# Water Conservation Flows Downstream: Assessing the Performance of State Conservation Policies and Municipal Conservation

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**Abstract**

Many southwest states are creating water policies focused on conservation or water restriction mandates. Our research aims to determine how effective these policies are at encouraging conservation accomplishments at the municipal level. Additionally, we analyze which specific municipal actions are most cost-effective and politically feasible. We used a quantitative and qualitative pilot survey of water managers in three southwest states to examine how water conservation initiatives vary within and between states, which water conservation measures are most cost-effective and politically feasible, and how state-level policies affect municipal actions. The survey questions helped to analyze water managers' perceptions of state conservation policies and municipal conservation actions, track the level of reported conservation progress in each state, and document which measures are reported to be most popular and effective. We also provide recommendations for states interested in creating water conservation goals, and for municipal water managers seeking to implement cost-effective and politically feasible conservation measures. By grounding our work in place-informed context, we aim to critically examine the planning, execution, and evaluation of water conservation policy among its practitioners, and help bridge the gap between abstract research and day-to-day management. Our findings will help researchers inform more efficient policies to allocate funding for water system changes, and will help geographers understand how water conservation measures are implemented across a variety of political cultures and climatological zones.

*Key words*: water conservation, drought, innovation, state water policy, United States

## 1. Introduction

For a community to be sustainable, it is important that its systems, including water utilities, are resilient to disturbances such as droughts (Derissen et al., 2011). Water utilities lie at the intersection of science and politics (White and Corley, 2013). The implication is that water resource managers face scientific pressures from hydrologists, on the one hand, who may indicate that water supplies in a community are vulnerable, and political pressures from residential developers, agricultural producers, and industrial and commercial water users, on the other hand, who require increasing water supplies for growth. These pressures are further amplified by climate change and its anticipated impacts on water systems.

Severe drought once seemed like a thing of the past for the American southwest, relegated to grainy newsreel footage of Dust Bowl disasters. However, many areas of Oklahoma, California, and Arizona are once again affected by recurring water shortages, and climate change could lead to a further increase in the frequency and severity of such events. While the effects of climate change will not be uniform across the southwestern United States, droughts in the region overall are predicted to increase in both duration and severity during the course of the next half-century (Karl et al., 2009). Researchers anticipate that climate change will reduce water availability in each of the three states included in our study (Hayhoe et al., 2004; Hsiang et al., 2017; Ojima et al., 2009). The resulting water shortages are expected to disrupt existing water practices while creating new challenges for managers (Kundzewicz et al., 2009).

Studies have examined various factors for their influence on water conservation actions, including household income, water manager education and certification levels, water availability and/or quality, or the particular water source (e.g., the proportion of surface water to ground water) (Hartman et al., 2017; Hornberger et al., 2015). Municipal water managers play a key role in influencing conservation actions in the direction of sustainability principles (Widener et al., 2017). Some California water utilities, for example, enhanced their capabilities and became more resilient in response to long-term drought (Gonzales and Ajami, 2017), while utilities in Oklahoma developed surplus adaptive capacity when not experiencing recurring or intense drought (Widener et al., 2017). However, the ability of state-level policy to influence municipal water conservation actions is uncertain, as is the role of geographic variation in guiding water conservation policy. While studies of federal water system funding show that "bureaucrats will rely on their expertise and preferences in directing drinking water investment" (Daley et al., 2014, p. 568), differences in institutions may lead to a wide range of utility actions within these complex multi-level water systems (Teodoro, 2010).

Through this study, we investigate ways in which state goals can best influence municipal water conservation policies, and determine which conservation measures can be used by managers to implement such policies most efficiently. As water managers must balance an array of competing priorities and make decisions based on information from multiple scales, we analyze both strategic state-level water resource planning and the tactical development of specific conservation actions at the municipal level. A popular pro-conservation slogan states "think globally, act locally." Our work incorporates a similar multi-scalar perspective, as we aim to identify patterns of both perception and action among a diverse sample of municipal managers, and extrapolate from these patterns to inform state-scale policy.

To address the aforementioned research question, we gathered information from practitioners directly involved with day-to-day water resource decisions. Specifically, we analyze the cost-effectiveness of water conservation measures and identify what challenges municipal leaders face when implementing such measures. The geographical variation in these factors between southwestern states is examined by focusing on the municipal response to recently implemented state-level water conservation policies in Oklahoma and California. Arizona is included as a control since it faces water resource scarcity but had not implemented a statewide water conservation act. These three states were selected because they share drought-mitigation challenges, but have responded differently due to their different political cultures. While Oklahoma's conservation act, passed in 2012, is voluntary (Steele et al., 2012), California's first key act, passed in 2009, set mandated conservation targets (Steinberg, 2009). Water issues in California are particularly salient due to the exceptional severity of that state's drought. During the period of our study (spring of 2015), surface reservoirs in California, the state's primary source of fresh water, contained roughly a year's supply, and groundwater levels had dropped by eight million acre-feet since 2011 (Famiglietti, 2016).

The key goals of our work are to determine how states can help facilitate successful municipal water conservation policy, what challenges most affect municipalities in their efforts to conserve water, and which strategies are most promising for municipal governments, particularly in an era when command-and-control environmental legislation has fallen out of favor, and has given way to market-based management strategies (Olmstead and Stavins, 2008). Water resource decisions are categorized as soft- or hard-path (Gleick et al., 2003). Soft-path decisions focus on institutional or behavioral changes to encourage conservation and demand-side management, while hard-path decisions are intended to increase supply through investments in infrastructure and technology. Hard-path decisions designed to address water shortages include producing more supply via finding new sources or utilizing wastewater. Soft-path decisions, including high-efficiency plumbing codes, consumer education, and price manipulation, can be just as effective at enhancing water supply capacity as hard-path decisions (Glieck et al., 2003). They are also less expensive than new infrastructure (NY State Dept. of Environmental Conservation, 2015; San Diego County Water

Authority, 2007). A popular axiom in the water management community states that "the cheapest water you will ever find is the water you already have in your system" (Green, 2009, p. 3). For example, high-efficiency plumbing codes encourage conservation by requiring plumbing-fixture retrofits, which save hundreds of thousands of gallons of water annually when combined with consumer education and/or pricing measures to prevent or minimize the rebound effect (Antoniou, 2010).

Raising the price of water can provide a direct incentive for more efficient use; a study of three cities in California's drought-burdened Central Valley found that replacing flat-rate water pricing structures with volumetric pricing can cut household water use by over 15 percent (Tanverakul, 2015). Although pricing changes can save water, they often require a costly and intensive procedure of installing water meters at homes and businesses (Houk, 2010). However, non-price alternatives have been shown to reduce water demand by 1.1 to 4.0 percent when implemented simultaneously (Michelsen et al., 1999).

In keeping with our goal to compare specific conservation measures, our study evaluates the cost-effectiveness and feasibility of soft-path and hard-path decisions. The major challenge to soft-path solutions is often believed to be their political feasibility rather than their cost (Hornberger et al., 2015). For example, while rainwater collection tanks require support and maintenance at the household level, their overall life-cycle cost is less than alternative water infrastructure projects like pipelines and desalination plants (Tam et al., 2010). This cost-advantage could mean that soft-path decisions are more likely to be implemented first in response to state-level conservation acts, if those acts break down the municipal political barriers.

However, hard-path decisions are a common choice for addressing water supply challenges. Wastewater reclamation technology has been applied in communities from Wichita Falls, Texas to Orange County, California. The Colorado School of Mines has developed a small-scale reclamation plant, which can recycle over 7200 gallons of residence hall wastewater per day (Hancock, 2013). In Norman, Oklahoma, a successful grey-water reuse system helps keep the University's golf course green without consuming valuable potable water (City of Norman, 2015). While water reuse can achieve significant savings, it can also face powerful political resistance, especially from water system stakeholders unfamiliar with the technology. Residents in arid regions often disapprove of introducing reclaimed water into municipal supplies (Dishman et al., 1989; Theodori et al., 2009); however, public opinion about water reuse can be changed (Dolnicar and Schäfer, 2009) by well-coordinated education and engagement efforts. Education and communication efforts require a variety of media platforms to engage stakeholders (Robinson et al., 2005). This requirement increases the cost of hard-path recycling measures compared to soft-path conservation methods.

Effective state policy may empower municipalities to address large-scale sustainability issues while guiding the changes made to their water systems (Spiller et al., 2015), but state policy may also weaken the ability of municipalities to develop solutions. Successful implementation of conservation approaches may depend on municipal leadership's responses to the state's policies. The cases of renewable energy, telecommunications, and climate change adaptation systems reveal typical positive and negative interactions between a state and its municipalities. An analysis of 20 municipal climate-adaptation plans found that 90 percent were implemented in states that had already issued state climate-adaptation plans (Bassett and Shandas, 2010). In California, state tax incentives have encouraged office-building developers to install renewable energy systems that contribute to LEED certification (Choi, 2010). Conversely, misguided state policy can slow innovation locally. For example, in terms of communication "utilities," some states have passed laws that restrict the creation of municipal broadband networks (Mandviwalla et al., 2008). Another example of limiting state-level policy is a law enacted in Oklahoma in 2014 that hinders the development of small-scale wind and solar power projects. S.B. 1456 permits centralized electric utilities to levy surcharges on customers who produce power using distributed generation systems (Griffin et al., 2014). Thus, state laws can positively or negatively affect municipal decisions, and therefore, help to shape the water landscape.

## 2. Methods

This study examines municipal water managers' perceptions of and experiences with hard- and soft-path conservation solutions. Local water-treatment and water-distribution managers in Arizona, California, and Oklahoma were surveyed using SurveyMonkey during January, February, and March of 2015. Potential informants were identified using the League of Arizona Cities and Towns database, the League of California Cities database, and the Oklahoma Municipal League database. The survey was directed only to municipal water managers, neither special water districts nor county governments were included. Only one manager from each municipality was surveyed. The survey instrument contained ranking, rating, and open-ended questions designed to gather both quantitative and qualitative data (Appendix). A paper version was physically mailed to water managers who did not respond to the initial invitation to complete the electronic survey. Despite this approach that included four electronic and one snail mail follow-up, an overall (all three states combined) response rate of 14 percent was achieved (Table 1).

Due to the weak response rate, it is necessary to address potential non-response bias. A low response rate does not automatically render a study useless, especially in light of universally declining response rates due to the proliferation of online surveys (Rogelberg and Stanton, 2007). In previous surveys concerning water policy, respondents were more likely than non-respondents to feel "identification with and awareness of environmental issues" (Brox et al., 2003). This suggests that water managers who answered the survey are more likely to be managers who put more effort into providing reliable responses. In effect, the responses are biased in favor of more credible and more trustworthy information.

To analyze the data, comparisons were made between the three states. Arizona served as a "control" case due to its lack of a state-level conservation policy. Quantitative data (i.e. gallons of water saved using a given measure) were averaged within states and averages were compared between states. To calculate the cost-effectiveness of each management measure, the average costs in each state were divided by the average number of gallons projected to be saved by those measures in each state. Qualitative data were compared both between states and between the various conservation measures within each state. Open-ended responses were coded by a single researcher using open rather than a-priori methods. Chi-square testing was used for statistical analysis, as chi-square is a non-parametric method suitable for nominal and ordinal survey data (McHugh, 2013). The threshold of significance was set at a p value of 0.05. In many cases, statistical p values determined by chi-square tests were negligible. However, the number of respondents to each question was logged and displayed for verification.

## 3. Results

The completion rate in the three states (i.e., proportion of respondents who completed 100% of the survey questions) ranged from 57 to 68%. Responding managers were generally from larger communities than were non-respondents. The large discrepancy in the response rates is likely impacted by a range of factors. One key factor is the dramatically different number of municipalities in each state. Variance in completion rates is explained less by the absolute number of completed surveys than by the 'denominator' of municipalities contacted. Only four states in the U.S. have fewer municipalities than Arizona (Maciag, 2012). Arizona had the highest response rate, as fewer communities contacted led to fewer non-returned surveys. "The prevalence of [local] governments varies widely throughout [the U.S.]…historic boundaries and agreements, along with population and geography, often explain much of the regional differences" (Maciag, 2012).

Utility managers in Oklahoma and California were asked how water use had changed in their communities since the implementation of statewide water conservation acts, whereas in Arizona, managers were asked how water use had changed since the year 2010 to provide a comparison (Table

**Table 1: Sample and Response Characteristics of Survey**

| | OK | CA | AZ |
|---|---|---|---|
| *N* | 547 | 411 | 74 |
| *Number of Respondents* | 65 | 44 | 33 |
| *Response Rate* | 12% | 11% | 45% |
| *Fully Completed Responses: n* | 44 | 25 | 20 |
| *Completion Rate* | 68% | 57% | 61% |
| *Median Population of Responding Communities* | 2,058 | 39,032 | 45,129 |
| *Median Population of Non-Responding Communities* | 583 | 31,144 | 6,106 |

2). The average water use change in each of four sectors – residential, commercial, industrial, and agricultural – was determined. By percentage, the residential sector in California and Arizona decreased its use the most, but in Oklahoma it increased its use the most. Overall, average water use decreased by 3.5% in California and 2.6% in Arizona, but it increased by 0.6% in Oklahoma. These figures demonstrate the difficulty of water conservation, even in drought-stricken regions; in the case of Oklahoma, they suggest that soft-path strategies based on voluntary efforts may not achieve conservation.

To understand the factors that posed the greatest barrier to the implementation of water conservation measures, four challenges were analyzed (political feasibility, cost, lack of knowledge among utility staff, and technical complexity) and compared between Oklahoma and California (Table 3). Cost was the most frequently identified obstacle to conservation measures overall. This suggests that

**Table 2: Average Water Use Change by State and Sector as Reported in Survey**

| | n (OK) | OK | n (CA) | CA | n (AZ) | AZ (Since 2010) |
|---|---|---|---|---|---|---|
| Agricultural | 16 | 0.5% | 10 | -1.3% | 11 | -2.3 |
| Commercial | 15 | 0.7% | 12 | -3.2% | 11 | -1.1 |
| Industrial | 14 | 0.4% | 12 | -3.1% | 12 | -3.1 |
| Residential | 15 | 0.8% | 11 | -6.5% | 12 | -4.0 |

**Table 3: Challenges to Water Conservation Changes Reported in Survey: Oklahoma vs. California**

| | | **Oklahoma** | | | | | **California** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | Political Feasibil-ity | Cost | Technical Complexi-ty | Lack of Familiar-ity | *n* | Political Feasibil-ity | Cost | Technical Complex-ity | Lack of Familiari-ty |
| Water Price Increase | 34 | 85% | 6% | 3% | 6% | 20 | 30% | 30% | 30% | 10% |
| Rainwater Collection | 35 | 11% | 26% | 14% | 49% | 19 | 11% | 5% | 11% | 74% |
| Leak Detection and Repair | 31 | 3% | 65% | 26% | 6% | 20 | 35% | 30% | 20% | 15% |
| Meter Fault Detection and Replacement | 31 | 6% | 77% | 13% | 3% | 20 | 30% | 55% | 5% | 10% |
| Automated Meter Reading | 29 | 7% | 83% | 3% | 7% | 20 | 35% | 25% | 25% | 15% |
| Grey Water Reuse | 34 | 21% | 21% | 26% | 35% | 18 | 33% | 17% | 17% | 33% |
| Wastewater Reuse | 35 | 34% | 11% | 17% | 37% | 19 | 5% | 16% | 16% | 63% |
| Stormwater Retention Infrastructure | 35 | 6% | 37% | 26% | 31% | 19 | 16% | 32% | 21% | 32% |
| Residential Consumer Education | 31 | 13% | 42% | 10% | 35% | 20 | 60% | 30% | 10% | 0% |
| Commercial/ Institutional Consumer Education | 33 | 9% | 42% | 15% | 33% | 19 | 42% | 37% | 16% | 5% |
| Green Roofs | 35 | 9% | 14% | 26% | 51% | 19 | 5% | 11% | 5% | 79% |
| High Efficiency Plumbing Codes | 35 | 29% | 11% | 23% | 37% | 19 | 58% | 26% | 0% | 16% |
| **Overall** | | **19%** | **36%** | **17%** | **28%** | | **30%** | **26%** | **15%** | **29%** |

more sources of funding will be vital for municipal utilities to confront drought, and potential climate change impacts ranging from increased evaporation rates to flood-damaged infrastructure. For example, recent downscaled climate data indicate that even within a single river basin (the Red River of the South), by the middle of the 21st Century, the western regions of the basin will face increased risk of drought, while the eastern/southern regions face increased risk of severe, high-precipitation events (McCorkle et al., 2016; Qiao et al., 2017). While cost is a major challenge, political feasibility was also a significant obstacle to conservation progress, especially in the case of water price increase in Oklahoma. Although a majority of respondents from California identified political feasibility as the most significant challenge for residential-consumer education, this may simply be because the other three options were not frequently seen as significant barriers in that state. Lack of familiarity was also a major challenge especially for rainwater collection, water reuse, and the use of green roofs in both Oklahoma and California. Continuing education for water managers is important to allow them to gain up-to-date knowledge on effective water conservation measures.

While challenges limit water conservation, many communities have been able to overcome these factors and take steps to reduce their water use. Most respondents from all three states had either already conducted or were in the process of conducting upgrades for leak detection and repair, as well as meter-fault detection and replacement (Table 4). These options are popular among water managers because it

**Table 4: Implementation of Conservation Measures by State Reported in Survey**

| | Oklahoma | | | | | California | | | | | Arizona | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | Past | Current | Future | No plans to implement | *n* | Past | Current | Future | No plans to implement | *n* | Past | Current | Future | No plans to implement |
| Water Price Increase | *34* | 68% | 21% | 3% | 9% | *20* | 30% | 30% | 30% | 10% | *20* | 40 % | 25% | 15% | 20% |
| Rainwater Collection | *33* | 6% | 6% | 0% | 88% | *19* | 11% | 5% | 11% | 74% | *20* | 5% | 20% | 25% | 50% |
| Leak Detection and Repair | *36* | 44% | 47% | 0% | 8% | *20* | 35% | 30% | 20% | 15% | *20* | 25 % | 40% | 25% | 10% |
| Meter Fault Detection and Replacement | *35* | 43% | 40% | 9% | 9% | *20* | 30% | 55% | 5% | 10% | *20* | 40 % | 35% | 15% | 10% |
| Automated Meter Reading | *34* | 29% | 21% | 18% | 32% | *20* | 35% | 25% | 25% | 15% | *20* | 20 % | 25% | 40% | 15% |
| Grey Water Reuse | *32* | 3% | 0% | 3% | 94% | *18* | 33% | 17% | 17% | 33% | *19* | 16 % | 5% | 21% | 58% |
| Wastewater Reuse | *32* | 0% | 0% | 3% | 97% | *19* | 5% | 16% | 16% | 63% | *20* | 5% | 5% | 30% | 60% |
| Stormwater Retention Infrastructure | *33* | 9% | 6% | 9% | 76% | *19* | 16% | 32% | 21% | 32% | *20* | 20 % | 40% | 5% | 35% |
| Residential Consumer Education | *35* | 37% | 26% | 11% | 26% | *20* | 60% | 30% | 10% | 0% | *20* | 35 % | 40% | 10% | 15% |
| Commercial/ Institutional Consumer Education | *34* | 32% | 24% | 3% | 41% | *19* | 42% | 37% | 16% | 5% | *20* | 25 % | 35% | 15% | 25% |
| Green Roofs | *32* | 9% | 0% | 9% | 88% | *19* | 5% | 11% | 5% | 79% | *20* | 0% | 5% | 10% | 85% |
| High Efficiency Plumbing Codes | *32* | 9% | 6% | 9% | 75% | *19* | 58% | 26% | 0% | 16% | *19* | 42 % | 37% | 11% | 11% |

Note: This table shows the proportion of respondents in each state who plan to have implemented, are implementing, plan to implement, or will not implement each conservation measure. For instance, a plurality of Oklahoma respondents have already implemented residential consumer education, but 26% claim to have no plans to implement this measure. Respondents only were able to choose one timeframe per measure that best describes its implementation status in their organization.

is easier to build support for 'fixing leaky faucets' on a utility-wide scale than for constructing new infrastructure. Water price increases were the most popular conservation measure among water managers that had already been implemented in the past five years for Oklahoma, and was the second most popular among Arizona managers. This suggests that the Oklahoma utilities had successfully overcome political feasibility challenges resulting from unpopularity among consumers in the past, despite listing such challenges as a significant barrier to future water price increases (Table 3). Less than a third of California respondents had already implemented a price increase, but 60 percent were either currently trying to implement an increase or planned to do so in the coming years. This is a relatively low-cost measure, with few utility managers reporting cost as the greatest challenge to implementing water price increases. While its political feasibility is a challenge, that it is one of the most frequently-implemented measures suggests that political feasibility may be overcome by water managers perhaps more easily than is overcoming the challenge of achieving more costly measures.

The least frequently implemented water conservation measures were wastewater reuse systems; only five percent of California and Arizona respondents had implemented these systems, and none of the Oklahoma respondents had done so (Table 4). Greywater reuse was only slightly more frequently implemented in California and Arizona, but in Oklahoma, 94 percent of respondents had no plans to implement such systems. Furthermore, in Oklahoma, three-quarters of respondents had no plans to implement stormwater-retention infrastructure, despite the increasing variability in precipitation patterns that characterizes the state (Ojima et al., 2009; Oklahoma Climatological Survey, 2015). There was some difference between states regarding the popularity of different conservation measures when past, present, and future plans for implementation were combined. For example, all of the California respondents have implemented or plan to implement residential consumer education, but less than 75 percent of Oklahoma respondents have done this or plan to do so. The differences between these states suggest that water conservation programs are tailored to the specific priorities of individual geographic regions.

Although challenges to implementing water conservation measures persist, many water managers have found ways to overcome them because of powerful motivating factors. The importance of four motivating factors (water conservation acts, increasing community demand, drought/water shortages, and increasing water costs) were tabulated and compared between states (Table 5). The importance of drought/ water shortages to the majority of managers in all three states is clearly evident. Less than a quarter of managers in Oklahoma and California believed that the water conservation act was the most important factor for implementing water conservation measures. When it comes to local water policy decision-making, nature may trump the state legislature. We might infer that water conservation policies address long-term sustainability, while drought and water shortages pose direct and immediate threats to communities.

Water managers must overcome challenges to translate these motivations into water conservation action. Given that funding is a major challenge for water conservation, the cost-effectiveness of conservation measures may determine their implementation. The cost-effectiveness of each conservation measure was calculated (Table 6). High-efficiency plumbing codes and consumer education programs were the most cost-effective measures implemented. The next most cost-effective were leak detection and repair, meter fault detection and replacement, wastewater

**Table 5: Motivating Factors for Water Conservation by State as Reported in Survey**

| | OK<br>n =19 | CA<br>n=19 | AZ<br>n=19 |
|---|---|---|---|
| Water Conservation Act | 12% | 21% | N/A |
| Increasing Demand from Your Community | 0% | 0% | 20% |
| Drought/Water Shortages | 67% | 74% | 75% |
| Increasing Water Costs | 21% | 5% | 5% |

**Table 6: Cost-Effectiveness and Self-Reported Water Savings of Each Conservation Measure as Reported in Survey**

| | | | Average Water Savings of Each Measure (1000's of Gallons) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Oklahoma | | California | | Arizona | |
| | **Cost Effectiveness Ranking** | **Average Cost per Gallon Saved US$** | | *n* | | *n* | | *n* |
| High Efficiency Plumbing Codes | 1 | 0.0022 | 12,080 | 5 | 264,389 | 3 | 13,367 | 4 |
| Commercial/Institutional Education | 2 | 0.0050 | 5,014 | 5 | 164,796 | 2 | 19,300 | 4 |
| Residential Consumer Education | 3 | 0.0058 | 9,314 | 7 | 148,130 | 3 | 3,000 | 7 |
| Leak Detection and Repair | 4 | 0.0063 | 46,714 | 7 | 355,431 | 3 | 88,029 | 5 |
| Meter Fault Detection and Replacement | 5 | 0.0087 | 20,229 | 7 | 420,975 | 3 | 202,060 | 5 |
| Wastewater Reuse | 6 | 0.0098 | 4,625,000 | 3 | 2,439,629 | 3 | 292,281 | 4 |
| Rainwater Collection | 7 | 0.0230 | 2,200 | 4 | 8,646 | 2 | 6,350 | 3 |
| Water Price Increase | 8 | 0.0662 | 40,000 | 5 | 2,498,130 | 3 | 126,250 | 2 |
| Automated Meter Reading | 9 | 0.1428 | 19,543 | 7 | 4,027,154 | 3 | 2,860 | 5 |
| Grey Water Reuse | 10 | 0.1809 | 6,833 | 7 | 878,796 | 3 | 179,961 | 4 |
| Stormwater Retention Infrastructure | 11 | 0.2063 | 4,200 | 3 | 125,000 | 2 | 300,000 | 2 |
| Green Roofs | 12 | NA | NA | 5 | 5,000 | 2 | 20,000 | 3 |

**Note: The cost effectiveness ranking was calculated by the authors by dividing the average reported cost in U.S. Dollars by the average reported water savings in gallons.**

reuse, rainwater collection, water price increase, and automated meter reading. Although less expensive, the education options led to smaller overall water savings than other options such as wastewater reuse, leak detection and repair, meter fault detection and replacement, and water price increases (Table 6).

Conservation measures were also ranked according to political feasibility (Table 7). The largest proportion of managers considered leak detection and repair to be the most politically feasible, likely because they are improvements to existing infrastructure. Fixing system leaks is less political than is constructing new water-system components or imposing new rules. Automated meter reading and residential consumer education were ranked next in terms of political feasibility. Residential consumer education was the least expensive per gallon saved and the most politically feasible. Residential consumer education could be one of the best ways for Oklahoma water utilities to build upon existing accomplishments and improve their conservation performance.

Perceptions of statewide water conservation acts differed between Oklahoma and California. Most of California's water managers claim high levels of familiarity with the Water Conservation Act of 2009 (Table 8), and this is likely to increase due to the new emergency executive orders adopted in May 2015, which aim to reduce California's urban water use by 25 percent (California State Water Resources Control Board, 2015). However, most Oklahoma water managers claimed to have low or no familiarity with the Water for 2060 Act (Table 8). The low level of policy familiarity likely helps to explain Oklahoma's poor water conservation performance compared to California's. Lack of familiarity with Water for 2060 is also associated with less innovation in improvements of water systems in Oklahoma (Hartman et al., 2017). Clearly, steps must be taken to help Oklahoma

**Table 7: Political Feasibility of Conservation Measures as Reported in Survey**

| | Oklahoma | | California | | Arizona | | |
|---|---|---|---|---|---|---|---|
| | | *n* | | *n* | | *n* | Chi-square p-Value (df = 2) |
| Water Price Increase | 5% | 31 | 4% | 20 | 0% | 16 | NS |
| Rainwater Collection | 3% | 30 | 3% | 19 | 5% | 17 | NS |
| Leak Detection and Repair | 28% | 30 | 16% | 19 | 14% | 16 | NS |
| Meter Fault Detection and Replace-ment | 10% | 31 | 11% | 19 | 14% | 16 | 0.005 |
| Automated Meter Reading | 23% | 31 | 11% | 19 | 13% | 16 | NS |
| Grey Water Reuse | 0% | 30 | 9% | 19 | 6% | 16 | 0.011 |
| Wastewater Reuse | 0% | 30 | 1% | 19 | 3% | 16 | NS |
| Stormwater Retention Infrastructure | 3% | 29 | 7% | 19 | 5% | 16 | NS |
| Residential Consumer Education | 15% | 30 | 15% | 19 | 20% | 17 | NS |
| Commercial/Institutional Consumer Education | 13% | 30 | 11% | 19 | 9% | 17 | NS |
| Green Roofs | 0% | 29 | 3% | 19 | 0% | 14 | NS |
| High Efficiency Plumbing Codes | 3% | 29 | 11% | 19 | 11% | 17 | 0.002 |

Note: Measures with a p-value <0.05 have a statistically-significant level of variance between states in the proportion of respondents who assigned them the highest political feasibility ranking.

**Table 8: Familiarity with Water Conservation Acts as Reported in Survey: Oklahoma vs. California**

| | Oklahoma n = 32 | California n = 19 | Chi-square p-Value (df = 1) |
|---|---|---|---|
| 1 (Not At All Familiar) | 44% | 16% | 0.041 |
| 2 | 38% | 11% | 0.037 |
| 3 | 6% | 11% | NS |
| 4 | 9% | 21% | NS |
| 5 (Very Familiar) | 3% | 42% | 0.000 |

**Note: Measures with a p-value <0.05 have a statistically-significant**

managers develop their water-conservation knowledge, and to build capacity to implement conservation techniques.

When asked for suggestions to improve the Water for 2060 Act, most respondents reported that they were not familiar enough with it to offer suggestions (Table 9). A plurality of respondents from both states, however, reported that the acts should be made more holistic. This is understandable in light of the contrasting financial capacities of urban and rural utilities. Only 12 and 13 percent of respondents from Oklahoma and California, respectively, said that the water conservation acts should contain stricter regulations. Additionally, a plurality of respondents reported that the most effective component of the acts was the spreading of new ideas for conservation (Table 10), suggesting that all utility managers are interested in increasing their conservation expertise.

**Table 9: Feedback about the Water Conservation Acts as Reported in Survey: Oklahoma vs. California**

| | Oklahoma n = 30 | California n = 18 |
|---|---|---|
| More Holistic Approach (i.e. "Ensure that [the Water Conservation Act] is small-town friendly") | 24% | 27% |
| Stricter Regulation (i.e. "have existing state agencies do something ...") | 12% | 13% |
| More Funding (i.e. "Funding mechanisms tied specifically to municipal water conservation") | 6% | 13% |
| Other (i.e. "alternate water sources") | 12% | 13% |
| Not Familiar Enough to Offer Suggestions | 47% | 27% |

**Table 10: Most Effective Part of the Water Conservation Acts as Reported in Survey: Oklahoma vs. California**

| | Oklahoma n = 17 | California n = 16 |
|---|---|---|
| Provision of Ideas for Conservation Measures (i.e. "encourage better leak detection and repairs") | 29% | 25% |
| Declaration of Specific Conservation Goal (i.e. "specific statewide goal") | 12% | 31% |
| Raising of Education/Awareness (i.e. "Education for residential consumers" | 12% | 13% |
| Do not know | 47% | 25% |

## 4. Conclusion

Our findings illustrate the diversity of communities engaged in water planning, as well as the heterogeneity of water management decision-making (Daley et al., 2014; Teodoro, 2010). They illustrate concepts involving both strategic state-level water resource planning, as well as tactical community-level conservation actions. The Water for 2060 Act is an important step forward for Oklahoma water planning (Hartman et al., 2017). Many Oklahoma water managers applaud its effectiveness at disseminating innovative ideas for water conservation. However, most are not familiar with it, and many perceive room for improvement in its relevance to the local scale. Rather than the Water for 2060 Act, the more immediate concerns of drought/water shortages primarily motivate conservation measure implementation. California's strict April 2015 conservation ordinances may not be politically feasible in all states, especially those not facing an urgent water crisis. The primacy of "drought/ water shortages" as a motivating factor for conservation measure implementation shows that dramatic short-term situations, rather than long-term priorities, often take center stage in the water planning process. However, the high level of familiarity observed among

California managers with XB7-7, coupled with that state's leading conservation performance, suggests that assertive state policy can foster awareness of long-term issues among those charged with day-to-day resource management.

Residential consumer education is the most cost -effective conservation measure that also ranks in the top quartile of political feasibility scores. High-efficiency plumbing codes also score highly on both metrics, especially with regard to cost-effectiveness at conserving water. While no single measure represents a conservation panacea; the outstanding performance of these tools suggests that they would be a worthwhile focus of future study by geographers and policy researchers.

Implementing conservation measures is urgently needed, as Oklahoma has made limited progress thus far at reducing water use compared to California and Arizona. Arizona has recently succeeded in reducing municipal water use; however, it still lacks statewide conservation legislation and lags behind its neighbor to the West in conservation performance. California's effective statewide legislation provides a useful example, while its crisis situation provides a consequential warning. Even when drought is not as severe in Oklahoma as in California, taking firm, proactive action now to mandate water conservation could help avert emergency situations in years to come. While a community facing an existential water shortage may be induced to build a wastewater reclamation plant or other hard path measure no matter the price, cost was the single most common challenge to water conservation efforts reported by responding water managers. If managers are successfully motivated to implement conservation measures by either an effective statewide water conservation act or a dramatic decrease in water availability, soft path demand-side programs would be more cost-effective tools compared to many of their hard-path counterparts.

## 5. Recommendations

Going forward, continuing education is one of the most important considerations for water policy planning and research, especially in Oklahoma. Institutional inertia is a significant challenge within the water sector as a whole, and many managers who responded to the survey specifically reported that they have very limited familiarity with the Water for 2060 Act. Perhaps statewide water agencies could establish a "Blue Drinks" program to promote events where water managers could network with each other and with state water policy officials. This would help build a base of tacit knowledge among water managers, and would give state officials a captive audience for information regarding water conservation acts. Researchers could gather data from managers using interviews and surveys in order to refine the effectiveness of conservation messaging. This measure was inspired by the "Green Drinks" programs created to promote networking among sustainability professionals (Horwitch and Mulloth, 2010).

Another measure policymakers could take to promote water conservation is increased funding, especially if linked to conservation progress. The mandatory California Water Conservation Act of 2009 stipulates that utilities that do not meet conservation goals will experience even greater challenges due to a reduction in funding and ineligibility for grants. This 'stick' was identified as the most effective component of SB X7-7 by many California officials. It has become even stronger in recent months as a result of emergency conservation measures. However, the voluntary Oklahoma Water for 2060 Act includes no such penalties. Future Oklahoma water conservation goals should include an enforcement mechanism. For instance, comparison of energy efficiency policies shows that enforceable mandates, such as those applied to the lighting sector in the state of California, maximize conservation inducement performance (Akashi et al., 2003). If such a provision is politically infeasible, a similar measure could be added in the form of a 'carrot': water utilities that meet conservation goals could be eligible for additional grant funding to support further conservation measures.

This funding could be especially impactful if it were distributed through a policy mechanism known as infrastructure banking. State infrastructure banks are revolving funds that loan money at low or zero interest to municipalities (Yusuf and Liu, 2008). Once a municipality that has received funding completes a capital project, it repays what it borrowed, providing funding for the bank to make further investments in other communities. Since these banks are subsidized by states, they offer lower borrowing costs than the bond market (Yusuf and Lin, 2008). States have good reasons to invest in such banks; Federal Reserve research shows that increased public investment in water and sewer systems is linked with increased economic output (Munnell and Cook, 1990). Infrastructure banks also help direct funding where it is needed most. For example, nearly 40 percent of funds allocated by the EPA's State Drinking Water Revolving Fund aided water systems serving fewer than 10,000 people (EPA, 2010).

Outreach to community and institutional stakeholders is just as important as federal partnerships. Oklahoma City already has a successful residential consumer education program, which is centered on an engaging anthropomorphic water droplet. This program uses multiple media platforms to teach residential consumers how to fix plumbing leaks and live more water-conscious lives. Oklahoma City also partners with local universities to provide lessons regarding water-efficient gardening (City of Oklahoma City Utilities Dept., 2015). Tulsa and Norman, Oklahoma's second and third largest cities, could potentially add similar efforts to their existing stable of environmental programs. As a college town, Norman has opportunities for conservation success due to the University of Oklahoma's sustainability research and education initiatives related to water conservation and innovation. Using indirect initiatives to encourage local action is a practical way to help conservation "flow" from state to municipal governments. As states take action to better promote water conservation, research can help track their progress and identify promising strategies.

The scale of water governance is an important consideration for future research because smaller municipal water utilities lack adaptive capacity to respond to frequent droughts (Widener et al., 2017) and could therefore benefit from regional scale collaborative management (Gonzales and Ajami, 2017). States with effective water policies (e.g., California) could collaborate with neighboring states to encourage water conservation, technology and infrastructure innovation, and more sustainable forms of management in the face of uncertainty and growing water demands.

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**Appendix:**

**This survey was sent to Oklahoma water managers; similar surveys were sent to managers in CA and AZ, but with state and conservation act names changed.**

1. Please tell us about yourself:

Name:
Utility:
Address:
City/Town:
County:
Email Address:
Phone Number:

2. What is your job title?

3. What are your job responsibilities?

4. How many years have you worked at your current position?

5. Describe past employment information and experiences that are relevant to water management.

6. Who in your organization do you feel is most responsible for water system management and innovation?

7. Please describe your organization's experience with implementing the following water conservation measures (past, current, future, no plans to implement):

- Water Price Increase
- Rainwater Collection (e.g. Rain Barrels, Cisterns)
- Leak Detection and Repair
- Meter Fault Detection and Replacement
- Automated Meter Replacement
- Grey Water Reuse (e.g. "Purple Pipe")
- Wastewater Reuse (e.g. "Toilet-to-Tap")
- Stormwater Retention Infrastructure (e.g. Permeable Pavement)
- Consumer Education Measures
- Commercial/Institutional Consumer Education
- Green Roofs
- High Efficiency Plumbing Codes
-

8. Please rate the following water conservation measures from 1 (least) to 5 (most) according to your perception its effectiveness at conserving water, its political feasibility, its cost-effectiveness, and its priority for order of im-

plementation (1 is lowest priority and 5 is highest):

- Water Price Increase
- Rainwater Collection (e.g. Rain Barrels, Cisterns)
- Leak Detection and Repair
- Meter Fault Detection and Replacement
- Automated Meter Replacement
- Grey Water Reuse (e.g. "Purple Pipe")
- Wastewater Reuse (e.g. "Toilet-to-Tap")
- Stormwater Retention Infrastructure (e.g. Permeable Pavement)
- Consumer Education Measures
- Commercial/Institutional Consumer Education
- Green Roofs
- High Efficiency Plumbing Codes

9. Please select the challenge (political feasibility, cost, technical complexity, lack of familiarity) that most limits the ability of your organization to implement each water conservation measure:

- Water Price Increase
- Rainwater Collection (e.g. Rain Barrels, Cisterns)
- Leak Detection and Repair
- Meter Fault Detection and Replacement
- Automated Meter Replacement
- Grey Water Reuse (e.g. "Purple Pipe")
- Wastewater Reuse (e.g. "Toilet-to-Tap")
- Stormwater Retention Infrastructure (e.g. Permeable Pavement)
- Consumer Education Measures
- Commercial/Institutional Consumer Education
- Green Roofs
- High Efficiency Plumbing Codes

10. Please estimate the cost ($/year) and water savings (gallons/year) of each of the following measures if implemented in your community:

- Water Price Increase
- Rainwater Collection (e.g. Rain Barrels, Cisterns)
- Leak Detection and Repair
- Meter Fault Detection and Replacement
- Automated Meter Replacement
- Grey Water Reuse (e.g. "Purple Pipe")
- Wastewater Reuse (e.g. "Toilet-to-Tap")
- Stormwater Retention Infrastructure (e.g. Permeable Pavement)
- Consumer Education Measures
- Commercial/Institutional Consumer Education

- Green Roofs
- High Efficiency Plumbing Codes

11. Please rank the following motivations for implementing conservation measures in your community, with 1 being most important and 4 being least important:
___OWRB Water for 2060 Act
___Increasing Demand from your Community
___Drought/Water Shortages
___Increased Water Costs

12. Regarding the OWRB's Water for 2060 Act, please rate the following options, with 1 being not at all and 5 being very:
How familiar are you with the Act?
How supportive are you of the Act?
How useful do you feel the Act is to your water system?
How successful do you think the Act will be at encouraging water conservation?

13. Please estimate how water demand has changed in the following sectors since the passage of the OWRB Water for 2060 Act in November 2012 (e.g. 5% increase, 10% decrease, etc.)?
Commercial/Institutional
Industrial
Residential
Agricultural

14. What implications does the Water for 2060 Act have on your water system's planning process?
15. What changes, if any, would you suggest to the OWRB Water for 2060 Act?
16. Which part(s) of the OWRB Water for 2060 Act do you think are most effective at encouraging conservation?