptions by neighbors of xeriscaped outdoor areas when redesigns occur without the desire or funds to hire sufficiently educated professionals (Seapy, 2015).

The cost of providing xeriscape information is low depending on investment in materials or advertisements and the potential potable water savings are significant [24.6 gallons per square foot per year (Tull et al., 2016)], making xeriscape education a financially beneficial water conservation strategy (**Feasibility of Implementation – Cost Score: 5**).

The amount of water utility staff time required to successfully develop a xeriscape information/workshop program is variable depending on the time invested in developing original materials and the frequency of workshops **(Feasibility of Implementation – Staff Time Score: 3)**. Like the greywater information/workshop alternative, the xeriscape information strategy generally allows for manageable and variable time commitment.

3.2.4 Turf Replacement Rebate

The ability to confidently quantify savings from turf replacement rebates is considered moderate and the potential reduction in total daily water use by each account is considered moderate (**Water Savings Potential Score: 3**). The potable water savings of replacing the water-intensive plants in an outdoor area replaced is predominantly based on an easily quantified data source, the size of the area; however, the water savings are ultimately determined by the end-user's behavior. The potential reduction in total daily water use for turf replacement is similar to that of providing xeriscape information.

The account saturation potential for turf replacement programs is similar to xeriscape information programs, with most residential ratepayers expected to be able to implement xeriscape practices (**Account Saturation Score: 4**).

The community and social acceptance of turf replacement is considered relatively high (**Community and Social Acceptance Score: 4**).

The cost of providing turf replacement rebates is higher than simply providing information on xeriscaping and is variable depending on the reimbursement rate (Median rate of $1.00 per square foot). A review of nine different turf replacement rebate programs in California found the average cost per acre foot of water saved to be $2,011, less than half the calculated cost of producing water savings through greywater reuse (Seapy, 2015). Therefore, the turf replacement alternative is considered financially feasible (**Feasibility of Implementation – Cost Score: 4**).

The amount of water utility staff time required to successfully maintain a turf replacement program is considered high, with most programs requiring development of the application, review and acceptance of submitted applications, a pre-inspection to determine the potential savings, customer guidance, and a post-inspection. Therefore, a turf replacement program is considered a strategy that may implemented in lieu of other programs **(Feasibility of Implementation – Staff Time Score: 2)**.

3.2.5 Recycled Water Infrastructure

Recycled water infrastructure, a centralized system of water distribution, is considered a conservation alternative with a high confidence in quantification of water savings and a high potential for total daily water use (**Water Savings Potential Score: 5**). Once a conveyance system is installed, recycled water can replace a significant percentage of potable water consumption and is metered, like potable water distribution systems.

The account saturation capacity for recycled water infrastructure is considered limited, due to the physical limitations of existing conveyance systems and the public investment necessary to expand recycled water pipelines (**Account Saturation Score: 1**).

The community and social acceptance of recycled water infrastructure can be described as limited acceptance (**Community and Social Acceptance Score: 2**). The current public perception of recycled water is not universally favorable, especially for residential applications.

The cost of installing recycled water infrastructure is very high and incurred by water agencies. Currently, many recycled water supplies are subsidized to keep rates below potable water (**Feasibility of Implementation – Cost Score: 1**).

Maintaining recycled water infrastructure requires staff specialized in treatment and delivery of recycled water. Additional staff would be required if a public water utility were managing the treatment and conveyance of recycled water **(Feasibility of Implementation – Staff Time Score: 1)**.

3.2.6 Water Use Audits

For the water use audit alternative, the ability to confidently quantify savings is considered moderate and the potential reduction in total daily water use by each account is considered moderate (**Water Savings Potential Score: 3**). Calculating the potable water savings following a water use audit is a straight forward process for a public water retailer; however, a water use audit is often conducted in conjunction with other water conservation strategies complicating the amount of potable water savings that can attributed to the audit solely.

The vast majority of residential ratepayers would be expected to be able to participate in water use audits (**Account Saturation Score: 5**). Water use audits are predominantly free to customers, thereby making interest the only limiting factor to their application.

The community and social acceptance of water use audits is considered neutral (**Community and Social Acceptance Score: 3**). Some ratepayers are expected to embrace the chance to identify potable water conservation opportunities, while other residential ratepayers may be suspicious of allowing public officials into their home.

The direct financial costs associated with providing water use audits are low and the potential potable water savings are moderate, making water use audits financially beneficial (**Feasibility of Implementation – Cost Score: 5**).

The major investment associated with water use audits is the time agency staff spend conducting site visits and reporting the results of audits. Therefore, water use audits are expected to be a conservation strategy that would be implemented at the expense of other strategies **(Feasibility of Implementation – Staff Time Score: 2)**.

3.2.7 Indoor/Outdoor Appliance Rebate

For indoor/outdoor appliance rebates, the ability to confidently quantify potable water savings would be considered high. The number of rebates or free appliances provided through the rebate program can be easily quantified and the water savings of each appliance is fairly consistent as compared to traditional appliances.

The potential reduction in total daily water use by each account would be considered moderate depending on the appliance considered. The effective water savings of replacing different indoor and outdoor appliance was found to be primarily driven by occupancy, with water-efficient showerheads and bathroom faucets providing net savings under various replacement timing scenarios (Berhanu, et al., 2016) (**Water Savings Potential Score: 4**).

The account saturation capacity for appliance rebate programs is considered limited (**Account Saturation Score: 2**) due to the pervasiveness of appliance rebate programs and the resulting limited potential for further potable water savings. The Department of Interior WaterSMART grant program has provided federal funding to more water districts and municipalities in California than any other state since 2010 (U.S. Department of the Interior, 2016). Many of these grants were utilized to support appliance rebate programs.

The community and social acceptance of indoor and outdoor appliance rebates is considered moderately popular (**Community and Social Acceptance Score: 4**). Water users consider the cost of water efficiency appliances a barrier to their implementation being the most effective action to reduce water consumption (Attari, 2014). Therefore, providing rebates or giveaways of efficient appliances is expected to be well received.

Appliance rebate programs have been found to be financially beneficial, with costs that track with the proliferation of efficiency appliances. Although the installation of high-efficiency toilets is an effective means of reducing household water consumption, only 37% of total water reduction was found to be attributable to the rebate program versus water savings that would have occurred naturally (Bennear et al, 2013). Based on the limited water savings attributable to some appliance rebate programs, the alternative is considered feasible (**Feasibility of Implementation – Cost Score: 4**).

The amount of water utility staff time required to successfully implement an appliance rebate program is relatively small as compared to the other conservation strategies considered. Appliance rebates or giveaways do not require agency staff to confirm implementation; therefore, appliance rebate programs are considered feasible with existing water conservation staff **(Feasibility of Implementation – Staff Time Score: 4)**.

3.3 Alternative Scoring Summary

The characterization of the seven water conservation alternatives reveals benefits and drawbacks of each water conservation program. The findings of the characterization are displayed in the figures below.

Alternatives	Water Savings Potential	Account Saturation	Community Acceptance	Feasibility of Implementation - Cost	Feasibility of Implementation - Staff Availability
Greywater Information/Workshops	1 (Low Q, Med R)	1	2	4	3
Greywater Rebate	4 (High Q, Med R)	2	2	2	4
Xeriscape Information/Workshops	1 (Low Q, Med R)	4	4	5	3
Recycled Water Infrastructure	5 (High Q, High R)	1	2	1	1
Turf Replacement Rebate	3 (Med Q, Med R)	4	4	4	2
Water Use Audits	3 (Med Q, Med R)	5	3	5	2
Indoor/Outdoor Appliance Rebate	4 (High Q, Med R)	2	4	4	4

Figure 2: Criteria scores for the seven alternatives with water savings potential matrix scores described (Q = Ability to Confidently Quantify Savings; R = Reduction in Total Daily Water Use by Account).

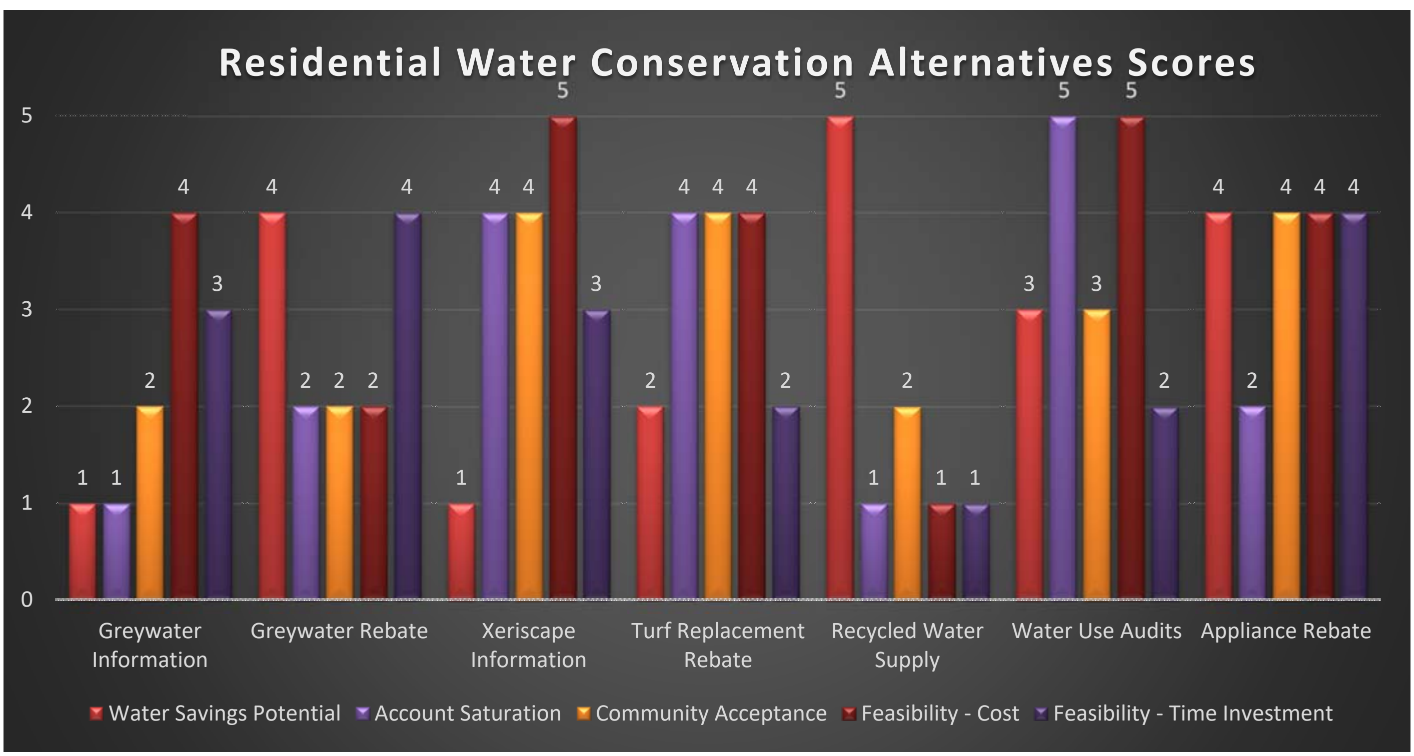

Figure 3: Histogram displaying criteria scores for the seven alternatives.

The three strategies that received the highest overall scores included water use audits, indoor/outdoor appliance rebates and xeriscape information/workshops, each alternative scored moderately well to very well in four categories and poorly in one category. In the case of conducting water use audits, the strategy scores poorly in terms of the time investment necessary indicating water agencies with limited staffing would struggle to implement this conservation strategy.

The indoor/outdoor appliance rebate strategy scores poorly in account saturation based on the existing pervasiveness of water efficient appliances, especially in a drought-prone state, like California. The water conservation specialist representing the City of Austin noted that providing a rebate for water efficient toilets and showerheads has been less effective over time as the number of high efficiency toilets and showerhead already installed within the city increases. Despite the lower score assigned to this strategy, some regions of the state may not have the water efficient appliance saturation level of other service areas where appliance rebate programs have been in place for a long period of time.

The xeriscape information/workshops strategy received a poor water savings potential rating due to the difficulty in quantifying the potable water savings attributed to the strategy and the moderate expected reduction in total daily water use per account. Despite the low confidence in being able to quantify water savings, the xeriscape alternative is a low cost conservation strategy with the potential to reduce potable water use for a large portion of a water utility's ratepayers.

The characterization of the considered alternatives revealed a general tradeoff between alternatives that involve financial rebates and those that involve solely providing information/workshops. Alternatives that involve financial rebates, including greywater rebates, turf replacement rebates and indoor/outdoor appliance rebates, are generally less feasible to implement in terms of financial cost, and in some cases, staff time. However, the additional financial or time investment results in higher confidence in quantifying the water savings of those programs; whereas, information/workshop strategies score lower in terms of water savings potential because of the difficulty in quantifying the savings associated with those programs.

The criteria evaluation of the recycled water alternative highlights the distinctiveness of this strategy. Recycled water scores low on most criteria due to the investment necessary to install and maintain a centralized recycled water system, the limited number of customers serviced by the conveyance systems, and the "yuck" factor associated with reusing wastewater. However, the recycled water alternative was evaluated as the strategy with the highest water savings potential due to the potential to offset significant potable water use per account and easily quantifiable water savings. Considering the California DWR required water providers to consider the feasibility of recycled water use in 2015 urban water management plans, the strategy can be considered a priority for the state of California.

3.4 Limitations

The characterization of the identified alternatives was conducted to develop a decision framework to assist with the evaluation of water savings strategies in California; however, all possible strategies were not considered. The distribution of rain barrels is notable water conservation strategy that was not considered as an alternative in this evaluation. Rain barrel rebate programs were not found to significantly residential reduce water demand, and they were not discussed prominently in the reviewed 2015 urban water management plans (Price et al., 2014).

Further, the scores assigned to each alternative may differ from one region of California to another. The perceived benefits of measures which improve energy efficiency were found to differ amongst regions of the United States (Cole et al., 2018). The community acceptance scoring of different alternatives may differ amongst regions of California. Additionally, the financial feasibility, account saturation, and water savings potential for conservation strategies may change over time with technology changes or if additional commercial water conservation products are introduced.

The water conservation strategy alternatives were evaluated considering the present day regulatory framework. If more stringent water use regulations were to be passed or additional public grants made available, the feasibility and account saturation potential of the alternatives may change.

The assignment of quantitative scores to qualitative criteria, such as community acceptance, is another critical limitation of this evaluation. Evaluating different criteria on a similar 0 to 5 scale implies equal weighting of the criteria, which is unlikely to be the case for most public utilities. Additionally, an alternative with a score of 4 should not be considered twice the value of an alternative with a score of 2. Public water utility representatives considering the decision framework must resist motivational biases when considering the evaluation of different water savings strategies.

4.0 Discussion

4.1 Present Day Water Conservation Strategies

The decision framework developed in this study is designed to assist public water utilities in California to determine whether to promote greywater systems, and more broadly assist in the development of an ideal portfolio of water conservation strategies. Urban water management plans, a document prepared by water utilities in California and submitted to the state DWR, were reviewed to develop parameters for the decision. The plans provide valuable information on the water conservation progress made by Californians to date, a critical factor for determining which conservation strategies to support in the future.

In 2017, the California DWR prepared a status report on the 2015 Urban Water Management Plans which was provided to the state legislature for review. The main purpose of the Report of Findings was to determine if changes to water use efficiency standards or urban water use targets were needed (State of California, 2017). Further analysis of the submitted plans can be found through the California Open Data Portal, where basic population, water and recycled water information has been accumulated from the submitted plans.

The California DWR did not recommend changes to water use efficiency standards in order to achieve the water reduction goal because water utilities were considered likely to meet the 20% target. Specifically, each of the urban retail water suppliers that submitted urban water management plans met their 2015 interim water use target, which was calculated as half of the overall water use reduction to be achieved by 2020 (State of California, 2017).

Statewide water use in 2015 was calculated to be 133 GPCD which is 33% less than the 2020 target identified in 2009 (State of California, 2017). The DWR's review of the urban water management plans can be interpreted as demonstrating the success of existing water conservation strategies being implemented by water utilities in California. Considering their success at meeting the state-mandated potable water use reductions, water utilities are not expected to significantly alter their water conservation strategies on a short-term basis due to the upfront financial and time investments necessary to launch a new water conservation strategy.

Despite surpassing the state-wide conservation standards established in 2009, residential water use has increased since the state-mandated drought restrictions were eased in April 2017 (Guerin, 2018). The statewide residential daily use for January 2018 was 13.1 GPCD higher than the same month in 2017 (State Water Resources Control Board, 2018). The degree to which urban water use continues to increase is expected to greatly impact how public water utilities evaluate their water conservation plans in the future. The interviewed water conservation specialist from the West Basin Municipal Water District has described anecdotal decrease in inquiries regarding water conservation strategies since the drought emergency was declared over.

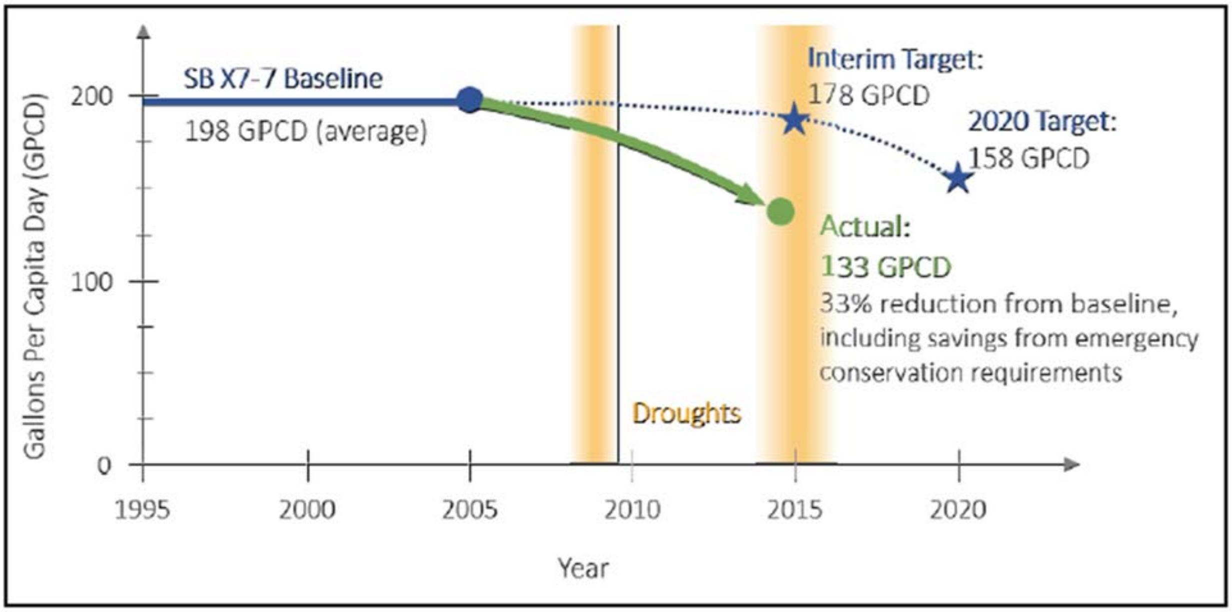

Figure 4: Water use reduction (gallons per capita day) in California over time including the goals established in 2009 and the actual reduction achieved as of 2015. Adapted from Status of 2015 Urban Water Management Plans, A report to the Legislature pursuant to Section 10644 and 10608.42 of the California Water Code, State of California Department of Water Resources (August 2017).

The California Open Data Portal dataset included information from 336 submitted urban water management plans, including public and private water suppliers. The urban water management plans submitted by water suppliers in 2015 were required to include an evaluation of the existing and potential opportunity for recycled water beneficial use. Of the submitted plans, 41% indicated recycled water was utilized in 2015 in a manner that qualifies as beneficial use. As summarized in the table below, more than 367,000 acre-feet of recycled water was utilized in 2015, most commonly for irrigation.

Reviewed Urban Water Management Plans	336
Water Providers using Recycled Water for a Beneficial Use	41.1%
Total Recycled Water Use utilized for Beneficial Use in 2015 (AF)	367,718.93
Most Common Uses (Occurrences)	Landscape Irrigation (119)
	Golf Course Irrigation (63)
	Industrial Use (37)
	Agricultural Irrigation (31)
	Other (25)
	Commercial Use (21)
	Geothermal and other energy production (6)
	Groundwater Recharge (5)
	Recreational impoundment (3)
	Seawater intrusion barrier (1)

Table 3: Recycled water use by water suppliers in California as described in 2015 urban water management plans. Data from Urban Water Management Plans (UWMP) 2015, California Department of Water Resources, California Open Data Portal, Modified January 2018.

Although a significant portion of water suppliers in California have some existing recycled water use, many of the water providers acknowledged lacking conveyance infrastructure and noted that recycled water was used exclusively at the treatment facilities where it was generated. As such, the financial investment considered in the decision framework for recycled water infrastructure remains high, especially to supply residential neighborhoods.

In addition to the status report prepared by the California DWR, forty-five (45) urban water management plans submitted by public utilities were reviewed and the conservation strategies discussed in the plans were considered.

The most frequent water conservation program discussed in 2015 Urban Water Management Plans was appliance rebate programs, followed by xeriscape information/workshops. Of the reviewed plans, 31% referred to greywater reuse materials or workshops available to ratepayers, and 22% of the plans mentioned rebate programs for the installation of greywater programs.

Water Conservation Strategy Prevalence in California	
Greywater Information	31.1%
Greywater Rebates	22.2%
Xeriscape Information	75.6%
Recycled Water Available	68.9%
Turf Replacement Rebate	71.1%
Water Audits	73.3%
Indoor/Outdoor Appliance Rebate	91.1%

Table 4: The percentage of public water utilities which included discussion of the potable water conservation strategy alternatives in their final 2015 urban water management plans.

The prevalence of indoor/outdoor appliance rebate and xeriscape information programs is consistent with high scores those alternatives received in the decision framework. Water use audits received moderate to high scores in four of the five criteria considered in the decision framework, but was implemented at a lower frequency than xeriscape information. This discrepancy could be attributed to limited water conservation staff at public utilities in California.

The significantly lower frequency of greywater strategies is consistent with perceptions described by all four of the water utility representatives interviewed. Interviewees discussed a lack of knowledge by ratepayers and policymakers related to the legality and best practices of greywater reuse as major reasons for the limited promotion of greywater. Additionally, the 2015 urban water management plan prepared for the city of Los Angeles summarizes issues, opportunities, and recommendations related to various water conservation strategies. For greywater, the following were identified as potential issues:

- Permitting and regulations;
- Cost;
- Drain-line carry – The ability of wastewater to flow effectively through septic pipes;
- Potential health and environmental risks; and,
- Potential conflict with other resources

The Los Angeles plan recommends continuing to encourage research and exploring additional public education efforts. In response to public comment on the city's Urban Water Management Plan, the Los Angeles Department of Water and Power (LADWP) indicated they are focused on using their limited conservation budget for cost-effective programs such as the residential turf removal rebate and water-efficient clothes washer rebates. Although the LADWP does not provide rebates for greywater reuse systems, they do provide rate payers with information related to safely installing greywater systems via their dedicated greywater website (ladwp.com/graywater).

4.2 Decision Framework Application

The established framework illuminates potentially opposing priorities of public water utilities in California while evaluating their water conservation strategy. The alternatives considered can be implemented in conjunction with one another; however, the resources available to an agency for investment in water conservation are expected to be limited.

The water source and composition of users in a supplied region are expected to influence how each California public water utility prioritizes different water conservation strategies. Two of the water conservation specialists interviewed as part of this study mentioned the saturation of their service area with certain types of conservation strategies. As appliance rebate programs become less effective, public water utilities are expected to value less common alternatives, such as greywater and recycled water infrastructure.

Analysis has shown that less accepted and more expensive water conservation technologies have a higher uncertainty of acceptance by water users (Bakit et al., 2018). Therefore, public water utilities in California may consider rolling out greywater rebate programs as part of a long-term conservation strategy following several years of greywater information/workshops. This strategy has been implemented by the West Basin Municipal District, with greywater rebates reported to begin in 2018.

In addition to prioritizing criteria differently, certain water providers may score alternatives differently from the characterization determined in this report. For instance, the account saturation and community acceptance scores of greywater reuse systems and recycled water may be altered by increased public education on the technology or additional drought periods that would trigger water use restrictions in California.

Two of the regions represented by interviewed water conservation specialists demonstrate the range of circumstances and perspectives on water conservation strategies. Whether a given region is supplied by groundwater, local surface water, or imports can play a critical role in their approach to water conservation. Further, the seasonality of certain regions can influence criteria prioritization for water suppliers.

Big Bear Lake is a community which includes a significant percentage of second homes where water use is variable. Greywater is not currently a prominent component of the Big Bear Lake Department of Water & Power conservation portfolio, due to the limited potable water savings relative to the cost for a home not occupied on a regular basis. However, the value of greywater for community members whose primary home is in Big Bear would be relatively high.

Pasadena is an established community with mature conservation development. Toilets, shower heads, smart nozzle heads, clothes washer rebates are not expected to achieve significant potable water consumption on a long-term basis. Pasadena's water conservation specialists mentioned community interest in greywater was a major factor in the development of their greywater workshops and rebate program.

Additionally, the supply source for a water provider factors into how conservation strategies are selected. Utilities predominantly supplied by imported water might value recycled water infrastructure to a greater degree considering it could diversifying water supplies.

4.3 Decision Making Steps

The established decision framework is designed to help public water utilities decide whether to promote greywater reuse systems; however, any conservation strategy could be evaluated in a similar manner.

The following broad decision-making process could be applied by water suppliers to consider whether to allocate conservation resources towards a particular strategy:

- Identify and weigh the priorities and corresponding criteria for the overall water conservation;
- Review existing water supplies, demand, and conservation strategies;
- Identify potential conservation strategy alternatives by engaging with ratepayers and researching strategies implemented elsewhere;
- Score existing and considered conservation strategy alternatives;
- Identify grants available for funding the highest priority alternatives;
- Implement the portfolio of alternatives that corresponds to the established priorities.

This flow of decisions could be followed on a periodic basis, as well as if significant changes to water supplies or public sentiment occur.

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