Alliance *for* Water Efficiency

Outdoor Water Savings Research Initiative

PHASE 1 - ANALYSIS OF PUBLISHED RESEARCH

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Abstract

A review, analysis, and synthesis of published and pending research on outdoor water use and water savings.

Authors

Peter Mayer, P.E., Paul Lander, Ph.D., and Diana Glenn, M.S.

Alliance for Water Efficiency
300 W. Adams Street, Suite 601
Chicago, Illinois 60606-5109

www.allianceforwaterefficiency.org

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Executive Summary

The Alliance for Water Efficiency plans to implement a comprehensive Outdoor Water Savings Research Program to develop actionable information and data on the savings potential and actual water savings from a variety of outdoor conservation measures. The goal of this research program is to provide relevant, statistically validated, and peer reviewed information on water savings and costs from different outdoor measures and programs, regional differences, and evaluation methods, and to provide key inputs for the AWE Conservation Tracking Tool and other demand forecasting models.

This report summarizes the work completed in Phase 1 of the AWE Outdoor Water Savings Research Initiative. Phase 1 is a review, analysis, and synthesis of published research on outdoor water use and water savings. In particular, studies that documented water savings were sought. The research in Phase 1 was conducted specifically for the purpose of informing the direction of the AWE Outdoor Water Savings Research Initiative so that the limited research budget can be focused on the area(s) of greatest need.

General Findings

Outdoor water savings are achievable and can be significant. Numerous recent studies documented outdoor water savings from specific measures such as conservation oriented rates, xeriscape, or soil moisture sensors that reduced outdoor water use by 15 – 65% or more. The research shows that successful approaches to reducing outdoor water use are available and are in fact being implemented across the U.S.

Quantifying water savings from outdoor programs and measures is challenging. Remarkably few studies quantify water savings from measures such as xeriscape or landscape contractor training and certification. Many studies that originally sought to measure water savings instead report "hypothetical" or modeled savings results because of data collection problems or climate variability.

Reporting of outdoor water savings in research varies and there is a lack of geographic and climate variability in the research. Many studies report savings as a percentage, but the basis of the percentage is not consistent across all studies. Some studies reported savings in gallons per square foot of landscape impacted. Much of the urban landscape outdoor water savings research to date of real significance has been conducted in Florida, California, and Nevada. Except for Florida, outdoor water savings research east of the Mississippi is hard to come by.

Cost savings are rarely documented. Water savings are documented in some good studies, but cost savings – from either the customer perspective or the utility perspective - are documented in very few of the studies. If cost savings are documented, it is almost always based on water reductions only. Very few studies consider the time and maintenance costs associated with a landscape and how these may be impacted by the efficiency program.

Standardized approaches and methods for measuring and evaluating outdoor water efficiency programs are needed. Work has begun on establishing conservation metrics, and robust methods for measuring changes in water use are available. Developing standardized approaches and performance indicators, similar to what has been accomplished for water loss control, could be highly beneficial for water utilities in measuring their progress.

Research Needs

The following were identified as the areas of greatest need for additional research on outdoor water savings and costs:

- Impact of native, water-wise, and xeric landscapes vs. turf on water use and cost.
- Impact of water rates, rate structures, and billing information on demand.[1]
- Impact of various drought restrictions on demand. The best/only research on this topic is now 10 years old.
- Water requirements and drought tolerance of landscape turfs and plants under different climate and drought conditions. Water requirement should be based on acceptable appearance rather than maximum growth.
- Impact of landscape contractor training, education, and certification.
- The human element of landscape water management – how people manage and interact with the entire irrigation system and the installed landscape.
- Impact of improving system efficiency through audits, tune ups, sprinkler-head retrofits, and other measures.
- Reasons and rationale for customer landscape choices.
- Cost-effectiveness and cost savings of various outdoor water saving programs.
- Impact of regional variability (climate, soils, demographics, etc.) on outdoor water demand and savings, with a standard measure for comparison across regions.
- Standard methods for monitoring and verifying water savings.
- Long-term reliability and projected lifetime of outdoor water savings.

Areas Where Sufficient Research Exists

The following were identified as areas where more and potentially sufficient research and information are already available:

- Impact of water budget-based rates.
- Irrigation control technology including weather-based controllers and soil moisture sensors.

Additional research in these areas would be welcome, but these are not currently the areas of greatest need.

Data to Improve Demand Forecasts

Care should be taken when applying results from the research studies identified in this report to demand and water savings forecasts. The applicability of each study reviewed differs significantly and few of the studies cited were designed specifically with the goal of providing broadly generalizable results. Regional variability is a significant issue that has not been well addressed in research to date, and thus this lack of localized information can impair the accuracy of long-term outdoor water use demand planning by water utilities in varying climate zones.

[1] Economists are primarily interested in correctly pricing a community's water resources in relation to the available supply through proper specification of water demand models. In order to do this, they attempt to control for variables that cause variation in demand; e.g. seasonality and weather. Consequently, their work is largely theoretical and usually encompasses the entire water system not just outdoor water use. Price elasticity identifies entry points for conservation, but may not be sufficient to inform water utilities about the likely impacts of different rates and rate structures. The water savings from water budget-based rates have been studied more recently and better than other rate forms.

A summary of the water savings measured from different outdoor water conservation programs are presented in Table 1. Differences in research methods, location, timing, and numerous other factors should be considered before applying any of these results in demand forecasting models. There is no accepted standard 'baseline' from which outdoor savings are measured. Actual savings may vary.

Table 1: Summary of water savings by measure

Measure	Lower Bound of Water Savings	Higher Bound of Water Savings	Best Available Estimate of Water Savings*
Water budget-based rates	10 %	20%	18% (Barenklau et. al. 2013)
Mandatory drought irrigation restrictions	18%	56%	Varies by severity of restriction. More severe = more savings.
Voluntary drought irrigation restrictions	4%	12%	Varies.
Customized mailed home water use reports		5%	5% (Mitchell et. al. 2013)
Conservation education programs	2%	12%	Varies.
Florida-Friendly Landscaping	50%	76%	50% (Boyer, et. al. 2014)
Xeriscape rebates (NM)		33%	Varies (Price, et. al. 2014)
Xeriscape conversion (NV)	34 gpsf	60+ gpsf	55.8 gpsf savings (Sovocool, et. al. 2005)
Urban densification (MA)		5%	5% (Runfola, et. al.)
Natural and manufactured shade (Israel)		50%	50% (Shashua-Bar, et. al. 2009)
Soil moisture sensor-based control (FL)	24%	92%	65% (Haley, et. al. 2012)
Residential weather-based control (CA)	6%	14.9%	9.4% (MWDOC 2011)
Commercial weather-based control (CA)	8%	27.5%	27.5% (MWDOC 2011)
ET signal-based control (FL)	23%	34%	Varies. (Davis, et. al. 2014)
Rain switch and pause (FL)	25%	41%	Varies. (Rutland et. al. 2012)
Weather-based control (NM)	34%	54%	Varies. (Al-Ajlouni, et. al. 2012)
Weather-based control (NV)	4.6%	68%	Varies. (Devitt, et. al. 2008)
Rotating sprinkler heads	0 or negative	31% (hypothetical)	Unknown

*Some savings estimates did not differentiate between indoor and outdoor reductions, but in all cases the primary focus was on outdoor.

Introduction

Outdoor Water Savings Initiative Research Goal

The Alliance for Water Efficiency plans to implement a comprehensive Outdoor Water Savings Research Program to develop actionable information and data on the savings potential and actual water savings from a variety of outdoor conservation measures. The goal of this research program is to provide relevant, statistically validated, and peer reviewed information on water savings and costs from different outdoor measures and programs, regional differences, and evaluation methods, and to provide key inputs for the AWE Conservation Tracking Tool and other demand forecasting models.

Phase 1 Goal

This report summarizes the work completed in Phase 1 of the AWE Outdoor Water Savings Research Initiative. Phase 1 is a review, analysis, and synthesis of published and pending research on outdoor water use and water savings. In particular, studies that documented water savings were sought. The research in Phase 1 was conducted specifically for the purpose of informing the direction of the AWE Outdoor Water Savings Research Initiative so that the limited research budget can be focused on the area(s) of greatest need.

Phase 1 Components

Key elements of this Phase 1 report include:

- Definition of five distinct outdoor research topic areas.
- Description of relevant research and findings on water savings.
- Identification of gaps in topic areas where additional empirical research is needed.
- Identification of the best/most useful research completed to date.
- Useful results applicable for use in the AWE tracking tool.
- Ongoing and upcoming research yet to be published.
- Bibliography of published research.

This Phase 1 report is intended to establish the groundwork for the development and implementation of AWE's Outdoor Water Savings Research Initiative.

Research Team

The Phase 1 research was conducted by Peter Mayer, P.E. of Water Demand Management, Paul Lander, Ph.D. (University of Colorado), and Diana Glenn, M.S. (Utah State University).

Research Methodology

Five Areas of Investigation

Prior to the start of this project, the Alliance for Water Efficiency identified five distinct areas of research for this project's focus. These areas were deemed the most useful characterizations of need in utility planning of outdoor savings measures. They are described briefly below:

1. **Restrictions, Rates, Education, and Information:** Top down irrigation management including irrigation restrictions, efficiency oriented water rates, water budgets, education, and information programs.

2. **Landscape Transformation:** Creating landscapes that require less water, based on local and regional conditions. Includes new landscapes, renovated landscapes, alternative landscapes, voluntary hands-on education programs, and regulations, codes, and standards that mandate and/or restrict landscape design and installation.
3. **Irrigation Management:** Technology, information, methods, and projects to optimize and improve irrigation management. Includes: smart controllers, soil moisture sensors, rain shutoff devices, irrigation management training programs, audit recommendations, and contractor and customer education.
4. **Landscape and System Efficiency:** Improving the performance and efficiency of landscapes and irrigation beyond the control device. The right plant in the right place and with the right amount of water. Includes research on the inherent characteristics of plants, landscapes, and irrigation systems.
5. **Monitoring and Verification:** Tracking and verification of landscape water use and savings.

Literature Review

The research team rigorously explored national and international research on outdoor water use, outdoor water use efficiency, and the impacts of or programs created to reduce outdoor water use, including conservation oriented rate structures designed to target outdoor demands. Using the five proposed areas as a guide, the research team assembled published research on outdoor water savings. A matrix of research reports was prepared that allows for basic comparison of research studies and results.

The research team sought out instructive examples from the US, Canada, and countries like Australia that have addressed water supply shortfalls implementing rigorous outdoor demand management programs as well as encouraging technological innovation.

The literature review examined both published research and un-published utility sponsored research as well as conference proceedings and internet resources. The research team worked to identify the studies that are most relevant and that offer the best data and examples for consideration.

Interviews with Irrigation and Outdoor Use Experts and Practitioners

The research team conducted a series of short interviews with noted irrigation and outdoor water use experts and utility practitioners to further identify research and data. The interviews were conducted via telephone and via email.

Outdoor Use Experts

The research team consulted the following irrigation and outdoor water use experts and utility practitioners to further identify research and data.

- Dr. Michael Dukes
  University of Florida
- Dr. Kelly Kopp
  Utah State University
- Dennis Pittenger
  University of California, Riverside
- Dr. Joanna Enter-Wada
  Utah State University
- Dr. David Zoldoske
  Fresno State University
- Brent Mecham
  Irrigation Association
- Dr. Tony Koski
  Colorado State University
- Dr. Roger Kjelgren
  Utah State University

In some cases, researchers were simply asked to review the bibliography and provide any additional research not already included.

Outdoor water use experts that the research team interviewed for this project included: Michael Dukes, Kelly Kopp, Dennis Pittenger and Joanna Enter-Wada. Other experts were contacted by email, provided a copy of the bibliography and asked to recommend changes and additions. These experts included: Dave Zoldoske, Brent Mecham Tony Koski, and Roger Kjelgren.

The personal interviews helped the research team identify additional studies and data for the literature review as well as to establish what gaps exist in understanding and measurement of outdoor water use and savings.

Analysis of Assembled Research and Data

The research team organized the most useful information and data into a summary matrix to help improve understanding of outdoor water use and savings potential in each of the five different topic areas. This process was extremely useful in identifying areas where significant research gaps exist.

Preparation of Phase 1 Report

The research team prepared this Phase 1 report to describe the project, summarize the findings of the literature review, and identify areas where AWE could provide substantial benefit by supporting additional research. It is hoped that the results from the Phase 1 report can be used to guide research efforts in subsequent phases of the AWE Outdoor Water Savings Initiative.

Phase 1 Research Findings

The research team identified more than 170 research studies spread across the five identified subject areas. The pie chart in Figure 1 shows the relative percentage of studies that were identified in each of the five areas. Based on perspective of quantity of research that could be identified, the research areas of System Efficiency and Monitoring and Verification appear thin compared with the other three categories. The categories vary in breadth, so a qualitative perspective and review of the work is essential.

The discussion below presents key findings from each topic area. For each topic area, research papers of significance are identified. Key findings for each topic area are also highlighted.

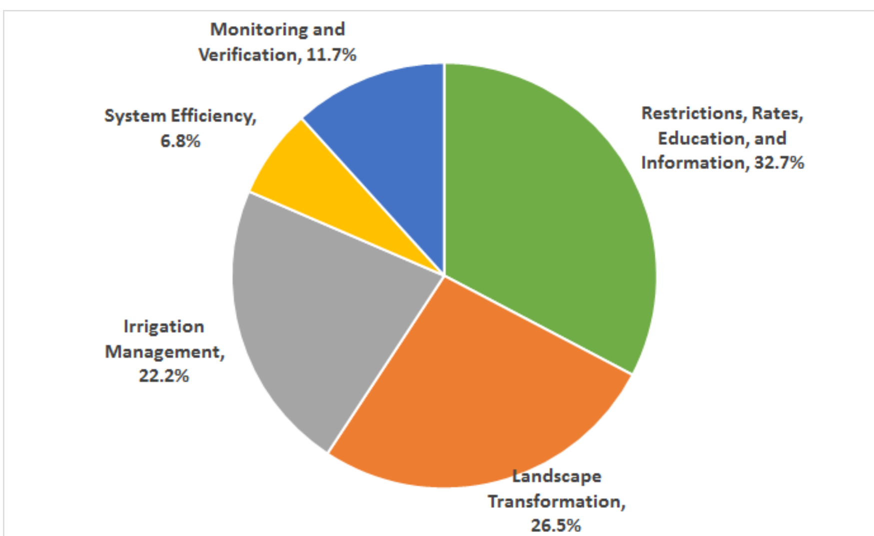

Figure 1: Percent of research publications identified in each of the 5 topic areas

Topic Area 1 - Restrictions, Rates, Education, and Information

This topic area covers top down irrigation management including irrigation restrictions, efficiency oriented water rates, water budgets, education, and information programs.

Summary of Research Findings

Although more than 60 studies were identified in this topic area, only a handful provided quantified reductions in overall or outdoor water use. Results from the most relevant studies are presented below. Available information is limited, and additional research quantifying the impacts of rate structures, drought restrictions, and/or education programs would be beneficial.

Rates and Rate Structure Impacts

- An 18% reduction was found in residential water use from an increasing block rate water budget price structure in Southern California (Baerenklau, Schwabe, and Dinar 2013).
- Among the economic policy tools, this Israeli study found that a smooth increase of water tariffs was not effective, while a drought surcharge led to a significant reduction in residential water demand (Lavee, Danieli, Beniad, Shvartzman, and Ash 2013).
- There is emerging theoretical and empirical evidence that using prices to manage water demand is more cost effective than implementing non-price conservation programs, similar to results for pollution control in earlier decades (Olmstead and Stavins 2009).
- A meta-analysis of 24 residential water use studies published between 1967 and 1993 found that inclusion of evapotranspiration and rainfall in water demand model resulted in significantly less price elasticity. Models that included rate structures found the increasing block rate to be significantly more elastic. Summer demand was also found to be significantly more elastic than average demand (Espey, Espey, and Shaw 1997).
- Peak water demand was found to be twice as elastic as off-peak demand and exhibited a lagged response. Adjustments to peak demand were more durable than off-peak demand (Lyman 1992).
- A 2007 study utilizing the largest and most geographically diverse data set to date found a significantly different price elasticity between increasing block rate (IBR) households (-0.59) and the full sample (-0.33) , however a behavioral response could not be confirmed due to unobserved community and/or utility characteristics. Measuring price elasticity of IBR is inherently different from linear uniform rate structures where the price is apparent. It is not clear what current models analyzing IBRs with multiple prices actually measure (Olmstead, Haneman, and Stavins 2007).
- Water bill content is important in order for rates and rate structures to be effective. Price elasticity was increased by a factor of 1.4 when bills included the marginal price next to the quantity consumed. This means that conservation targets can be achieved with smaller rate increases when a bill includes price information. Billing frequency, combination bills (include other utilities and charges) and increasing block rates were not found to have a significant impact of price elasticity (Gaudin 2006).
- Consumer knowledge of rates and rate structures is low, but few water bills contain this information (Jordan 2011).
- Affluence increases water use. Homes with larger irrigable yards and larger swimming pools consumed significantly more water than homes w/backyards that were mostly lawn. Affluent

households used 16% more water than low income households, with a peak difference of 2,660 gals in June. Affluent households were found to be largely insensitive to price changes and rate structures (Harlan, Yabiku, Larsen, and Brazel, 2013).

Drought Restriction Impacts

- During periods of *mandatory* drought restrictions in Colorado, savings measured in expected use per capita ranged from 18 - 56%, compared to just 4 - 12% savings during periods of *voluntary* restrictions. Providers with the most stringent restrictions achieved the greatest savings (Kenney, Klein, and Clark 2004).
- Varying levels of mandatory drought restrictions in the UK resulted in reductions ranging from 7 – 10% on an annual basis (Inman and Jeffrey 2006) but the data come from 1998.
- Conflicting policies defeat effectiveness of irrigation restrictions. In a Florida study of 3 communities belonging to home owners associations, all sampled homes (225) *increased* usage 6-15% during moderate and wet seasons of the transition from twice weekly watering to once weekly. In addition, homes cited for irrigation violations (67) *increased* their use in all seasons 11-25% more than uncited homes (Ozan and Alshariff 2013).
- Customer response during two drought periods in Seattle was studied. Larger values of income, lot size, and living space enhanced water reductions, whereas larger family size tended to reduce the effectiveness of curtailments. Increasing household size hardened demands (decreased curtailment effectiveness) whereas decreasing household size increased per-capita curtailment effectiveness (Polebitski and Palmer 2013).

Education and Information Impacts

- 5% water savings resulted from receiving customized home water reports using a normative comparison. Paper reports were more effective than email. Indoor and outdoor savings components unknown. Reports did not improve participant understanding of water consumption (Mitchell and Chesnutt 2013).
- Meta-analysis of research reported water savings from conservation education programs ranging from 2 – 12 % (Inman and Jeffrey 2006).
- The effect of information campaigns has been inconclusive. A literature review revealed many studies may be too short to measure an effect and that the lack of program evaluation has resulted in little improvement in campaigns (Syme, Nancarrow, and Seligman 2000).
- Irrigation interventions at schools were carefully studied. Type of irrigation system (automated or manual) overshadowed impact of interventions directing custodians to conserve water, providing an ETo –based irrigation schedule, or participating in an educational water conservation workshop. Schools equipped with automatic systems used the most water and custodians response to interventions varied. Schools equipped with manual systems were most efficient yet many still managed further reductions in response to interventions. Effectiveness of interventions was more likely when accounting for context and employing situational problem solving. School districts investing in remotely operated automatic irrigation systems are cautioned (Kilgren, Endter-Wada, Kjelgren, and Johnson 2010).
- Misinformation is a problem. People identify "curtailment" activities as more conserving than adopting more "efficient" infrastructure (often the focus of water conservation programs). People overestimate how much water efficiency products use, hence they don't fully realize the potential savings (Attari 2014).

- All education/communication interventions in this Australian study led to significant water savings even in a population with already low water use. Effectiveness of simple "how to" information was thought to be enhanced by a recent drought. However, in all cases the reductions dissipated and returned to pre-intervention levels after 12 months (Fielding, Spinks, McCrea, Stewart, and Gardner 2013).
- Voluntary conservation varies with the need for such action. This Australian study found a substantial voluntary conservation response when information about changing water storage levels was provided (Aisbett and Steinhauser 2011).

Research of Direct Relevance and Significance

Aisbett, E. and R. Steinhauser. 2011. Maintaining the Common Pool: Conservation in Response to Increasing Scarcity. Australian National University, Canberra, Australia. Crawford School Research Paper No. 11. (August).

Attari, S.Z. 2014. Perceptions of water use. Proceedings of National Academy of Science, 111(14):5129-5134.

Baerenklau, K., K.A. Schwabe, and A. Dinar. 2013. Do Increasing Block Rate Water Budgets Reduce Residential Water Demand? A Case Study in Southern California. University of California, Riverside. Riverside, CA. Water Science and Policy Center Working Paper 01-0913. (September).

Espey, M., J. Espey, and W.D. Shaw. 1997. Price elasticity of residential demand for water: A meta-analysis. Water Resources Research*, 33(6):1369-1374.*

Fielding, K.S., A. Spinks, S. Russell, R. McCrea, R. Stewart, J. Gardner. 2013. An experimental test of voluntary strategies to promote urban water demand management. Journal of Environmental Management, 114:343-351.

Gaudin, S. 2006. Effect of price information on residential water demand. Applied Economics 38:383-393.

Harlan, S.l., S.T. Yabiku, L. Larsen, A.J. Brazel. 2013. Household Water Consumption in an Arid City: Affluence, Affordance, and Attitudes. Society and Natural Resources, (22):691-709.

Inman, J. and P. Jeffrey. 2006. A review of residential water conservation tool performance and influences on implementation effectiveness. Urban Water Journal, 3(3):127-143.

Jordan, J. L. 2011. Pricing to Encourage Conservation: Which Price? Which Rate Structure?. Journal of Contemporary Water Research and Education, 114(1), 5.

Kenney, D., R.A. Klein, and M.P. Clark. 2004. Use and Effectiveness of Municipal Water Restrictions During Drought in Colorado. Journal of the American Water Resources Association. 40(1):77-87.2.

Kilgren, D.C., J. Endter-Wada, R.K. Kjegren, and P.G. Johnson. 2010. Implementing Landscape Water Conservation in Public School Institutional Settings: A Case for Situational Problem Solving. Journal of the American Water Resources Association, 45(6):1205-1220.

Lavee, D., F. Danieli, F. Beniad, T. Shvartzman, and T. Ash. 2013. Examining the effectiveness of residential water demand-side management policies in Israel. Water Policy, 15:585-597.

Lyman, R.A. 1992. Peak and Off-Peak Residential Water Demand. Water Resources Research, 28(9):2159-2167.

Mansur, E.T. and S.M. Olmstead. 2012. The value of scarce water: Measuring the inefficiency of municipal regulations. Journal of Urban Economics, 71:332-346.

Mitchell, D. and T. Chesnutt. 2013. Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports. California Water Foundation and East Bay Municipal Utility District, M.Cubed. Policy Analysis. (December).

Olmstead, S.M., W.M. Hanemann, R.N. Stavins. 2007. Water Demand Under Alternative Price Structures. Journal of Environmental Economics and Management, 54:181-198.

Olmstead, S.M. and R.N. Stavins. 2009. Comparing price and nonprice approaches to urban water conservation. Water Resources Research 45:1-10.

Polebitski, A.S. and R.N. Palmer. 2013. Analysis and Predictive Models of Single-Family Customer Response to Water Curtailments during Drought. Journal of American Water Resources Association, 49(1):40-51.

Syme, G.J., B.E. Nancarrow, and C. Seligman. 2000. The Evaluation of Information Campaigns to Promote Voluntary Household Water Conservation. Evaluation Review, 24(6):539-578.

Research Needs

Rates and Rate Structure Impacts

Increasing water rates reduces demand, but where, how, and by how much remains murky. The best analysis of water savings to date has been conducted on water budget-based rate structures. Similar research on inclining block rates, seasonal rates, and other conservation-oriented rate forms appears lacking. Simply measuring elasticity is not sufficient to inform water utilities about the likely impacts of different rates and rate structures. Additional research on the effectiveness of rate structures for impacting outdoor water use and the cost of implementation and administration of different rate structures would be welcome.

Water bill design appears to be critical in increasing the effectiveness of rates and rate structures. While several studies found billing information to increase price elasticity, few studies have investigated water bill design and content important for improving household decision-making regarding water use. This subject is well studied in the energy sector, but it is not known if this information directly translates to water utilities.

Drought Restriction Impacts

The best research on drought restrictions is now 10 years old (Kenney et. al. 2004). Understanding likely demand reductions from varying drought restrictions, particularly in the case of multiple-year droughts, is of great significance to water utilities across the country. California’s current mega-drought offers many potential research opportunities in this area.

Education and Information Impacts

Some good studies on the impact of specific education programs (e.g. home water reports) have been completed. Many education and information campaigns employ a prescriptive approach and fail to take into account the needs of water users. More research is needed to evaluate program content in order to provide more useful information to the end user. Forecasting the potential impact of a program will be challenging, regardless of the amount of research completed, because of various unique local conditions. There is likely much to be learned from outreach and education research in the field of energy efficiency.

Topic Area 2 – Landscape Transformation

This topic area covers efforts to create and study landscapes that require less water than traditional turf-dominated design; this includes new landscapes, renovated landscapes, alternative landscapes, voluntary hands-on education programs, and regulations, codes, and standards that mandate and/or restrict landscape design and installation.

Summary of Research Findings

Water Savings

- Homes using the Florida-Friendly Landscaping (FFL) program used 50% less water for irrigation compared to traditionally landscaped homes. Irrigation savings increased to 76% when considering only good examples of FFL and comparison landscapes with high-quality turfgrass. The FFL customers reduced their irrigation use (279 mm or 9.0 inches per year) after their landscapes became recognized (202 mm or 7.9 inches per year). Prior to recognition, these customers were already using less irrigation than their neighbors (279 versus 464 mm per year, or 9.0 versus 18.3 inches per year respectively), indicating that those most concerned with water use were more likely to choose Florida-Friendly Landscaping (Boyer, Dukes, Young, and Wang 2014).
- An evaluation of conservation rebate programs in Albuquerque, NM found that participants in the xeriscape rebate reduced water use by 33% from the pre- to post-rebate period (Price, Chermak, Felardo, 2014).
- Research conducted in Las Vegas produced models that predict outdoor water use will decrease an average of 55.8 gallons per year for every square foot of turf landscape converted to Xeriscape (Sovocool 2005). Earlier studies found a savings range of 34 – 54 gpsf in Las Vegas. (Sovocool and Rosales 2004), (Aquacraft 2000).
- In Las Vegas, turf takes more time to maintain (8.2 hours/month avg.) vs. xeriscape (6.0 hours/month avg.). Turf costs more to maintain ($680 per year avg). vs. xeriscape ($474 per year avg.) (Sovocool 2005).
- In Phoenix, increasing daily low temperatures by 1° Fahrenheit is associated with an average monthly increase in water use of 290 gallons for a typical single-family unit. This study has important implications for climate change (Guhathakurta, and Gober 2007).

Plant Material, Design, and Irrigation Considerations

- Selection of plant species is critical. When considering species of Kentucky Bluegrass and ornamental groundcovers, *S. album, L. muscari*, and *P. terminalis* are the most drought-resistant among the species evaluated in landscapes where severe drought may occur. *V. minor* and *V. major* are good selections in less severe droughts as is *P. pratensis* if periods of dormancy are acceptable (Domenghini, Bremer, Fry, and Davis 2013).
- Trees and shading are important. For woody plants and herbaceous perennials, *canopy cover* rather than plant type or water use classification was the key determinant of water use relative to reference evapotranspiration (ETo) under well-watered conditions (Sun, Kopp, and Kjelgren, 2012).
- Irrigation requirement can vary significantly, even within the same state or region. In the southeast US (Florida and Alabama), irrigation requirement varied from 423 mm per year in Mobile, AL, to 1,063 mm year in Key West, FL (Romero and Dukes 2013).

- In Massachusetts, researchers created a model to estimate future water demand in 2030 under two growth scenarios (i.e. “smart growth” vs. current trends). They found the impact of densification alone over 25 years could result in water savings of 5% when compared to current trends scenario. The key factor to reduced water use was smaller lawn size. The authors note the context-specific nature of water use reflected in the model’s assumptions (Runfola, Polsky, Nicholson, Giner, Pontius Jr., Krahe, and Decatur, 2013).
- Research conducted in Colorado found that water can be conserved while maintaining acceptable turfgrass quality by irrigating these two turfs every 3 days by adjusting ET (for Kent. Blugrass 0.7 and for Tall Fescue 0.6) provided soil conditions are adequate (Ervin and Koski 1998).
- Water use does *not* equal water need. More water does not always yield better plant performance. Less water often limits growth with limited loss of visual appearance. No true landscape coefficients (needed for calculating ET requirement) have been developed for landscape plants (Pittenger 2010).
- Households with xeriscape landscaping in Canada were motivated mainly by factors related to landscape aesthetic and physical activity rather than water conservation (Smith and Patrick, 2011).
- Xeriscaping does not increase proportionate to income. Researchers found that yards in Florida are a display of cultural capital and that xeriscapers are invested in an environmentalist field that operates at an imagined global scale, as opposed to the neighborhood and national scale values invoked with the traditional turfgrass lawn. Xeriscaped landscapes may entail a more environmentally benign set of landscaping practices but that the adoption of xeriscaping is no less implicated in the reproduction of privilege and distinction than is the traditional turfgrass lawn (Mustafa, Smucker, Ginn, Johns, and Connely, 2010).
- Efforts to introduce ecologically innovative designs to metropolitan residential landscapes should approach change at the neighborhood scale in order to enhance initial success and long term cultural sustainability (Nassauer, Wang, and Dayrell 2009).
- Visual turfgrass quality is significantly correlated with soil water content. Data from this study support recommendations for deeper, frequent irrigation of established tall fescue grown on sandy loam soils in southern California interior valleys with an irrigation budget of 80% ETcrop/irrigation uniformity (Richie, Green, Klein, and Hartin. 2002).
- Residents in Arizona, preferred high-water-use landscapes over dry landscapes for their own yards, even though they considered desert landscapes to be aesthetically pleasing. Women and long-term residents of the area were significantly more averse to dry landscapes. Stronger environmental attitudes did not lead to preference for xeriscapes but did lead to compromises on the amount of turf grass preferred in lush landscapes. This may contribute to the "oasis" mentality found among area residents (Yabiku, Casagrande, Farley-Metzger, 2008).
- Little is known about drought tolerance and drought responses of many ornamental plants, especially herbaceous perennials (Zollinger, Kjelgren, Cerny-Koenig, Kopp, and Koenig, 2006).
- Little research has examined water requirements of entire irrigated urban landscapes integrating different types of plants (Sun, Kopp, and Kjelgren, 2012).

Research of Direct Relevance and Significance

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Research Needs

Landscape Transformation and Non-Turf Landscapes

Only four high quality recent studies measuring the impact of native, water-wise, and xeric landscapes vs. turf on water use were identified. These studies often require long-term commitment of time and resources to complete, but are extremely important from an outdoor use and savings perspective. This is an important area of need for future research.

Plant Cultivation

More research on the water requirements of landscape turfs and plants under different climate and drought conditions is needed. Some good work has been done as described above, but it is limited in scope. Understanding the drought tolerance on a broad range of plants in different climates is important.

Landscape Design and Management

There appears to be a body of research on the reasons and rational for different landscape choices, but water demand and conservation was *not* an important factor according to several of these studies. This was important work towards the development of a native and water-wise plant market. Currently, more research is needed to understand how people manage natural landscapes and what additional education is needed to grow these landscapes and realize actual water savings over the life of the landscape.

Topic Area 3 – Irrigation Management

This topic area covers technology, information, methods, and projects to optimize and improve irrigation management; this includes smart controllers, soil moisture sensors, rain shutoff devices, irrigation management training programs, and contractor and customer education.

Summary of Research Findings

Water Savings

General Research

- In Florida, regular seasonal adjustments to irrigation controllers resulted in reduced water use. Even more significant reductions were observed when the overall water requirement of the landscape was reduced (Haley, Dukes, Miller, 2007).
- In hot and dry Israel, a study of the cooling effects of landscape choices found unshaded grass to cause only a small air temperature depression and had the highest water requirement. However when the grass was shaded, either by the trees or by a manufactured shade mesh, a synergic effect produced greater cooling as well as a reduction of more than 50% in total water use (Shashua-Bar, Pearlmutter, Erell. 2009).
- Baseline landscaped area and water use of landscapes in Texas is estimated. Conservation potential is reviewed, but not quantified to the level needed for use in modeling (Cabrera, Wagner, and Wherley, 2013).
- Wasteful watering is the result of many factors embedded in the complex context of urban landscapes. The most significant factors predicting actual water use were the type of irrigation system and whether the location was a business or household. 57% of programmed irrigation systems are wastefully operated and 65% of businesses were wasteful compared to 39% of households. Attitudinal & motivational characteristics were not significant (Endter-Wada, Kurtzman, Keenan, Kjelgren, and Neale, 2008).
- A 1992 study conducted in the North Marin Water District of California evaluated the effectiveness of an indoor and outdoor water audit program. The audit evaluated the sprinkler system and provided a site specific watering schedule. The study found that one year later outdoor water use at audited homes had decreased an average of 1,918 gals., which was much less than hypothesized potential of 7,200 gals (Nelson 1992).

Weather-Based Control Savings Summary

- Homes with soil moisture sensor irrigation controllers bypassed unneeded events during both rainy and dry periods, averaging 2 irrigation events per month; all other treatments averaged 4.5–6 events per month. Reduction in number of irrigation events by soil moisture sensor control systems resulted in significant savings, with 65% cumulative reduction compared to homes with typical timer irrigation control. Savings were comparable to previous plot research, indicating that plot savings could be scaled up so long as soil moisture control systems are installed and set properly (Haley and Dukes, 2012).
- In Southern California, water savings from the installation of weather-based controllers per site were estimated to be, on average, 9.4% at single family residential sites and 27.5 percent at commercial sites (MWDOC, and A&N Technical Services, 2011).
- In Florida, Toro ET controllers reduced vs. historical average by 23% - 34% in a study of 21 sites. Other/different technology was recommended for sites in which the current irrigation rate is

"less than the gross irrigation requirement" because of the potential for increased water use (Davis and Dukes 2014).

- In Florida during periods of more frequent rainfall, the combination of rain switch and rain pause reduced irrigation 41% compared with the use of no rain features, whereas the rain pause feature alone saved 25% (Rutland and Dukes, 2012).
- 34% - 54% reduced water use for specific models of smart controller vs. standard controller in New Mexico field-laboratory experiments using identical test landscape plots (Al-Ajlouni, Vanleeuwen, and St. Hilaire, 2012).
- 4.6% - 68% reduced water use for specific models of smart controllers; some smart controller sites used more water vs. standard controller sites in actual Las Vegas landscapes. 24% of variability in use is accounted for by money spent on landscape. 57% of water savings is accounted for by time spent outside, importance of landscape to homeowner, and use of professional maintenance services. 87% of participants using ET controllers say the quality of their landscape improved or at least stayed the same after installation (Devitt, Carstensen, and Morris. 2008).
- 28% - 92% water savings were documented from soil moisture sensor-based (SMS) irrigation control in test plots in Florida. Most SMS systems recorded significant irrigation water savings, compared to the time-based irrigation schedules typically used by homeowners. Water savings were achieved without decreasing turfgrass quality below acceptable levels (Dukes, Cardenas-Lailhacar, and Miller, 2008).
- 24% - 39% savings were documented from soil moisture control. 11% MORE water use for ET control vs. timer-based test plots. Both irrigation efficiency and adequacy were best for the SMS2 treatment when averaged over all three years. The ET treatment provided good irrigation adequacy, but had the poorest irrigation efficiency. (Grabow, Ghali, Huffman, Miller, Bowman, and Vasanth, 2013).
- 6% overall reduction was achieved in a large (1,000+ sites) sample of properties equipped with ET weather-based control. A higher percentage of sites reduced water use, but in more than 40% of sites, water use increased after weather-based controller installation (Mayer, DeOreo, Hayden, Davis. 2009).
- Smart controllers evaluated in California in 2003 adjusted irrigation schedules through the year roughly in concert with weather and ETo changes, but the magnitudes of their adjustments were not consistently in proportion to the changes in real-time ETo. Unfortunately, *no product was able to produce highly accurate irrigation schedules consistently for every landscape setting when compared to research-based reference comparison treatments* (Pittenger, Shaw, and Richie, 2004).

Research of Significance

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Research Needs

Far more is known about irrigation control technology and water use than some of the more human and cultural practices that go into landscape irrigation. For example, no research studies were identified on the impact of landscape contractor training and certification (as in Texas) or customer information and education. The next realm of research in this area is the complex three way interaction between people, the entire irrigation system, and the landscape. This work may require interdisciplinary research teams that can integrate quantitative and qualitative methods to provide a more holistic understanding of these relationships. How can water savings with proven technologies like soil moisture and weather-based control be improved through education and training? How can the relationship between human aesthetics and the science of adapting plants to specific climates be leveraged to reduce water use?

Weather-based irrigation control technologies have been successfully researched through high quality studies of both test plots and field sites. Test plot analysis is important, but at this point additional long-term field research is needed to understand the impact of weather-based control under real world conditions as these products become more widespread. Research results indicate soil moisture-based irrigation control offers significant water savings when properly installed and programmed. In rainy climates, rain shutoff and rain pause combined are effective. The story on ET based control is more mixed, but many studies have found that by and large these systems also offer water savings when compared against standard irrigation control. ET-based controllers are most effective in reducing water use when implemented at sites that regularly over-irrigate.

Recent research has established the water saving potential of soil moisture sensors to be significant. Soil moisture control technology has been around for many years, but has not been widely adopted in urban markets. Many experts agree that the concept of controlling irrigation based on the moisture level at the root zone makes more sense than using just about any other measure. However, in practice, soil moisture sensors have been expensive to install and maintain and diverse landscapes may require multiple sensors for full success. It is anticipated that soil moisture control technology will become less expensive and more broadly implemented in the coming years as WaterSense has issued a Notice of Intent to develop a specification for soil moisture–based control technologies, which will complement the existing weather–based irrigation controller specification.

Topic Area 4 – System Efficiency

This topic deals with improving the performance and efficiency of landscapes and irrigation systems beyond the control device; this includes, pressure regulation, pressure compensating nozzles, drip irrigation, and other factors influencing overall efficiency.

Summary of Research Findings

Distribution Uniformity (DU) and Landscape Audits

- An analysis of the maintenance problems uncovered through 3,416 water audits conducted by Florida's mobile irrigation lab found that five problems represent half of all recorded problems: 1) zones with mixed plant water requirements, 2) zones with unmatched application rates, 3) sprinkler heads blocked by vegetation, 4) watering too frequently, and 5) watering too long. It was estimated that given the effort, cost and water savings expected by addressing these problems, the most savings with the least effort is gained by using the correct watering schedule (Olmsted and Dukes. 2011).
- A controlled experiment conducted in South Central Florida at 25 residential sites and a control site with multiple treatment plots found that different catch can test procedures and calculations resulted in significantly different uniformity results; average residential DU was 45% with Control plots at 55%; rotor heads (55%) have better uniformity at all pressures tested than do spray heads (49%); spray heads with fixed arc patterns were more uniform than adjustable arc heads. Many sites had poor head spacing resulting in low DU. A key finding was the need for better/properly designed and installed residential systems and for conducting catch can tests with more cans (Baum, Dukes, and Miller, 2005).
- A controlled experiment in Florida quantified the relationship between catch can DU and soil moisture uniformity, comparing bare soil test plots to 21 residential sites. A key findingwas that the lower quarter DU calculation does not capture the process of water infiltration into the soil. Soil moisture becomes more uniform after application and more closely approximates the lower half DU calculation (Dukes, Haley, and Hanks. 2006).
- A 2001-2004 study of landscape water use at an Indian River, FL resort community highlights the importance of: Resetting controllers after landscapes are established, frequent observation of sprinkler system function, and availability of water conservation professionals to support landscape maintenance personnel's adoption of audit recommendations. Savings could not be measured because of significant climate differences pre- and post (Bargar, Culbert, and Holzworth, 2004).
- An Australian study with some methodological problems found there are few well-designed irrigation systems in operation, homeowners have limited knowledge of irrigation, maintenance is usually forgotten, and the audit process itself needs to be streamlined so it can be completed in 2 or 3 hours (Maheshwari 2012).

Rotating Sprinkler Heads

- A pressure compensating, rotating sprinkler head retrofit study of 29 sites in California, Nevada, Arizona, and Washington found average low quarter distribution uniformity improved by 0.26, from 0.44 to 0.70, after the conversions. Estimated water conservation potential due to the conversion from fixed spray to rotating sprinklers depends on pre-conversion uniformity and choice of run time multiplier (RTM). A *hypothetical* (not measured) single-point estimate for water conservation potential due to sprinkler conversions was 31% (Solomon, Kissinger, Farrens, Borneman, 2007).

- Several unpublished studies on rotating sprinkler heads have been conducted. Two conducted in Colorado in 2013 by the Center for Resource Conservation and WaterDM found that water use increased in 66% of the homes retrofitted and decreased in only 33% of the homes (CRC, WaterDM 2013). However, these results have not been published or peer reviewed.
- Significant research on the impact of retrofitting rotating pressure compensating sprinkler nozzles is currently being conducted for the Metropolitan Water District by A & N Technical Services. It is anticipated this research will be released later in 2014.

Research of Significance

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Research Needs

Only limited research and information is available on water savings in the system efficiency category. There is good information on the variability of water use and the typical problems encountered when auditing in-ground irrigation systems. However, there is little (if any) current data that show measured short- or long-term water savings from irrigation audits, and no studies were identified that evaluated the effect of irrigation system tune-ups, sprinkler head retrofits, and other measures to improve efficiency.

The Olmsted and Dukes 2011 research that reports on results from over 3,400 mobile irrigation lab audits appears to be the most substantial research conducted to date in this area. The five most common irrigation system problems identified from this research are significant and the conclusion that given the effort, cost and water savings expected by addressing these five problems, the most savings with the least effort is gained by using the correct watering schedule is important. . However, the relative effect of correcting these problems and adopting an appropriate water schedule were not empirically verified.

It is possible that lack of research uncovered in this category is a result of the way the categories were defined, or it could be that there simply has not been as much peer-reviewed research in this area. The literature identified is mostly university extension publications and conference proceedings. It appears that irrigation system efficiency testing has been left to green industry and audit results have only been used internally by water providers. Field studies of the performance of sprinkler system components used on actual landscapes are needed, as well as the effectiveness of water audit programs.

Topic Area 5 – Monitoring and Verification

This topic area covers the measurement of landscape water requirements and the tracking and verification of landscape water use and savings.

Summary of Research Findings

- Water conservation metrics for water utilities are defined and described and case studies presented. Methods for estimating indoor and outdoor use, and the difficulties in developing outdoor use metrics for SF and MF customer categories are evaluated (Dziegielewski and Kiefer, 2010).
- Statistical methods for evaluating water savings from conservation measures when a utility has imposed drought restrictions are presented. Although it is a 20 year old study, it is high quality work, but likely challenging for utility staff to implement without assistance (Bamezai 1995).
- Conservation programs rarely receive comprehensive, in-depth, external, peer-reviewed evaluations. Water conservation programs usually measure the end-users success in implementing recommendations. However, programs themselves would benefit from evaluation to ensure they meet the needs of program participants (Kleiman, Reading, Miller, Clark, Scott, Robinson, Wallace, Cabin and Felleman, 2000).
- An evaluation of conservation rebate programs in Abuquerque, NM found that participants in the xeriscape rebate reduced water use by 33% from the pre- to post-rebate period (Price, Chermak, Felardo, 2014).
- In the field of conservation and environmental management there needs to be further engagement of scientists and practitioners to develop and take ownership of an evidence-based framework (Pullin and Stewart, 2006).
- Demand "backcasting", modeling, and end use measurements are recommended as pre-requisites for evaluation of water efficiency programs (White, Milne, and Riedy, 2004).
- End use research in the Gold Coast region of Australia found evidence for water savings from the installation of rain water harvesting systems which include capture, filtration, and pumping (Willis, R.M., R.A. Stewart, D.P. Giurco, M.R. Talebpour, and A. Mousavinejad, 2011).

Research of Significance

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Research Needs

Best practices for evaluating and monitoring the impact of outdoor water efficiency programs have yet to be established. Excellent research has been conducted, and data logging with end use analysis appears to be one of the most important and useful techniques, but overall approaches have not been standardized and results are often not comparable. Variability in weather conditions in particular has proved vexing for water utilities, even though methods for normalizing for weather exist. Some researchers believe the water conservation field could benefit from monitoring and evaluation methods employed by other disciplines such as energy and energy management.

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Zollinger, N., R. Kjelgren, T. Cerny-Koenig, K. Kopp, and R. Koenig. 2006. Drought responses of six ornamental herbaceous perennials. Scientia Horticulturae, 109:267-274.

Selected Annotated Bibliography

The research team prepared these tables to summarize the review effort and to help identify the most relevant pieces of research.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Aisbett, E. and R. Steinhauser. 2011. *Maintaining the Common Pool: Conservation in Response to Increasing Scarcity*. Australian National University, Canberra, Australia. Crawford School Research Paper No. 11. (August).	This paper studies the impact of changing storage levels on urban water usage in the context of a prolonged drought and an extensive public information campaign which emphasized communal responsibility for maintaining 'dam levels'.	We identify a substantial voluntary conservation response to changing storage levels. The paper thus contributes a rare piece of real-world, behavioral evidence that voluntary conservation varies with the need for such action.	Affirmation that information influences behavior. Level of impact/savings not quantified in a particularly useful way. Demand elasticity estimates for Australia are included. (-0.47)
Allcott, H. 2011. Social norms and energy conservation. *Journal of Public Economics* 95:1082-1095.			Not a study of outdoor water use.
Arbués, F., I. Villanúa, and R. Barberán. 2010. Household size and residential water demand: an empirical approach. *Australian Journal of Agricultural and Resource Economics,* 54:61-80.	Household size as a key determinant of water use.		
Attari, S.Z. 2014. Perceptions of water use. *Proceedings of National Academy of Science*, 111(14):5129-5134.	*National on-line survey of 1020 participants in USA conducted April 21&25, 2013 via Amazon's Mturk panel. Data: Survey, actual water use based on engineering standards. Multilevel regression model.* Results show that participants underestimate water use by a factor of 2 on average, with large underestimates for high water-use activities. High numeracy scores, older age, and male sex associated with more accurate perceptions of water use.	ASKED 1 outdoor water use question: "How many gallons of water do you think watering a lawn with a garden hose at its maximum flow rate for 10 minutes requires? Mean Answer: 40 gals - Actual: 110 gals. WHEN asked what the single most effective thing they could do is, people identify "curtailment" activities as more conserving than adopting more "efficient" infrastructure. OVERESTIMATE how much water efficient appliances use, so don't realize potential savings. ANSWERS revealed anchoring bias related to gal unit of measure.	Responses to garden hose water use were off by a factor of 4.2. It is easy to see why people have no concept of how much water is applied in 1 watering session w/an irrigation system. Thomas Dietz, a conservation psychologist, wrote a reply commentary that pointed out even if a consumer is motivated, they can't accurately assess their actions so will not choose the most effective action, which has huge implications for efficiency policy.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Baerenklau, K., K.A. Schwabe, and A. Dinar. 2013. Do Increasing Block Rate Water Budgets Reduce Residential Water Demand? A Case Study in Southern California. University of California, Riverside. Riverside, CA. Water Science and Policy Center Working Paper 01-0913. (September).	This study investigates the effect of introducing a revenue-neutral increasing block-rate water budget price structure on residential water demand. It is estimated that demand was reduced by at least 18 percent, although the reduction was achieved gradually over more than three years. At intermediate steps the study derives estimates of price and income elasticities that rely only on longitudinal variability. We investigate how different subpopulations responded to the pricing change and find evidence that marginal, rather than average, prices may be driving consumption.	18% reduction in residential water use over three years from increasing block-rate water budget price structure.	Excellent research on the impact of water budget - based rates. In this study, average prices paid rose by less than 4 percent under the block-rate structure, average prices paid under the flat-rate structure would have had to rise by nearly 48 percent to achieve the same demand reduction.
Beal, C.D., R.A. Stewart, K. Fielding. 2013. A novel mixed method smart metering approach to reconciling differences between perceived and actual residential end use water consumption. *Journal of Cleaner Production,* 60:116-128.			Not a study of outdoor water use.
Beecher, J.A. 2013. Trends in Consumer Prices (CPI) for Utilities through 2012. Research Note, Institute of Public Utilities. East Lansing, MI: Michigan State University.			Not a study of outdoor water use.
Bendon, L. 2012. *Qualitative Market Research and Stakeholder Forum Report.* California Landscape Contractors Association.			Not a study of outdoor water use and savings.
Borisova, T. and C. Rawls. 2010. Conservation Water Rates for Residential Customers: A Practical Overview. *Florida Water Resources Journal*, Aug:16-22.			Does not measure impact on outdoor use.
Britton, T., G. Cole, R. Stewart and D. Wiskar. 2008. Remote Diagnosis of Leakage in Residential Households. *Water*, Sept:56-60.			Not a study of outdoor water use.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Cole, G. and R.A. Stewart. 2013. Smart meter enabled disaggregation of urban peak water demand: precursor to effective urban water planning. *Urban Water Journal*, 10(3):174-194.			Not a study of outdoor water use.
DeLorme, D.E., S.C. Hagen, and I.J. Stout. 2003. Consumer's Prespectives on Water Issues: Directions for Educational Campaigns. *Journal of Environmental Education* 34(2):28-35.			Not a study of outdoor water use.
Environment Agency. 2013. *Quantifying the impact of water company drought measures on water demand.* Report - LIT 8953, Bristol, UK.	Evaluation of drought response in the UK.	Restrictions can significantly influence demand. Scale/severity of drought impacts customer response. Temporary water bans did not reduce demand measurably.	Elaborate analysis with few useful findings on the differential impact of drought response.
Espey, M., J. Espey, and W.D. Shaw. 1997. Price elasticity of residential demand for water: A meta-analysis. Water Resources Research, 33(6):1369-1374	A meta-analysis of 24 residential water use studies that were published between 1967 and 1993, which provided 124 estimates of price elasticity of water demand. 11 studies included enough data to calculate a dummy variable for summer demand. 21 studies analyzed the effect of the rate structure.	The analysis found that inclusion of evapotranspiration and rainfall resulted in significantly less price elasticity of demand. Models that included rate structures found the increasing block rate to be significantly more elastic. Summer demand was also found to be significantly more elastic than average demand.	The authors noted that most of the usable studies were already quite dated and economic analysis techniques had improved, so the study should be used with caution. This meta-analaysis is 17 years old and it seems reasonable to expect that economic analysis techniques have improved further during that time.
Faruqui, A., S. Sergici, and A. Sharif. 2010. The Impact of informational feedback on energy consumption - A survey of the experimental evidence. *Energy*, 35:1598-1608.			Not a study of outdoor water use.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Fielding, K.S., A. Spinks, S. Russell, R. McCrea, R. Stewart, J. Gardner. 2013. An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management,* 114:343-351.	*SE Queensland, Australia; 183 households; June 2010-Dec. 2011 (475 days); Experimental intervention study - 3 information interventions & a control group; Data: Survey, Smart Meters w/data loggers, water audit, & water diaries; Analysis: Trace Wizard; Growth curve, simple variance components, random intercept models.*3 intervention groups all showed reduced levels of household consumption over the course of the interventions and for some months afterwards. All interventions led to significant water savings, but long-term household usage data showed that in all cases, reductions dissipated and returned to pre-intervention levels after about 12 mos.	VOLUNTARY demand management can be effective even in a population with low water use. PROCEDURAL information alone was as effective as procedural information plus descriptive norm or water end use information. WATER conservation norms may require environmental cues like drought to activate behavior.	Although an indoor water use study, information effects should be relevant to outdoor use as well. The information interventions are easily translatable to an outdoor study.
Froehlich, J., L. Findlater, M. Ostergren, S. Ramanathan, J. Peterson, I. Wragg, E. Larson, F. Fu, M. Bai, S.N. Patel, and J.A. Landay. 2012. The Design and Evaluation of Prototype Eco-Feedback Displays for Fixture-Level Water Usage Data. In *Proceedings of the Conference on Human Factors in Cumputing Systems May 5-12, 2012.* Austin, TX:CHI.			Not a study of outdoor water use.
Gaudin, S. 2006. Effect of price information on residential water demand. *Applied Economics* 38:383-393.	A study of water bill content from 383 utilities across the USA based on the microeconomic law of demand (as price increases, consumption decreases). The law assumes "perfect knowledge" of price information,however, most water bills lack price information. The study found that "price elasticity increases by 30% or more when price information is given on the bill."	Price elasticity was increased by a factor of 1.4 when bills included the marginal price next to the quantity consumed. This means that conservation targets can be achieved with smaller rate increases when a bill includes price information. Billing frequency, combination bills (include other utilities and charges) and increasing block rates were not found to have a significant impact of price elasticity.	In practical terms, people must be able to easily ascertain what they pay for water in order for the price of water to have a conservation effect.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Gerald T. Gardner & Paul C. Stern 2008. The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change. *Environment: Science and Policy for Sustainable Development*, 50(5):12-25. doi: 10.3200/ENVT.50.5.12-25.			Mostly focused on energy conservation.
Grafton, R.Q., M.B. Ward, H. To, and T. Kompas. 2011. Determinants of residential water consumption: Evidence and analysis from a 10-country household survey. *Water Resources Research,* 47:1-14.			Not a study of outdoor water use.
Hamm, J.A., L.M. PytlikZillig, M.N. Herian, A.J. Tomkins, H. Dietrich, and S. Michaels. 2013. Trust and Intention to Comply with a Water Allocation Decision: The Moderating Roles of Knowledge and Consistency. *Ecology and Society, 18(4):49.* doi: 10.5751/ES-05849-180449			Too esoteric to be of much use to water providers.
Harlan, S.l., S.T. Yabiku, L. Larsen, A.J. Brazel. 2013. Household Water Consumption in an Arid City: Affluence, Affordance, and Attitudes. *Society and Natural Resources,* (22):691-709.	*Phoenix, AZ; 205 single-family households; 2001-2002; Purposive sample of 8 neighborhoods based on demographic & housing characteristics; Data: Survey, 24 mos of metered water use, property records, and Temperature & rainfall data; Analysis: random effects model.* Household income had a positive, significant effect on consumption that was mediated by house size. Irrigable lot size and landscape type also had significant effects on consumption, although attitudes did not.	HOMES w/larger irrigable yards and larger swimming pools consumed significantly more water than homes w/backyards that were mostly lawn. AFFLUENT households used 16% more water than low income households, with a peak difference of 2660 gals in June.	HYPOTHESIZED that affluence, having more and bigger of everything, would outweigh the effect of efficiency standards and result in higher water use. Striving for affluence is part of the "American Dream." USED the Soil-Adjusted Vegetation Index (SAVI) to control for outdoor water use.
icaro consulting. 2013. *Understanding household water behaviours and testing water efficiency messages.* London, UK: DEFRA.			Not useful.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Inman, J. and P. Jeffrey. 2006. A review of residential water conservation tool performance and influences on implementation effectiveness. *Urban Water Journal*, 3(3):127-143.			Useful summary research on a wide range of conservation savings. Somewhat dated as much research comes from 1990s and early 2000s.
Jeong, S.H. 2013. "The Impact of Water-Energy Feedback on Water Conservation at Residence Halls." MS thesis, Virginia Polytechnic Institute and State University, Blacksburg.	Study of water and energy feedback systems in university residential buildings.	The outcome of the study suggests that representing water consumption in terms of gallons together with the embodied energy associated with water consumption can lead to a statistically significant reduction in water conservation while representing water consumption only in terms of gallons may not.	Not a study of outdoor water use.
Jessoe, K. and D. Rapstone. 2012. *Knowledge is (Less) Power: Experimental Evidence from Residential Energy Use.* Working Paper 18344. Cambridge, MA: National Bureau of Economic Research.			Not a study of outdoor water use.
Jordan, J. L. 2011. Pricing to Encourage Conservation: Which Price? Which Rate Structure?. *Journal of Contemporary Water Research and Education*, 114(1), 5.	A concise literature review to identify price and rate structure information available to consumers from billing information and evaluate the proper price specification used in demand models.	Cites several key findings in the literature: Agthe (1988) survey in Tulsa 21% of survey respondents were aware of the block rate structure. 1992 Georgia survey of 400 people, 62% knew their water bill of those 12 stated they knew their water rate or rate structure and 8 of them were wrong. 1995 Georgia survey of water managers found 48% misidentified their current rate structure.	Jordan concludes that conservation rate structures are less effective indoors and suggests that as long as seasonal or peak use produces a higher water bill, the rate structure may not matter.
Jorgensen, B.S., J.F. Martin, M. Pearce, and E. Willis. 2013. Some difficulties and inconsistencies when using habit strength and reasoned action variables in models of metered household water conservation. *Journal of Environmental Management, 115:124-135.*	Queensland, Australia; 183 households; June 2010-Dec. 2011 (475 days); Experimental intervention study - 3 information interventions & a control group; Data: Survey, Smart Meters w/data loggers, water audit, & water diaries; Analysis: Trace Wizard; Growth.		Not a study of outdoor water use.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Kenney, D., R.A. Klein, and M.P. Clark. 2004. Use and Effectiveness of Municipal Water Restrictions During Drought in Colorado. *Journal of the American Water Resources Association.* 40(1):77-87.2.	*8 water providers serving 1.85 mil customers. Study Period: May 1 thru Aug 31, 2002. Meter Data: 2000-2002. Multiple regression model.* Drought conditions in the summer of 2002 prompted several cities along *Colorado's Front Range* to enact restrictions on outdoor water use, focusing primarily on limiting the frequency of lawn watering. The different approaches utilized by eight water providers achieved, measured as a comparison of 2002 usage to 2000 to 2001 were tracked to determine the level of water savings average usage, based on a statistical estimate of 2002 "expected use" that accounts for the impact of drought conditions on demand.	During periods of mandatory restrictions, savings measured in expected use per capita ranged from 18 to 56 percent, compared to just 4 to 12 percent savings during periods of voluntary restrictions. As anticipated, providers with the most stringent restrictions achieved the greatest savings.	Excellent research. One of the best available sources on impacts of drought restrictions. Percent reductions can be reasonably applied to utilities with similar seasonal demand profiles.
Kilgren, D.C., J. Endter-Wada, R.K. Kjegren, and P.G. Johnson. 2010. Implementing Landscape Water Conservation in Public School Institutional Settings: A Case for Situational Problem Solving. *Journal of the American Water Resources Association*, 45(6):1205-1220.	Institutional outdoor water use study at public schools.	Large irrigation system effects overshadowed impact of conservation interventions. Schools using automatic systems had high landscape water use and substantial capacity for conservation but actual savings varied. Schools using manual systems were the opposite yet many still managed further reductions in response to interventions. Effectiveness of interventions depend on the context they are applied. Interventions were more effective when leading to situational problem solving that integrated general scientific and technical knowledge with experiential knowledge. School districts investing in remotely operated automatic irrigation systems are cautioned.	
Larsen, K.L., D.D. White, P. Gober, S. Harlan, and A. Wutich. 2009a. Divergent perspectives on water resource sustainability in a public-policy-science context. *Environmental Science & Policy,* 12:1012-1023.			Conservation views of residents, water managers, and scientists is compared. Interesting and useful, but not directly relevant. Residents tend to blame others for high water use!

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Larson, K.L., E. Cook, C. Strawhacker, and S.J. Hall. 2010. The Influence of Diverse Values, Ecological Structure, and Geographic Context on Residents' Multifaceted Landscaping Decisions. *Human Ecology*, 38:747-761.		Values were not strongly related to land management decisions. Of those that were significant, most were related to groundcover and herbicide use. Yet diverse environmental values influenced landscaping practices in varying and complex ways. In addition, the historic and socioeconomic setting of neighborhoods affect the extent of lawns and related management inputs, while heightened use of pesticides in rock-based, drought-tolerant yards challenged the notion of these lawn alternatives as environmentally friendly and low maintenance.	
Larson, K.L., A. Gustafson, and P. Hirt. 2009b. Insatiable Thirst and a Finite Supply-An Assessment of Municipal Water-Conservation Policy in Greater Phoenix, Arizona, 1980-2007. *Journal of Policy History*, 21(2):107-137.			Broad view of water conservation policy in Phoenix since 1980.
Lavee, D., F. Danieli, F. Beniad, T. Shvartzman, and T. Ash. 2013. Examining the effectiveness of residential water demand-side management policies in Israel. *Water Policy*, 15:585-597.		among the economic policy tools, a smooth increase of water tariffs was not effective, while a drought surcharge led to a significant reduction in residential water demand	
Lee, M., B. Tansel, and M. Balbin. 2011. Influence of residential water use efficiency measures on household water demand: A four year longitudinal study. *Resources, Conservation and Recycling*, 56(1):1-6.		About 6–14% reduction in water demand has been observed during the first and second years. The water savings continued during the third and fourth years at a lower percentage.	

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Lyman, R.A. 1992. Peak and Off-Peak Residential Water Demand. *Water Resources Research*, 28(9):2159-2167.	The study investigated price elasticity of water demand during peak and off-peak periods utilizing a dynamic model that incorporated explanatory variables describing a household's demographics, characteristics of the home and yard, and climate.	Peak demand is twice as elastic as off-peak demand and exhibits a lagged response with cross-price effects. Household income and property value are more than proxies for income - they represent wealth and lifestyle behavior reflected in water using durable goods (sprinkler systems) and landscapes. Peak water demand adjustments are lagged and more durable.	Further specification of water demand equation
Mansur, E.T. and S.M. Olmstead. 2012. The value of scarce water: Measuring the inefficiency of municipal regulations. *Journal of Urban Economics,*71:332-346.	A model simulating the effect of 4 increasingly stringent outdoor watering restrictions and a market-based approach (drought pricing) using the REUW data set.	Replacing rationing with "drought pricing" results in *welfare gains* of more than 29% of what sample households spend each year on water. The authors argue drought pricing will make "cheating" watering restrictions very difficult.	
Mieno, T. and J.B. Braden. 2011. Residential Demand for Water in the Chicago Metropolitan Area. *Journal of American Water Resources Association*, 47(4):713-723.		Price response is greater in the summer than winter. Seasonal pricing can mitigate equity issues.	Not a study of outdoor water use.
Mitchell, D. and T. Chesnutt. 2013. Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports. California Water Foundation and East Bay Municipal Utility District, M.Cubed. Policy Analysis. (December).	Compared treatment and control group water use. Treatment group received WaterSmart Home Water Reports. Researchers estimate mean treatment effects on residential water use of 4.6% and 6.6% for the Random Group and Castro Valley Group experiments, respectively.	5% water savings resulted from receiving water use reports and comparison. Paper reports more effective than email.	Excellent new research on the impact of a targeted information campaign. Not specifically targeted at outdoor use.
Olmstead, S.M., W.M. Hanemann, R.N. Stavins. 2007. Water Demand Under Alternative Price Structures. *Journal of Environmental Economics and Management,* 54:181-198.	Utilizing a data set of 1082 single family households from 11 N. American cities served by 16 public water utilities, researchers investigated the price elasticity of water demand and the affect of increasing block and uniform rate structures. Data were analyzed using a discrete/continuous choice model, which the authors suggest is a better model for analyzing non-linear block rate (IBR) structures and a random effects model for uniform price (UP) structures.	A significantly different price elasticity between IBR households (-0.59) and the full sample (-0.33) was found, however a behavioral response could not be confirmed due to unobserved community and/or utility characteristics; e.g. environmental consciousness, long-term aridity, length of growing season etc. that may explain the difference. Measuring price elasticity of IBR is inherently different from linear UP structures where the price is apparent. It is not clear what current models analyzing IBRs with multiple prices actually measure.	A general note on economic literature: Economists are primarily interested in correctly pricing a community's water resources in relation to the available supply. In order to do this, they attempt to control for variables that cause variation in demand; e.g. seasonality and weather. Consequently, their work is more broad and cannot be characterized as "outdoor water use studies."

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Olmstead, S.M. and R.N. Stavins. 2009. Comparing price and nonprice approaches to urban water conservation. *Water Resources Research* 45:1-10.		The analysis emphasizes the emerging theoretical and empirical evidence that using prices to manage water demand is more cost effective than implementing nonprice conservation programs, similar to results for pollution control in earlier decades.	Price can be a key element in reducing demand and perhaps the most important element.
Ozan, L.A. and K.A. Alsharif. 2013. The effectiveness of water irrigation policies for residential turfgrass. *Land Use Policy,* 31:378-384.	A study of irrigation restrictions in place from June 2004 to May 2008 in 3 communities in northern Tampa, FL that each belong to a Home Owner's Association. The area had the highest number of cited irrigation violations. Residents are caught between the HOA rules requiring the maintenance of turf quality and the city's irrigation restrictions.	When irrigation restrictions changed from twice weekly to once weekly, all sampled homes (225) increased usage 6-15% during moderate and wet seasons, while cited homes (67) increased their use in all seasons 11-25% more than uncited homes.	Excellent study of conflicting policies and on-the-ground results.
Polebitski, A.S. and R.N. Palmer. 2013. Analysis and Predictive Models of Single-Family Customer Response to Water Curtailments during Drought. *Journal of American Water Resources Association,* 49(1):40-51.	Investigates customer response during two drought periods in Seattle.	Larger values of income, lot size, and living space enhanced water reductions whereas larger family size tended to reduce the effectiveness of curtailments. Increasing household size hardened demands (decreased curtailment effectiveness) whereas decreasing household size increased per-capita curtailment effectiveness.	These results suggest that changes in the number of residents within a home are likely to be the most important factor in determining future curtailment effectiveness. This could be true for indoor water use, but it's quite unclear what this actually means for outdoor water use which is the primary target of curtailment.
Sadalla, E., A. Berlin, F. Neel, and S Ledlow. 2012. Priorities in Residential Water use: A Trade-Off Analysis. *Environment and Behavior,* 46(3):303-328.			Reaches the obvious conclusion that residents are more willing to curtail outdoor water use than indoor water use.
Sauri, D. 2013. Water Conservation: Theory and Evidence in Urban Areas of the Developed World. *Annual Reviews in Environmental Resources*, 38:227-48.		The relative merits of personal factors (age, income, education, etc.), economic factors (pricing), technology and public awareness on water conservation "remains inconclusive".	
Schnellenbach, J. 2012. Nudges and norms: On the political economy of soft paternalism. *European Journal of Political Economy,* 28:266-277.			Not a study of outdoor water use.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
SEE Action. 2011. Analyzing and Managing Bill Impacts of Energy Efficiency Programs: Principles and Recommendations. State and Local Energy Efficiency Action Network. [Online]. Available: <http: //www.seeaction.energy.gov>. [cited January 27, 2014]	Provide a set of principles and recommendations for regulatory commissions to consider in assessing rate impacts of utility-sector energy efficiency programs.	Not relevant.	Not relevant.
Sevä, M. and S.C. Jagers. 2013. Inspecting environmental management from within: The role of street-level bureaucrats in environmental policy implementation. *Journal of Environmental Management*, 128:1060-1070.			Not a study of outdoor water use.
Sibly, H. and R. Tooth. 2013. The consequences of using increasing block tariffs to price urban water. *The Australian Journal of Agricultural and Resource Economics,* 58:223-243.	Investigates impact of increasing block structures from a mathematical/theoretical standpoint.	Critiques increasing block rates and proposes modifications for improvement.	Does not measure impact on outdoor use.
Sofoulis, S. 2013. Below the Double Bottom Line: The challenge of socially sustainable urban water strategies. *Australian Journal of Water Resources,* 17(2):211. doi: 10.7158/W13-018.2013.17.2.			Not a study of outdoor water use.
Sofoulis, Z. 2011. Skirting complexity: The retarding quest for the average water user. *Continuum: Journal of Media & Cultural Studies,* 25(6):795-810.			Not a study of outdoor water use.
Stewart, R.A., R. Willis, D. Giurco, K. Panuwatwanich, and G. Capati. 2014. Web-based knowledge management system: linking smart metering to the future of urban water planning. *Australian Planner,* 47(2):66-74.			Not a study of outdoor water use.

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Strengers, Y. 2011. Negotiating everyday life: The role of energy and water consumption feedback. *Journal of Consumer Culture,* 11(3):319-338.			Not a study of outdoor water use.
Syme, G.J. , B.E. Nancarrow, and C. Seligman. 2000. The Evaluation of Information Campaigns to Promote Voluntary Household Water Conservation. Evaluation Review, 24(6):539-578.	An extensive literature review of water conservation information campaigns.	The results of program evaluations seem to largely depend on the type of statistical analysis employed. Regressions studies tend to find little effect, while narrative reviews and quasi-experimental studies estimate 10 - 25% water savings.	An older article, but still the best evaluation of media campaigns to date. But, little information specifically on outdoor use/savings.
Tom, G., G. Tauchus, J. Williams, and S. Tong. 2011. The Role of Communicative Feedback in Successful Water Conservation Programs. *Applied Environmental Education and Communication,* 10:80-90.	Investigates the impact of using a data logger and TW analysis to inform customers about their water use.		Not a study of outdoor water use.
UNEP International Environmental Technology Centre. *Every Drop Counts: Environmentally Sound Technologies for Urban and Domestic Water Use Efficiency*. UNEP/Earthprint, 2008.			Not a study of outdoor water use.
Whitcomb, J.B. 2005. *Florida Water Rates Evaluation of Single-Family Homes*. Report, July 13, Brooksville, FL:Southwest Florida Water Management District.		Water pricing can be an effective tool in managing scarce water resources. Results show that price is an undeniable and predicable indicator of water use.	Excellent research on rates, but does not specifically quantify outdoor demand reductions.
Willis, R.M., R.A. Stewart, K. Panuwatwanich, and P.R. Williams. 2011. Quantifying the influence of environmental and water conservation attitudes on household end use water consumption. *Journal of Environmental Management* 92:1996-2009.		Residents with very positive environmental and water conservation attitudes consumed significantly less water in total and across the behaviorally influenced end uses of shower, clothes washer, irrigation and tap, than those with moderately positive Residents with very positive environmental and water conservation attitudes consumed significantly less water in total and across the behaviorally influenced end uses of shower, clothes washer, irrigation, and tap, that those with moderately positive attitudinal concern.	

Topic Area 1 - Restrictions, Rates, Education, and Information			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Willis, R.M., R.A. Stewart, K. Panuwatwanich, S. Jones and A. Kyriakides. 2010. Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. *Resources, Conservation and Recycling,* 54:1117-1127.			Interesting study of indoor use.
Woltemade, C. and K. Fuellhart. 2013. Economic Efficiency of Residential Water Conservation Programs in a Pennsylvania Public Water Utility. *The Professional Geographer,* 65(1):116-129.			Not a study of outdoor water use.
Yabiku, S.T., D.G. Casagrande and E. Farley-Metzger. 2008. Preferences of Landscape Choice in a Southwestern Desert City. *Environment and Behavior,* 40(3):382-400.		Residents preferred high-water-use landscapes over dry landscapes for their own yards, even though they considered desert landscapes to be aesthetically pleasing. Women and long-term residents of the area were significantly more averse to dry landscapes. Stronger environmental attitudes did not lead to preference for xeriscapes but did lead to compromises on the amount of turf grass preferred in lush landscapes. This may contribute to the "oasis" mentality found among area residents.	Not a study of outdoor water use, but rather aesthetics and preferences.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Al-Kofahi, S.D., D.M. VanLeeuwen, Z.A. Samani, and R. St. Hilaire. 2012. Water Budget Calculator Created for Residential Urban Landscapes in Albuquerque, New Mexico. *Journal of Irrigation and Drainage Engineering,*138(6):525-533.	Description of creation of water budget calculator.		Interesting, but not highly relevant. Water savings not part of project.
Aquacraft, Inc. 2000. *Impacts of Xeriscape on Outdoor Water Use.* Las Vegas, Nevada: Southern Nevada Water Authority (August 24).	Physical measurements of water savings from transformation from turf to xeriscape.	Models predict outdoor water use will decrease by 34 gallons per year for every square foot of turf landscape converted to Xeriscape.	Excellent study conducted in Las Vegas. Results will vary by region.
Balling Jr., R.C., P. Gober, and N. Jones. 2008. Sensitivity of residential water consumption to variations in climate: An intraurban analysis of Phoenix, Arizona. *Water Resources Research*, 44:1-11.	in Phoenix, one third of census tracts have little to no sensitivity to climate, while one tract had over 70% of its monthly variance in water use explained by atmospheric conditions. Greater sensitivity to atmospheric conditions occurred in census tracts with large lots, many pools, a high proportion of irrigated mesic landscaping, and a high proportion of high-income residents. Low climatic sensitivity occurred in neighborhoods with large families and many Hispanics.	Households with significant outdoor water use are more likely to respond to climate changes. The sky is blue except when cloudy.	This research mostly confirms obvious conclusions already understood. Question: Why was ethnicity even considered as a factor?
Beck, T.B., J.E. Heimlich, and M.F. Quigley. 2002. Gardeners perceptions of the aesthetics, manageability, and sustainability of residential landscapes. *Applied Environmental Education and Communication: An International Journal* 1(3):163-172.	Perceptions of landscape manageability and sustainability were influenced (somewhat) by factual information presented.		Not particularly useful.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Boyer, M. J., M. D. Dukes, L. J. Young, and S. Wang. 2014. Irrigation conservation of Florida-Friendly Landscaping based on water billing data. *Journal of Irrigation and Drainage Engineering*, DOI: 10.1061/(ASCE)IR.1943-4774.0000774.	Florida-Friendly Landscaping (FFL) has been promoted as a method to reduce irrigation, but the actual water savings has not been previously quantified.	Analysis of monthly combined (indoor and outdoor) potable water billing records and parcel data for 125 FFL and 736 traditionally landscaped comparison homes in southwest Florida indicated that FFL homes used 50% less irrigation. Irrigation savings increased to 76% when considering only good examples of FFL and comparison landscapes with high-quality turfgrass. The FFL customers reduced their irrigation use (279 mm=year) after their landscapes became recognized (202 mm=year). Prior to recognition, these customers were already using less irrigation than their neighbors (279 versus 464 mm=year, respectively), indicating that those most concerned with water use were more likely to choose Florida-Friendly Landscaping.	Measured impacts of specific landscape choices.
Breyer, B., J. Chang, and G.H. Parandvash. 2012. Land-use, temperature, and single-family residential water use patterns in Portland, Oregon and Phoenix, Arizona. *Applied Geography*, 35:142-151.	Compared responses and changes in outdoor water use due to climate variability in Portland and Phoenix.	Temperature sensitive water use was found to be positively correlated with low vegetation and negatively correlated with impervious surfaces in both cities. Tree canopy coverage tends to increase with sensitivity in Portland, while the reverse relationship is found for Phoenix. Regression analysis indicates that building density explained the most variation in the dependent variable in Portland whereas, in Phoenix, the strongest correlations related to vegetation patterns.	Not a water savings study.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Cook, E.M., S.J. Hall, and K.L. Larson. 2012. Residential landscapes as social-ecological systems: a synthesis of multi-scalar interactions between people and their home environments. *Urban Ecosystems*, 15:19-52.			Interdisciplinary study. Overly jargon and complex.
Coutts, A.M., N.J. Tapper, J. Beringer, M. Loughnan, and M. Demuzere. 2013. Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress In Physical Geography* 37(1): 2-28.	Investigates Water Sensitive Urban Design (WSUD) as a method to cool urban areas.		Not a water savings study.
Domenghini, J.C., D.J. Bremer, J.D. Fry, and G.L. Davis. 2013. Prolonged Drought and Recovery Responses of Kentucky Bluegrass and Ornamental Groundcovers. *HortScience*, 48(9):1209-1215.	How long does it take for a plant species to go from healthy to dead/dormant?	When considering turf species, S. album, L. muscari, and P. terminalis are the most drought-resistant among the species evaluated in landscapes where severe drought may occur. V. minor and V. major are good selections in less severe droughts as is P. pratensis if periods of dormancy are acceptable.	Very specific, but this is exactly the type of research people need in drought prone regions.
Ervin, E.H. and A.J. Koski. 1998. Drought Avoidance Aspects and Crop Coefficients of Kentucky Bluegrass and Tall Fescue Turfs in Semiarid West. *Crop Science* 38:788-795.	Research developed crop coefficients for "acceptable appearance" of Kentucky Bluegrass and Tall Rescue in the west.	In Colorado, water can be conserved while maintaining acceptable turf grass quality by irrigating these two turfs every 3 days by adjusting ET (for Kent. Blue grass 0.7 and for Tall Fescue 0.6) provided soil conditions are adequate.	Very specific, but this is exactly the type of research people need in drought prone regions.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Farag, F. A., Neale, C. M. U., Kjelgren, R. K., & Endter-Wada, J. 2011. Quantifying urban landscape water conservation potential using high resolution remote sensing and GIS. Photogrammetric Engineering and Remote Sensing: 77(11), 1113-1122.	Residential landscaped area for Layton and West Jordan, UT was classified using high-resolution airborne multispectral imagery to estimate landscape water need. Data were linked with water billing data (1997-2001) to determine the communities landscape water conservation potentional.	In each of the five years, 9-13% of residential water users accounted for 50% of the excess irrigation, which ranged from 100,167 - 310,520 m^3. The model provides a practial process for evaluating water use on a city-wide basis.	This paper received the 2012 ESRI Award for Best Scientific Paper in GIS
Gerhart, V.J., R. Kane, and E.P. Glenn. 2006. Recycling industrial saline wastewater for landscape irrigation in a desert urban area. *Journal of Arid Environments,* 67:473-486.			Not a water savings study.
Ghosh, S., and L. Head. 2009. Retrofitting the Suburban Garden: morphologies and some elements of sustainability potential of two Australian residential suburbs compared. *Australian Geographer* 40(3): 319-346.			Not a water savings study.
Gobster, P., J.I. Nassauer, T.C. Daniel, G. Fry. 2007. The shared landscape: what does aesthetics have to do with ecology? *Landscape Ecology,* 22:959-972.			Not a water savings study.
Groffman, P.M., J. Cavender-Bares, N.D. Bettez, J.M. Grove, S.J. Hall, J.B. Heffernan, S.E. Hobbie, K.L. Larson, J.L. Morse, C. Neill, K. Nelson, J. O'Neil-Dunne, L. Ogden, D.E. Pataki, C. Polsky, R.R. Chowdhury, and M.K. Steele. 2014. Ecological homogenization of urban USA. *Frontiers in Ecology and the Environment,*12(1):74-81.			Not a water savings study.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Guhathakurta, S. and P. Gober. 2007. The Impact of the Phoenix Urban Heat Island on Residential Water Use. *Journal of the American Planning Association,* 73(3):317-329.	This study examines the effects of Phoenix's urban heat island on water use by single-family residences, controlling for relevant population and housing attributes.	In Phoenix, increasing daily low temperatures by 1° Fahrenheit is associated with an average monthly increase in water use of 290 gallons for a typical single-family unit.	
Gutzler, D.S. and J.S. Nims. 2005. Interannual Variability of Water Demand and Summer Climate in Albuquerque, New Mexico. *Journal of Applied Meteorology*, 44:1777-1787.	The effects of inter annual climate variability on water demand in Albuquerque, New Mexico, are assessed. This city provides an ideal setting for examining the effects of climate on urban water demand, because at present the municipal water supply is derived entirely from groundwater, making supply insensitive to short-term climate variability.	Over 60% of the variance of year-to-year changes in summer residential demand is accounted for by inter annual temperature and precipitation changes when using a straightforward linear regression model, with precipitation being the primary correlate. Long-term trends in water demand follow population growth closely until 1994, after which time a major water conservation effort led to absolute decreases in demand in subsequent years.	Not specifically a water savings study. Rather it describes the relationship between water use and climate.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Halper, E.B., C.A. Scott, and S.R. Yool. 2012. Correlating Vegetation, Water Use, and Surface Temperature in a Semiarid City: A Multiscale Analysis of the Impacts of Irrigation by Single-Family Residences. *Geographical Analysis* 44:235-257.	This study examined whether outdoor water use by residents of single-family homes (a practice that uses close to half of residential water supplies in Tucson) contributes to urban "greenness" and the mitigation of UHI effects.	Spatial analysis results demonstrate that cooling from vegetative evapotranspiration is mediated by development factors as well as by topography and wind patterns. Findings also suggest that outdoor water use aside from irrigation, particularly the use of swimming pools, promotes cooling without elevating the NDVI. Temporal analysis reveal that most residential areas maintained or increased greenness despite declining 1995–2008 water use due most likely to long-term regional climate cycles. Only high-density developments with little undeveloped ground cover and few natural drainage channels exhibit a strong relationship between household water use and NDVI trends. These results suggest that the preservation of natural drainage channels and limitation of impervious surfaces, as well as the siting of development in naturally cooled microclimates, may be sustainable strategies for UHI mitigation in water-scarce regions.	Useful research on urban heat island, but not a water savings study.
Hansen, Gail, Jennifer Ramos, E. A. Felter, and Celeste White. "Adopting a Florida-Friendly landscape: Steps for converting a typical development landscape to a Florida-Friendly Landscape." *Institue of Food and Agricultural Sciences, EDIS Document ENH1135.*(2012).			Not a water savings study.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Hof, A. and N. Wolf. 2014. Estimating potential outdoor water consumption in private urban landscapes by coupling high-resolution image analysis, irrigation water needs and evaporation estimation in Spain. *Landscape and Urban Planning,* 123:61-72.			Not a water savings study.
Hurd, B. 2006. Water Conservation and Residential Landscapes: Household Preferences, Household Choices. *Journal of Agricultural and Resource Economics*, 31(2):173-192.	This study examines landscape choices of homeowners in three cities in New Mexico in order to identify and measure behavioral factors affecting water conservation. Using survey data, landscape choices are analyzed with a mixed logic model that assesses the effects of landscape and homeowner characteristics on choice probabilities	Significant water savings ranging from 35% to 70% are possible from changes in residential landscaping and improved management of outside watering, which often accounts for more than 50% of total residential water use. Model coefficients and implied elasticities indicate that water cost, education, and regional culture are significant determinants of landscape choice.	Good study of landscaping choices. Includes savings numbers from Las Vegas (2004)
IFAS Extension. "The Florida Yards & Neighborhoods Handbook." *Institute of Food and Agricultural Sciences EDIS Document SP191.* (2009).			
Lerman, S.B., V.K. Turner, and C. Bang. 2012. Homeowner Associations as a Vehicle for Promoting Native Biodiversity. *Ecology & Society*, 17(4):45.			Not a water savings study.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Lowry Jr., J.H., M.E. Baker, and R.D. Ramsey. 2012. Determinants of urban tree canopy in residential neighborhoods: Household characteristics, urban form, and geophysical landscape. *Urban Ecosystems,* 15:247-266.	Uses regression analysis with interaction terms to assess the effects of 15 human and environmental variables on tree canopy abundance while holding neighborhood age constant. We demonstrate that neighborhood age is an influential covariate that affects how the human and environmental factors relate to the abundance of neighborhood tree canopy.		Not a water savings study.
McCammon, T.A., S.T. Marquart-Pyatt, and K. Kopp. 2009. Water-Conserving Landscapes: An Evaluation of Homeowner Preference. *Journal of Extension,* 47(2):2RIB5.	Landscape preferences were assessed for three identically designed Xeriscapes™, differing only in the plant material, under both well-watered and drought conditions. Landscapes were subjected to a 5-week dry-down period. Under drought conditions, respondents preferred drought/adapted and intermediate landscapes to traditional landscapes. A focus on Xeriscape™ education, practices, and visual exposure may result in greater adoption of Xeriscape™ practices by homeowners and may also result in significant residential water savings.		Not specifically a water savings study, but useful info when developing landscape transformation programs.
McCarthy, H.R. and D.E. Pataki. 2010. Drivers of variability in water use of native and non-native urban trees in the greater Los Angeles area. *Urban Ecosystems,* 13:393-414.	Seeks to develop a comprehensive understanding of the factors which influence water use of urban tree species in Los Angeles.	We found higher rates of sapflux (JO) in native California sycamore as compared to non-native Canary Island pine. Within each species, we found considerable site-to-site variability in the magnitude and seasonality of JO. For Canary Island pine, the majority of inter-site variability derived from differences in water availability: response to vapor pressure deficit was similar during a period without water limitations. In contrast, California sycamore did not appear to experience water limitation at any site; however, there was considerable spatial variability in water use, potentially linked to differences in nutrient availability.	Not specifically a water savings study, but useful info when developing landscape transformation programs.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Millock, K. and C. Nauges. 2010. Household Adoption of Water Efficient-Equipment: The Role of Socio-Economic Factors, Environmental Attitudes and Policy. *Environmental Resource Economics*, 46:539-565.	Using survey data of around 10,000 households from 10 OECD countries, we identify the driving factors of household adoption of water-efficient equipment by estimating Probit models of a household's probability to invest in such equipment. The results indicate that environmental attitudes and ownership status are strong predictors of adoption of water efficient equipment. In terms of policy, we find that households that were both metered and charged for their water individually had a much higher probability to invest in water-efficient equipment compared to households that paid a flat fee.		Not an outdoor water savings study.
Mustafa, D., T.A. Smucker, F. Ginn, R. Johns, and S. Connely. 2010. Xeriscape people and the cultural politics of turfgrass transformation. *Environment and Planning D: Society and Space,* 28:600-617.	Drawing on ethnographic and survey field research on everyday yard practices, resource use, and landscape perceptions, we explore the environmental and cultural dilemmas presented by the choice between conventional turf grass and the more environmentally benign xeriscaping. We engage with Bourdieu's notions of habitus, field, and distinction to explore how local and personal scale yards, as produced and consumed technonatures, mediate the scales of global environmentalism, national and regional cultural identities, classed aesthetics, and personal and collective security.	We find that xeriscaping does not increase proportionate to income. We argue that yards are a display of cultural capital and that xeriscapers are invested in an environmentalist field that operates at an imagined global scale as opposed to the neighborhood and national scale values invoked with the traditional turf grass lawn. Referring to Bourdieu's work on taste and distinction, we argue that xeriscaped landscapes may entail a more environmentally benign set of landscaping practices but that the adoption of xeriscaping is no less implicated in the reproduction of privilege and distinction than is the traditional turf grass lawn.	Interesting analysis of what goes into landscaping choices. Not specifically an outdoor water savings study.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Nassauer, J.I. 1995. Messy Ecosystems, Orderly Frames. *Landscape Journal,* 14:161-170.	Landscape language that communicates human intention, particularly intention to care for the landscape, offers a powerful vocabulary for design to improve ecological quality. Ecological function is not readily recognizable to those who are not educated to look for it. Furthermore, the appearance of many indigenous ecosystems and wildlife habitats violates cultural norms for the neat appearance of landscapes. Even to an educated eye, ecological function is sometimes invisible¯ Design can use cultural values and traditions for the appearance of landscape to place ecological function in a recognizable context¯		Interesting, but not highly relevant. Water savings not part of project.
Nassauer, J.I., A. Wang, and E. Dayrell. 2009. What will the neighbors think? Cultural norms and ecological design. *Landscape and Urban Planning,* 92:282-292.	Cultural norms for landscape appearance may affect preferences for and adoption of ecological design in exurban residential landscapes.	Efforts to introduce ecologically innovative designs to metropolitan residential landscapes should approach change at the neighborhood scale in order to enhance initial success and long term cultural sustainability. Neighborhood acceptability is a key factor.	Doesn't quantify savings, put points out important issues for consideration in program design.
Niu, G. and D.S. Rodriguez. 2010. Response of Bedding Plants to Saline Water Irrigation. *HortScience,* 45(4):628-636.			Interesting, but not highly relevant. Water savings not part of project.
Nouri, H., S. Beecham, A.M. Hassanli, and F. Kzemi. 2013. Water requirements of urban landscape plants-A comparison of three factor-based approaches. *Ecological Engineering*, 57:276-284.	Researched estimates of landscape water requirements vs. actual applications in South Australia.	The Water Use Classifications of Landscape Species (WUCOLS) method for estimating irrigation demands produced the best estimation of urban vegetation water requirements for the study area.	Provides confirmation that one of the current standard approaches for estimating outdoor demands in the US works well (at least in Southern Australia).

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Nouri, H., S. Beecham, F. Kzemi, and A.M. Hassanli. 2013. A review of ET measurement techniques for estimating the water requirements of urban landscape vegetation. *Urban Water Journal*, 10(4):247-259.	Researched estimates of landscape water requirements vs. actual applications in South Australia.	The Water Use Classifications of Landscape Species (WUCOLS) method for estimating irrigation demands produced the best estimation of urban vegetation water requirements for the study area.	Provides confirmation that one of the current standard approaches for estimating outdoor demands in the US works well (at least in Southern Australia).
Pittinger, D. 2010. How Much Water Does a Landscape Need? Proceedings of Water Smart Innovations 2010. Las Vegas, NV.	Crop coefficients for many landscape plants have not been developed. This study found that in many cases, more water does not yield better plant performance.	Less water may be better for some plant species.	Lacks specific details, but still provides solid info.
Polsky, C., J.M. Grove, C. Knudson, P.M. Groffman, N.Bettz, J. Cavender-Bares, S.J. Hall, J.B. Heffernan, S.E. Hobbie, K.L. Larson, J.L. Morse, C. Neill, K.C. Nelson, L.A. Ogden, J. O'Neil-Dunne, D.E. Pataki, R.R. Chowdhury, and M.K. Steele. 2014. Assessing the homogenzation of urban land management with an application to US residential lawn care. *PNAS,* 111(12):4432-4437.	Results suggest that US lawn care behaviors are more differentiated in practice than in theory. Thus, even if the biophysical outcomes of urbanization are homogenizing, managing the associated sustainability implications may require a multi-scale, differentiated approach because the underlying social practices appear relatively varied.		Theoretical research on "lawn care behavior".
Potts, L.E., M.J. Roll, and S.J. Wallner. 2002. Colorado Native Plant Survey -- Voices of the Green Industry. *Native Plants Journal,* 3(2):121-125.	Survey of Colorado landscape professionals about native plants.	Most responses to the survey referred to problems with native plant work and the great need for more information, education, and research.	Respondents agreed overwhelmingly that the native plant sector is growing slowly, and the growth is being driven primarily by water conservation concerns.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Richie, W.E., R.L. Green, G.J. Klein, and J.S. Hartin. 2002. Tall Fescue Performance Influenced by Irrigation Scheduling, Cultivar, and Mowing Height. *Crop Science*, 42:2011-2017.	Performance of Tall Fescue under different irrigation regimes was investigated.	Visual turf grass quality was significantly correlated with soil water content. Data from this study support recommendations for deeper, frequent irrigation of established tall fescue grown on sandy loam soils in southern California interior valleys with an irrigation budget of 80% ET crop/irrigation uniformity.	Useful info. Not a study of water savings.
Romero, C.C., and M.D. Dukes. 2013. Net Irrigation requirements for Florida turfgrasses. *Irrigation Science,* 31:1213-1224.	A long-term (30 year) historical analysis of turf grass monthly net irrigation requirements for southeast USA is analyzed and discussed.	Results showed that the calibrated Hargreaves–Samani adjustment coefficients varied from 0.14 in Tallahassee to 0.24 in Key West, with an inland average value of 0.15, and a coastal average value of 0.18. The calculated ETos ranged from 1,296 mm year-1 in Tallahassee to 1,658 mm year-1 in Miami. The estimated net irrigation ranged from 423 mm year-1 in Mobile, AL, to 1,063 mm year-1 in Key West, FL. The number of irrigation events per year varied from 25 in Mobile to 161 in Key West. May and December were the months with the highest and lowest net irrigation requirements, respectively.	Useful research on the variability of irrigation requirements. Not an outdoor water savings study.
Runfola, D.M., C. Polsky, C. Nicholson, N.M. Giner, R.G. Pontius Jr., J. Krahe, and A. Decatur. 2013. A growing concern? Examining the influence of lawn size on residential water use in suburban Boston, MA, USA. *Landscape and Urban Planning* 119:113-123.	An analysis of the relationship between household lawns and water use in suburban Boston for the year 2005, and extrapolates this relationship to the year 2030 under different scenarios of (sub)urban growth.	Found that lawn cover, living unit density, and the number of bathrooms can explain 90% of the variation in annual residential water use. Estimated that Ipswich, MA could save 46 million liters of residential water use (a reduction of 5%) by pursuing a smart growth strategy. These modest savings are notable as they are achieved strictly through a densification approach to development i.e., the scenario includes no demand side management.	Key finding: Impact of densification alone over 15 - 20 years was water savings of 5% . Key factor = reduced landscape size.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Serena, M., B. Leinauer, M. Schiavon, B. Maier, and R. Sallenave. 2014. Establishment and Rooting Response of Bermudagrass Propagated with Saline Water and Subsurface Irrigation. *Crop Science*, 54:827-836.			Not a water savings study.
Smith, B. and R.J. Patrick. 2011. Xeriscape for Urban Water Security: A Preliminary Study from Saskatoon, Saskatchewan, *Canadian Journal of Urban Research* 20(2):56-70.	This research explores household motivation for xeriscape gardening.	Households with xeriscape landscaping were motivated mainly by factors related to landscape aesthetic and physical activity rather than water conservation.	Research on xeriscape from Canada. Not a water savings study, but useful information.
Sovocol, K.A. 2005. *Xeriscape Conversion Study*, Las Vegas, NV: Southern Nevada Water Authority.	Results from Southern Nevada Water Authority's (SNWA) multi-year Xeriscape Conversion Study.	Significant average savings of 30% (96,000 gallons) in total annual residential consumption for those who converted from turf to xeriscape. The per-unit area savings as revealed by the submeter data was found to be 55.8 gallons per square foot (89.6 inches precipitation equivalents) each year. Results showed that savings yielded by xeriscapes were most pronounced in summer. A host of other analyses covering everything from the stability of the savings to important factors influencing consumption, to cost effectiveness of a xeriscape conversion program are contained within the report.	Still the best available study and the gold standard for turf conversion research. Measured water savings (55.8 gallons per converted SF of turf/year) for Las Vegas (hot and dry). Xeriscape costs less to maintain.
Stabler, L.B. and C.A. Martin. 2000. Irrigation Regimens Differentially Affect Growth and Water Use Efficiency of Two Southwest Landscape Plants. *Journal of Environmental Horticulture,*18(2):66-70.			Detailed analysis of water demand for two ornamental plants - red bird of paradise and blue palo verde. Too specific to be of much use for water planning.

Topic Area 2 – Landscape Transformation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Sun, H., K. Kopp, and R. Kjelgren. 2012. Water-efficient Urban landscapes: Integrating Different Water Use Categorizations and Plant Types. *HortScience*, 47(2):254-263.	Three landscape treatments integrating different types of plants—woody, herbaceous perennial, turf—and putative water use classifications—mesic, mixed, xeric—were grown in large drainage lysimeters. Each landscape plot was divided into woody plant, turf, and perennial hydrozones and irrigated for optimum water status over 2 years and water use measured using a water balance approach.	For woody plants and herbaceous perennials, canopy cover rather than plant type or water use classification was the key determinant of water use relative to reference evapotranspiration (ETo) under well-watered conditions. For turf, monthly evapotranspiration (ETa) followed a trend linearly related to ETo. Monthly plant factors (Kp) for woody plants, perennials, and turf species under well-watered conditions in this study ranged from 0.3 to 0.9, 0.2 to 0.5, and 0.5 to 1.2, respectively. Overall, Kl relative to ETo ranged from 0.6 to 0.8 for three water use classifications.	Canopy cover rather than plant type determines water use for woody plants. This is the type of research that can help utilities better understand water use patterns and establish more accurate water budgets.
Thompson, R.H. 2004. Overcoming Barriers to Ecologically Sensitive land management: Conservation Subdivision, Green Developments, and the Development of a Land Ethic. *Journal of Planning Education and Research,* 24:141-153.			Not a water savings study.
Zollinger, N., R. Kjelgren, T. Cerny-Koenig, K. Kopp, and R. Koenig. 2006. Drought responses of six ornamental herbaceous perennials. *Scientia Horticulturae*, 109:267-274.	Drought responses were assessed for six herbaceous ornamental landscape perennials in a 38 l pot-in-pot system in northern Utah over a 2-year period.	Penstemon barbatus showed the greatest tolerance to all levels of drought, avoiding desiccation by increasing rootshoot ratio and decreasing stomatal conductance as water became limiting. L. angustifolia and P. mexicali showed tolerance to moderate drought conditions, but died after exposure to the first episode of severe drought. Neither G. aristata nor L. superbum were able to regulate shoot water loss effectively. Instead, both species displayed drought avoidance mechanisms, dying back when water was limiting and showing new growth after they were watered.	Useful info. Not a study of water savings.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Al-Ajlouni, M.G., D.M. Vanleeuwen, and R. St. Hilaire. 2012. Performance of weather-based residential irrigation controllers in a desert environment. *Journal of American Water Works Association*, 104(12):E608-E621.	Performance of weather-based irrigation controllers in tall fescue landscapes was researched. Several different controller models were evaluated.	Irritrol saved 53% and Rainbird 34% compared with a standard controller.	Favorable study of smart controllers. Comparative savings are not broadly applicable however. COMPLEXITY of the programming parameters and depth of knowledge needed to understand them does not seem to make these controllers the "technology solution" they are touted to be. RELIABILITY of the service providing the ET data is critical to performance and an on-going cost to the user. The Rainbird ET Manager had no weather data for 162 days during the year-long study. NOTE Data in Table 4 does not match what is described in the text.
Andales, A.A., J.L. Chávez, and T.A. Bauder. "Irrigation Scheduling: The Water Balance Approach, Fact Sheet No. 4.707." *Colorado State University Cooperative Extension, Fort Collins, CO* (2011).	Method for developing complex water budgets and irrigation regimes.		Not a water savings study.
Booth, A. and N. Skelton. 2011. Anatomy of a failed sustainability initiative: government and community resistance to sustainable landscaping in a Canadian city. *Sustainability: Science, Practice & Policy*, 7(1):56-68.	A case study of a "failed" sustainability initiative to establish sustainable landscaping demonstration sites in a northern, resource-dependent Canadian community.	This failure is attributable to fears by municipal staff regarding public acceptance of landscaping alternatives and, in consequence, partial and ever-changing levels of support for the project. The outcomes suggest several lessons for achieving success in sustainability initiatives, including ensuring education for all parties, establishing and maintaining mutual commitments, and overt planning for potential negative public response.	Not a water savings study.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Bremer, D.J., S.J. Keeley, A. Jager, J.D. Fry and C. Lavis. 2011. In-ground Irrigation Systems Affect Lawn-watering Behaviors of Residential Homeowners. *HortTechnology,* 22(5):651-658.	Objectives were to compare lawn-irrigation perceptions, knowledge, and behaviors of residential homeowners with and without in-ground sprinkler systems. (IGS and NIGS, respectively).	Homeowners with IGS watered more frequently than NIGS. More IGS homeowners watered routinely and applied the same amount of water each time than NIGS homeowners, who mostly watered and adjusted watering amounts based on lawn dryness. More IGS than NIGS homeowners wanted their lawn green all the time, followed lawn care guidelines, and considered their neighborhood appearance important. The majority of all homeowners did not know: how much water a lawn needs, how frequently to water, or how much water they are applying.	
Bremer, D.J., S.J. Keeley, A. Jager, and J.D. Fry. 2013. Perceptions and behaviors of residential homeowners in three Kansas [USA] cities: Implications for lawn watering. *International Turfgrass Society Research Journal*, 12:23-29.	Same research project as in Bremer 2011 article. Only 2 new survey questions reported, "How do you decide when to water?" and "How do you decide how much to water?" Data compared by city instead of city & IGS/NIGS.	People water when their lawn looks dry or on a routine schedule and apply about the same amount of water. Unless, it looks dry, then they apply more.	
Cabrera, R.I., K.L. Wagner, and B. Wherley. 2013. An Evaluation of Urban Landscape Water Use in Texas. *Texas Water Journal,* 4(2):14-27.	This study calculates an estimated baseline of landscaped urban area (~1.6 million acres) based on census data and outdoor water use (1.898 - 4.021 mil. acre ft.) based the reported meter data in the Hermite & Mace study.	Ranks landscape water use as 2nd highest use after ag. Reviews the opportunities for water conservation and their limitations; water-conserving landscape plants, irrigation system design, Smart controllers, & use of brackish/saline or reclaimed water.	Seems to be a reasonable approach to trying to quantify the potential impact of urban landscape water use. Not a water savings study.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
de Loë, R., Moraru, L., Kreutzwiser, R., Schaefer, K., & Mills, B. 2001. Demand Side Management of Water in Ontario Municipalities: Status, Progress, and Opportunities. *JAWRA Journal of the American Water Resources Association*, 37(1):57-72.	A 1998 study with 153 Ontario, Canada municipalities serving 2.5 million people responded to a survey of demand side management measures currently in use. Distributions of responses are reported along with mostly estimated water savings.	*Rates (n=153):* 9.2% report using increasing block rate & 2.6% impose a summer surcharge; *Ordinances (n=88)*: 59.5% have a Lawn Watering Restriction ordinance in place; *Public Awareness (n=261):* 4.6% utilize demonstration gardens; *Other (n=141):* 21.8 % offer Water Audits to homes & businesses. *EFFECTIVENESS (n=81):* Respondents were asked to estimate the percent of water saved due to measures implemented - 65 provide their best guess and 11 provide responses based on studies (may be feasibility studies). Overall, respondents estimated water savings of 15.7%, while responses based on studies reported water savings of 22%.The majority of respondents (57.7%) stated that metering was the most effective measure implemented.	This is an early paper that started to discuss some of the issues in promoting water conservation and then accurately measuring success.
Devitt, D.A., K. Carstensen, and R.L. Morris. 2008. Residential Water Savings Associated with Satellite-Based ET Irrigation Controllers. *Journal of Irrigation and Drainage Engineering,* 134(1):74-82.	A controlled experiment conducted in Las Vegas at 27 residential sites w/ 17 treatment sites equipped w/WeatherTrak ET controllers & 10 control sites equipped w/Rainbird ESP controller. Study was conducted March 2004 thru Aug 2005 and analyzed historical & current meter data, soil data, plant health, site measurement, & participant questionnaires utilizing descriptive statistics & linear/multiple regression models.	13 of 16 ET controller sites save 4.6 - 61.6% & 3 sites use 12, 18 & 68 % more water, 4 of 10 CONTROL sites save 1.9 to 25.8 % & 6 use 5 to 40% more water, SURVEY: 24% of variability in use is accounted for by $ spent on landscape, 57% of water savings is accounted for by time spent outside, importance of landscape to homeowner, & use of professional maintenance service; 87% of participant using ET controllers say the quality of their landscape improved or at least stayed the same.	ET data "from a network of local weather stations," but there is no mention of area serviced by a weather station or its suitability for the sites in the study. NOTE: WeatherTrak declined participation in the 2012 Al-Ajlouni study.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Dukes, M.D., B. Cardenas-Lailhacar, and G.L. Miller. 2008. Evaluation of Soil Moisture-Based on-demand Irrigation Controllers. Final Report. Brooksville, FL: Southwest Florida Water Management District.	A four-year research project to evaluate a soil-moisture-sensor-based irrigation systems in test plots in Florida.	Most SMS systems recorded significant irrigation water savings compared to time-based irrigation schedules typically used by homeowners. During normal/wet weather in Florida, savings ranged from 69% to 92% for three of four SMS brands tested. During dry weather conditions, savings ranged from 28% to 83%. All these water savings were achieved without decreasing turf grass quality below acceptable levels.	Top notch lab research on soil moisture sensors. Among the best SMS studies available.
Endter-Wada, Joanna, J. Kurtzman, S.P. Keenan, R.K. Kjelgren, and C.M.U. Neale. 2008. Situational Waste in landscape Watering: Residential and Business Water Use in an Urban Utah Community. *Journal of the American Water Resources Association,* 44(4):902-920. DOI: 10.1111/j.1752-1688.2008.00190.x	*1997-2001 study in Layton, UT surveyed 296 households & 98 businesses drawn from a random sample stratified by outdoor water use. Data: metered water use & survey, chi square & gamma correlation model.* Created landscape water budgets based on remote sensing imagery and weather data. Compared water use from billing data to water budgets and classified use as conserving, acceptable, or wasteful. Survey investigated factors hypothesized to be predictive of wasteful watering practices.	The most significant factors predicting actual water use were they type of irrigation system and whether the location was a business or household. 57% of programmed irrigation systems are wastefully operated & 65% of businesses were wasteful compared to 39% of households. Attitudinal & motivational characteristics were not significant. Wasteful watering is the result of many factors embedded in the complex context of urban landscapes.	USU research
Fielding, K.S., S. Russell, A. Spinks, and A. Mankad. 2012. Determinants of household water conservation: The role of demographic, infrastructure, behavior, and psychosocial variables. *Water Resources Research,* 48:1-12.	*SE Queensland, AU; 1008 homeowners of freestanding dwelling; 09/2009 to 03/2010; test of Theory of Planned Behavior in the context of a collective behavior - household water use; Data: Survey & 6 months of meter data; Analysis: Sequential regression and correlations.* Demographic, psychological, behavioral, & infrastructure variables accounted to 40% of variance in household water use - demographic & water conservation habits were the strongest predictors of conservation while older residents, households with water efficient appliances, & residents confident in their ability to save water all used *more* water.	Household water use is a collective action and psychosocial variables that assess the household water context were important in explaining conservation. This has important implications for theoretical models of environmental behaviors that have collective outcomes (water or energy use) need to account for dynamics of the collective (instead of individual decision making).	Outdoor efficiency measures included "timed Irrigation" and "water-wise plants". Locations with either of these measures used significantly more water

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Fox, L.J., J.N. Grose, B.L. Appleton, and S.J. Donohue. 2005. Evaluation of Treated Effluent as an Irrigation Source for Landscape Plants. *Journal of Environmental Horticulture*, 23(4):174-178.			Not an outdoor water savings study
Friedman, K., J.P. Heaney, M. Morales, and J.E. Palenchar. 2013. Predicting and managing residential potable irrigation using parcel-level databases. *Journal of American Water Works Association,*105(7):E372-E386.	Analyzed single family residential water use for 30,903 homes in Gainesville Florida using monthly billing data. This database included 1,402 homes with separate outdoor meters and records indicating the 8,304 homes that have inground sprinkler. Indoor and outdoor water use were analyzed separately.	The differences in both application rates and irrigated areas for the separate groups was determined. An important contribution of this paper is the major impact of the relatively recent growth in the popularity of inground sprinkler systems which have gone from being a luxury item in new homes (about 10% of new homes) in 1980 to almost 90% in 2008. Results show much higher application rates for inground systems as compared with hose draggers. Partially offsetting this increased popularity of inground systems is the trend towards smaller lot sizes and associated irrigable area.	Excellent research on the impact and prevalence of inground irrigation systems.
Grabow, G.L., I.E. Ghali, R.L. Huffman, G.L. Miller, D. Bowman, and A. Vasanth. 2013. Water Application Efficiency and Adequacy of ET-Based and Soil Moisture-Based Irrigation Controllers for Turfgrass Irrigation. *Journal of Irrigation and Drainage Engineering,* 139:113-123.	The main objective of this study was to evaluate two types of commercially available irrigation control technologies: one based on evapotranspiration (ET) estimates and the other based on feedback from a soil-moisture sensor (SMS). Test plot research.	Both irrigation efficiency and adequacy were best for the SMS2 treatment when averaged over all three years. The SMS1 treatment provided good irrigation efficiency, but irrigation adequacy suffered, most noticeably with the twice per week treatment. The ET treatment provided good irrigation adequacy, but had the poorest irrigation efficiency. SMS treatments resulted in average water savings of 39% in SMS1 treatments and 24% in the SMS2 treatment compared to the timer-based treatments, whereas the ET treatments applied 11% more water, on average, than the timer-based treatments.	Soil moisture sensors performed significantly better than ET control.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Haley, M.B. and M.D. Dukes. 2012. Validation of Landscape Irrigation Reduction with Soil Moisture Sensor Irrigation Controllers. *Journal of Irrigation Drainage Engineering,* 138:135-144.	The objective of this project was to determine if automatic residential irrigation systems with soil moisture sensor irrigation controllers could reduce irrigation water application while maintaining acceptable turf grass quality as successfully in homes as in plot studies.	Homes with soil moisture sensor irrigation controllers bypassed unneeded events during both rainy and dry periods, averaging 2 irrigation events per month; all other treatments averaged 4.5–6 events per month. Reduction in number of irrigation events by soil moisture sensor control systems resulted in significant savings, with 65% cumulative reduction compared to homes with typical timer irrigation control. Observed on-site savings were comparable to previous plot research, indicating that plot savings could be scaled up so long as soil moisture control systems are installed and set properly.	Important study that confirms SMS savings in the field. 65% reduction!
Haley, M.B., M.D. Dukes, and G.L. Miller. 2007. Residential Irrigation Water Use in Central Florida. *Journal of Irrigation and Drainage Engineering*, 133(5):427-434/	The first objective of this study was to document residential irrigation water use in the Central Florida ridge region on typical residential landscapes T1 . The second objective was to determine if scheduling irrigation by setting controllers based on historical evapotranspiration ET T2 and reducing the percentage of turf area combined with setting the controllers based on historical ET T3 would lead to reductions in irrigation water use.	Compared to the T1 homes, T2 resulted in a 30% reduction 105 mm/month, and T3 had a 50% reduction 74 mm/month in average monthly water use. Average monthly water use was significantly different p 0.001 across the three irrigation treatments. Setting the irrigation controllers to apply water according to seasonal demand resulted in significantly less irrigation water applied. In addition, increasing the proportion of landscape area from 23% T1 and T2 ornamental plants irrigated with sprinklers to 62% and irrigated with micro-irrigation T3 resulted in the largest reduction in irrigation water applied. Compared to T2 where only the irrigation controllers were adjusted, this additional decrease in irrigation water applied was a result of low volume application on only a portion of the landscaped beds where irrigation is only applied to the root zone of plants.	Seasonal adjustments save water. Reducing water requirement of the landscape saved the most water.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
House-Peters, L., B. Pratt, and J. Chang. 2010. Effects of Urban Spatial Structure, Sociodemographics, and Climate on Residential Water Consumption in Hillsboro, Oregon. *Journal of American Water Resources Association,* 46(3):461-472.	(1) What are the significant determinants of SFR water consumption in Hillsboro, Oregon? (2) Is SFR water demand sensitive to drought conditions and interannual climate variation? (3) To what magnitude do particular census blocks react to drought conditions and interannual climate variation?		Not a water savings study.
Karpiscak, M.M., R.G. Brittain, and K.E. Foster. 1994. Desert House: A Demonstration/Experiment in Efficient Domestic Water and Energy Use. *Journal of American Water Resources Association*, 30(2):329-334.			Not a water savings study. No measurements.
Lowry Jr., J.H., R.D. Ramsey, and R.K. Kjelgren. 2011. Predicting urban forest growth and its impact on residential landscape water demand in a semiarid urban environment. *Urban Forestry and Urban Greening*, 10:193-204.	Innovative approach to estimating residential irrigation water demand for a large metropolitan area using GIS data, weather station data, and a water budget modeling approach commonly used by plant scientists and landscape management professionals.		Not a water savings study.
Maliva, R., and T. Missimer. 2012. "Domestic and Agricultural Water Conservation." In *Arid Lands Water Evaluation and Management*, pp. 669-697. Berlin Heidelberg: Springer-Verlag.			Not a water savings study. No measurements.
Mayer, P., Wm. DeOreo, M. Hayden, and R. Davis. 2009. Evaluation of California Weather-based "Smart" Irrigation Controller Programs. Sacramento, CA: Department of Water Resources.		6% reduction overall from smart controllers. Many homes increased outdoor use after installation.	Re-analysis of the data increased the savings numbers somewhat, but this study casts some doubt on the overall efficacy of ET-based irrigation control.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
McCready, M. S., and M. D. Dukes. 2011. Landscape irrigation scheduling efficiency and adequacy by various control technologies. *Agricultural Water Management* 98(4): 697-704.	The purpose of this research was to evaluate the capability of smart control technologies to schedule irrigation compared to a soil water balance model based on the Irrigation Association (IA) Smart Water Application Technologies (SWAT) testing protocol.	In general, the irrigation adequacy ratings (measure of under-irrigation) for the treatments were higher during the fall months of testing than the spring months due to lower ET resulting in lower irrigation demand. Scheduling efficiency values (measure of over-irrigation) decreased for all treatments when rainfall increased. During the rainy period of this testing, total rainfall was almost double reference evapotranspiration (ETo) while in the remaining three testing periods the opposite was true. The 30-day irrigation adequacy values, considering all treatments, varied during the testing periods by 0–68 percentile points. Looking at only one 30-day testing period, as is done in the IA SWAT testing protocol, will not fully capture the performance of an irrigation controller.	Not specifically a water savings study.
Merhaut, D., D. Pittenger, D. Jenerette, and J. Baird. 2012. Groundcovers for Water Conserving Landscapes. UC Riverside Report	The study objectives are to: (1) substantially expand the knowledge of groundcover water requirements; (2) evaluate the adaptation and performance of 17 groundcover and one turf grass species in the inland valley climate when receiving water in the amount of 60% ETo or less; and (3) evaluate the relative carbon fixation potential and water use efficiency among the plant species.	Results not published in this paper.	Incomplete.
Nelson, J.O., 1992. Water audit encourages residents to reduce consumption. *Journal of American Water Works Association*, 84(10): 59-64.	Study evaluated the water savings of a free home water audit offered to single-family residential customers with water use in the upper quartile of the sector. Homeowners were given a recommended seasonal water schedule based on catch-cups tests, ET data, and turf crop coefficents. A random sample of 169 homes were compared to a control group (n=157) and all SFR homes (n=13,200) in the service area.	One year later, audited homeowners outdoor water use had decreased an average of 1,918 gals., which was much less than hypothesized potential of 7,200 gals, and had saved $4.75 on their water bills.	This is one of the earliest papers reporting on outdoor water audits. Current outdoor water audit programs place more emphasis on sprinkler system repair and maintenance. However, there are remarkably few new studies investigating the effectiveness of water audit programs.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Ouyang, Y., E.A. Wentz, B.L. Ruddell, and S.L. Harlan. 2014. A Multi-Scale Analysis of Single-Family Residential Water Use in the Phoenix Metropolitan Area. *Journal of the American Water Resources Association,* (JAWRA) 50(2): 448-467.			Not specifically a water savings study.
Pittenger, D.R., D.A. Shaw, and Wm.E. Richie. 2004. Evaluation of Weather-Sensing Landscape Irrigation Controllers. Report, Sacramento, CA:Office of Water Use Efficiency, California Department of Water Resources.	A science-based evaluation of selected weather-sensing irrigation controllers to determine the climatic data the controllers use, how easy they are to setup and operate, and how closely their irrigation regimes match landscape irrigation needs established by previous field research.	The results of this study show each controller evaluated adjusted its irrigation schedules through the year roughly in concert with weather and ETo changes, but the magnitudes of their adjustments were not consistently in proportion to the changes in real-time ETo. Unfortunately, no product was able to produce highly accurate irrigation schedules consistently for every landscape setting when compared to research-based reference comparison treatments.	Not specifically a water savings study.
Romero, C.C. and M.D. Dukes. 2013. Estimation and Analysis of Irrigation in Single-Family Homes in Central Florida. *Journal of Irrigation and Drainage Engineering*, 140(2).	A methodology to estimate irrigation from potable use data in central Florida is presented in this paper.	Results showed that 57–62% and 45–64%% of homeowners over-irrigated in OCU, with an estimated irrigation amount of 104–62 mm/month when the per capita method and the minimum month method were used, respectively. In TWD, 31–36 to 22–27% of homeowners over-irrigated when the per capita method and the minimum month method were used, with averages of 54 and 31 mm=month, respectively. The minimum month method showed the lowest estimated values on irrigation compared to the per capita method. Further work is needed to determine which indoor use method is most accurate.	Not specifically a water savings study.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Rutland, D.C. and M.D. Dukes. 2012. Performance of Rain Delay Features on Sign-Based Evapotranspiration Irrigation Controllers. *Journal of Irrigation and Drainage Engineering*, 138(11):978-983.	Four treatments were created using the combination of rain delay features: no rain delay features (TN), rain pause (TRP), rain switch (TRS), and both rain delay features (TRP-RS). A fixed-time irrigation schedule with a rain switch and a fixed-time irrigation schedule without a rain switch were created for comparison: T, timer with a rain switch; and TWORS, timer without a rain switch.	During relatively dry periods (72% below historical seasonal rainfall) neither rain pause nor the rain switch resulted in irrigation reduction. However, during periods of rainfall (84% of historically rainy days), both features resulted in significant irrigation savings. The combination of rain switch and rain pause reduced irrigation 41% compared with the use of no rain features, whereas the rain pause feature alone saved 25%. Because of the variability of rainfall in humid climates, using both a rain switch and the rain pause feature is recommended to delay irrigation on the Toro Intelli-Sense controller.	Useful research on the impact of rain sensors.
Shandas, V. and G.H. Parandvash. 2010. Integrating urban form and demographics in water-demand management: an empirical case study of Portland, Oregon. *Environment and Planning B: Planning and Design,* 37:112-128.	This paper reports the results of a study on land-use zoning and development-induced water consumption in Portland, Oregon. We used a geographic information system to integrate land-use records, water-consumption data, socio-demographics, and property tax information for over 122 550 parcels of varying land uses, and employed multiregression analyses to measure the effect of urban forms measured by both the type and the structure of land uses on regional water demand.		Not specifically a water savings study.
Shashua-Bar, L., D. Pearlmutter, and E. Erell. 2009. The cooling efficiency of urban landscape strategies in a hot dry climate. *Landscape and Urban Planning*, 92:179-186.	Describes a climatic analysis of landscape strategies for outdoor cooling in a hot-arid region, and considers the efficiency of water use.	Unshaded grass was found to cause only a small air temperature depression and had the highest water requirement. However when the grass was shaded, either by the trees or by the shade mesh, a synergic effect produced greater cooling as well as a reduction of more than 50% in total water use.	One of the few studies that quantifies the impact of shading on water demand. Useful.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
St. Hilaire, R.S., M.A. Arnold, D.C. Wilkerson, D.A. Devitt, B.H. Hurd, B.J. Lesikar, V.I. Lohr, C.A. Martin, G.V. McDonald, R.L. Morris, D.R. Pittenger, D.A. Shaw, and D.F. Zoldoske. 2008. Efficient water use in residential urban landscapes. *HortScience* 43(7):2081-2092.	The purpose of the review is to summarize how irrigation & water application technologies; landscape design and management strategies; the relationship among people, plants, & the urban landscape; the reuse of water resources; economic and noneconomic incentives; and policy and ordinances; impact the efficient use of water in the urban landscape.	Since landscape irrigation comprises the majority of residential water use in the arid western US, improving its efficiency should be a central goal of water conservation programs. They argue that due to frequent droughts and anticipated effects of climate change, it is imperative that landscape irrigation efficiency become a long-term public strategy. In order to be effective, increasing landscape irrigation efficiency must be broadly addressed through improved technology, place appropriate landscapes, supporting policies, and appropriate price structures based on water budgets.	This literature review is based on the scholarly contributions to the 1st Symposium on Efficient Water Use in the Urban Landscape. The review of technology is somewhat dated due to the steady improvement of irrigation system components.
Steffen, J., M. Jensen, C.A. Pomeroy, and S.J. Burian. 2013. Water Supply and Stormwater Management Benefits of Residential Rainwater Harvesting in U.S. Cities. *Journal of American Water Resources Association*, 49(4):810-824.			Hypothetical. Not a water savings study.
Tsai, Y., S. Cohen, and R.M. Vogel. 2011. The Impacts of Water Conservation Strategies on Water Use-Four Cases Studies. *Journal of the American Water Resources Association*, 47(4):687-701.	We assessed impacts on water use achieved by implementation of controlled experiments relating to four water conservation strategies in four towns within the Ipswich watershed in Massachusetts. The strategies included (1) installation of weather-sensitive irrigation controller switches (WSICS) in residences and municipal athletic fields; (2) installation of rainwater harvesting systems in residences; (3) two outreach programs: (a) free home indoor water use audits and water fixture retrofit kits and (b) rebates for low-water-demand toilets and washing machines; and (4) soil amendments to improve soil moisture retention at a municipal athletic field.	It was found that (1) the municipal WSICS significantly reduced water use; (2) residences with high irrigation demand were more likely than low water users to experience a substantial demand decrease when equipped with the WSICS; (3) rainwater harvesting provided substantial rainwater use, but these volumes were small relative to total domestic water use and relative to the natural fluctuations in domestic water use; (4) both the audits ⁄ retrofit and rebate programs resulted in significant water savings; and (5) a modeling approach showed potential water savings from soil amendments in ball fields.	Interesting, but not as rigorous as Dukes et. al.

Topic Area 3 – Irrigation Management			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Wade, G.L. "Water-Wise Demonstration Landscape: A Case Study in Water Conservation." In *Proceedings of the 2005 Georgia Water Resources Conference*.[np]. 2005.	Case study of a single Xeriscape.	The data show that through careful plant selection and design according to Xeriscape principles, little supplemental irrigation is needed on landscapes in the coastal region of Georgia.	

Topic Area 4 – System Efficiency			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Bargar, J., D.F. Culbert, and E. Holzworth. 2004. "Landscape Irrigation as a Water Conservation Practice." *Proceedings, Florida State Horticultural Society (2004) 117:249-253.*	A 2001-2004 study of landscape water use at an Indian River, FL resort community consisting of 122 acres of residential landscapes (283 home sites). The study was conducted at the request of the owners association. The request was motivated by the fact that the development was at 60% build out, but was using 207% more water than their conditional use permit allowed. U of F mobile irrigation lab (MIL) conducted 5 landscape evaluations of the 5 different landscape plans used throughout the development and provided irrigation management recommendations. A landscape maintenance workshop was held 12 Sept 2001 for landscape personnel.	EXTREME variation in operating pressure - 75 psi daytime & 20 psi nighttime; CONTROLLERS had never been reset since landscapes had been installed; IN 2002 water use decreased 232 mil. gal., but rainfall increase 73% & couldn't determine if this was result of recommendations or rainfall; A follow-up workshop participants revealed a high turnover rate in groundkeepers.	This article highlights the importance of: resetting controllers after landscapes are established, the need for frequent observation of sprinkler system function, and availability of water conservation professionals to support landscape maintenance personnel's adoption of MIL recommendations.
Baum, M.C., M.D. Dukes, and G.L. Miller. 2005. Analysis of Residential Irrigation Distribution Uniformity. *Journal of Irrigation and Drainage Engineering,* 131(4):336-341.	A controlled experiment conducted in South Central FL at 25 residential sites and a control site w/multiple treatment plots. The study compared their more rigorous procedures to MIL results, methods of calculating uniformity (DU_{LQ} & CU), & 3 brands each of spray heads & rotors. Results were analyzed w/a GLM.	DIFFERENT catch can test procedures & calculations resulted in significantly different uniformity results (Tbls 1 & 3); AVG Residential DU 45% - Control plots 55%; ROTOR heads (55%) have better uniformity at all pressures tested than do spray heads (49%); SPRAY heads w/fixed arc patterns were more uniform than adjustable arc heads; RESIDENTIAL sites had poor head spacing resulting in low DU; BOTTOM LINE - need for properly design residential systems.	Findings differ from Lesmeister et al. who found only 2 - 8 cans were needed to accurately measure PR. So, the implication is that you can produce an accurate water schedule (when not adjusting run time for DU), but fail to find maintenance/functional problems when you use too few cans.
Dukes, Michael D., Melissa B. Haley, and Stephen A. Hanks. 2006. "Sprinkler irrigation and soil moisture uniformity." *27th annual international irrigation show*, San Antonio, TX, USA. pp (2006): 446-460.	A controlled experiment to quantify the relationship between catch can DU and soil moisture uniformity. Compared bare soil test plots to 21 residential sites.	Lower quarter DU does not capture the process of water infiltration into the soil. Soil moisture becomes more uniform and more closely approximates the lower half DU calculation.	
Ferguson, B.K. , 1987. Water conservation methods in urban landscape irrigation: An exploratory overview. Water Resources Bulletin, 23(1):147-152.	Provides an overview of how to effectively design, manage, and maintain a water conserving urban landscape without compromising aesthetics.	Suggests that proper irrigation can provide substantial water savings. The urban development plan, planting design, and irrigation must be considered together in order to achieve efficient water use.	An early paper acknowledging the complexity of urban irrigation.

Topic Area 4 – System Efficiency			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Lesmeister, D., L. Pochop, F. Kerr, S.S. Wulff, and D. Johnson. 2007. Evaluating the "Catch-Can" Test for Measuring Lawn Sprinkler Application Rates. *Journal of American Water Resources Association*, 43(4):938-946.	This study evaluated the "do-it-yourself" catch can test for application rate found on many water conservation web-sites.	ACCURACY depends on number of cans used, system's operating pressure, & duration of the test. TYPE of collector (tuna or soup can, coffee cup) did not appear to influence results. FOR in-ground systems number of can required ranged from 2 - 8 depending of psi & amount of head overlap.	These findings apply to water checker procedures as well.
Maheshwari, B. 2012. Water Conservation Around Homes--The Role of Audit in Improving Irrigation System Performance. *Irrigation and Drainage*, 61:636-644.	This study is a <u>first-time</u> application of a "public space" water audit process to a residential landscape at 50 home sites in the Sydney Metropolitan area, Australia. It presents many "lessons learned" in the course of conducting the study.	THERE are relatively few well-designed systems in operation, TYPICAL homeowner has limited knowledge of irrigation, MAINTENANCE is usually forgotten. AUDIT process itself needs to be streamlined so it can be completed in 2 or 3 hours!	This study had methodological issues; e.g. studying irrigation system maintenance during long-term water restrictions forbidding their use. Compared to other papers in this category, it highlights extent of progress in USA programs.
Mecham, Brent Q. "Distribution uniformity results comparing catch-can tests and soil moisture sensor measurements in turfgrass irrigation." *Proceedings, Irrigation Association's 2001 International Irrigation Show* (2001): 133-139.	This proceedings paper discusses the varied methodologies used in calculating Irrigation Water Requirements and compares catch can DU to soil moisture DU.	Calculation of IWR based on the LQ DU results in overwatering. Alternatively, the LH DU should be used to adjust the plant water requirement.	Dukes (2006), Mecham (2001) and this study all reached similar conclusions. B. Mecham points out that these 3 papers provided the defensible position for changing how landscape irrigation scheduling is taught today (personal correspondence, Sept 23, 2014).
Mecham, Brent, and Northern Colorado Water Conservancy District. "Using distribution uniformity to evaluate the quality of a sprinkler system." *Irrigation Association's* (2004).	This proceedings paper discusses the varied methodologies used in conducting catch can tests resulting in audit data that cannot be compared across the board. In addition, an industry standard quality rating scheme has not been adopted.	AUDIT data is rarely analyzed and published; QUALITY of sprinkler system needs to keep pace with improvements in controller technology.	Many of the issues raised regarding audit methodologies have been addressed by the WaterSense labeled auditor certification programs developed in the 10 years since this presentation.
Olmsted, T.R. and M.D. Dukes. 2011 "Frequency of Residential Irrigation Maintenance Problems." *Institute of Food and Agricultural Sciences, EDIS Document AE472.*	An analysis of the maintenance problems found in 3,416 water audits conducted by Florida's UMILs.	FIVE problems represent half of all recorded problems; 1) zones w/mixed plant water requirements, 2) zones w/unmatched application rates, 3) sprinkler heads blocked by vegetation, 4) watering too frequently, and 5) too long (Tbl2). They estimate the effort, cost & water savings expected by addressing these problems and suggest that the great savings for the least effort & cost is gained by using the correct water schedule.	I am not aware of any study that has evaluated and ranked water waste by maintenance problem. Currently, "expected savings" are mostly based on common sense logic instead of empirical study.

Topic Area 4 – System Efficiency			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Solomon, K. H., J. A. Kissinger, G. P. Farrens, and J. Borneman. 2007. Performance and water conservation potential of multi-stream, multi-trajectory rotating sprinklers for landscape irrigation. *Applied engineering in agriculture* 23(2): 153-163.	Results of field audits comparing the performance of fixed spray and MSMTR sprinklers in landscape irrigation. Individual zones were audited before and after a conversion from fixed spray to MSMTR sprinklers.	Average low quarter distribution uniformity (DULQ) improved by 0.26, from 0.44 to 0.70, after the conversions. Average low half run time multiplier (RTMLH) decreased by 0.39. Estimated water conservation potential due to the conversion from fixed spray to MSMTR sprinklers depends on pre-conversion uniformity and choice of run time multiplier (RTM). The average water conservation potential estimated for the fixed spray to MSMTR conversion ranged from 22% to 40% of the pre-conversion application depending on pre-conversion choice of RTM. A good single-point estimate for water conservation potential due to fixed spray to MSMTR conversion is 31%.	Measured 31% hypothetical water savings from rotating sprinkler conversion.
Thomas, D.L., K.A. Harrison, M.D. Dukes, R.M. Seymore, and F.N. Reed. "Landscape and Turf Irrigation Auditing: A Mobile Laboratory Approach for Small Communities." *Cooperative Extension, University of Georgia, College of Agriculture and Environmental Sciences, Bulletin 1253* (2009).	A pilot study of UGA water audit program conducted in Douglas, GA on 14 sites (7 commercial & 7 residential). The paper provides information on successfully implementing an auditing program for a community, as well as fully setting out their audit procedures. Estimate water savings for repairs based on part specifications & assumes no change in water schedule.	MAIN problems: MISMATCH nozzles in rotating heads (24% water savings), SAME operating time regardless of head type (19%), OVERSPRAY (minimal - more "an issue of public perception"), and NO seasonal adjustment on controllers. SOME sites were watering LESS than PWR.	Their program requires that the sprinkler system be operational in order to do an audit. This practice may be a missed opportunity for the auditor to influence what repairs are made on a system. This program stresses the importance of the program's accountability to the water purveyor & community through their community reports.
Vis, E., R. Kumar, and S. Mitra. Comparison of Distribution Uniformities of Soil Moisture and Sprinkler Irrigation in Turfgrass. *Proceedings 2007 International Irrigation Show.* Dec (2007): 9-11.			

Topic Area 5 – Monitoring and Evaluation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
ASLA, LJBWC, and USBG (American Society of Landscape Architects, Lady Bird Johnson Wildflower Center, and United States Botanic Garden). 2009. *Guidelines and Performance Benchmarks*. Washington D.C.			
Bamezai, A. 1995. Application of Difference-in-Difference Techniques to the Evaluation of Drought-Tainted Water Conservation Programs. *Evaluation Review,* 19(5):559-582.	This article illustrates some of the internal validity threats that arise when evaluating the impact of water conservation programs implemented during a drought.	This article shows how to deal with these problems in the context of water conservation programs when high-quality disaggregate data are available.	Good and useful research, but the complexity of the methods would make it difficult for utility staff to implement without assistance.
Bellamy, J.A., D.H. Walker, G.T. McDonald, and G.J. Syme. 2001. A systems approach to the evaluation of natural resource management initiatives. *Journal of Environmental Management,* 63:407-423.			Not specific enough to be of real use to the water industry.
Cunningham, M.B. 2013. Productivity Benchmarking the Australian Water Utilities. *Economic Papers,* 32(2):174-189.	This article presents a productivity benchmarking study of Australian water utilities using stochastic frontier analysis of the input distance function. It identifies total factor productivity (TFP) trends and comparative levels and, through decomposition, explores some of the reasons for productivity change.	Productivity is found to have declined between 2006 and 2010 over all regions, with the smallest declines in the four major urban Victorian utilities and the largest declines among the regional Victorian urban water utilities and the major utilities in other states. Comparative technical efficiency analysis finds the major urban Victorian utilities were more efficient than the average water utility, while the regional Victorian urban water utilities and the major utilities in other states were of below-average technical efficiency. The benchmarking method employed in the study may be relevant to economic regulation.	Not relevant for outdoor water savings.

Topic Area 5 – Monitoring and Evaluation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Dziegielewski, B., and J.C. Kiefer. "Water Conservation Measurement Metrics." *American Water Works Association Water Conservation Division Subcommittee Report* (2010).	Study identifies and characterizes a set of water use and conservation metrics for public water supply utilities. These metrics could be used as measurement tools to evaluate the effects of water efficiency programs over time in a single utility. Some metrics can also be used to compare water use and conservation effects across different utilities. This report provides guidance on standardized methods of calculating specific metrics and describes their advantages and limitations.	Essential terms like "efficiency," "metric", and "benchmark" are defined. Methods for calculating metrics are described in detail. Seven utility case studies are available.	Not specifically focused on outdoor water savings, but this study is the best available for measuring changes in water demand.
Friedman, K.R. "Evaluation of Indoor Urban Water Use and Water Loss Management as Conservation Options in Florida." MS Thesis, University of Florida, 2009.			Not an outdoor savings study.
Giurco, D.P., S.B. White, and R.A. Stewart. 2010. Smart Metering and Water End-Use Data: Conservation Benefits and Privacy Risks. *Water,* 2:461-467.	This paper explores questions regarding the degree of information detail required to assist utilities in targeting demand management programs and informing customers of their usage patterns, whilst ensuring privacy concerns of residents are upheld.		Not an outdoor savings study.
González-Gómez, Francisco, and Miguel A. García-Rubio. 2008. Efficiency in the management of urban water services. What have we learned after four decades of research? *Hacienda Pública Española/Revista de Economía Pública* 185(2): 39-67.			Not a water efficiency study.
Howarth, D. and S. Butler. 2004. Communicating water conservation: how can the public be engaged? *Water Science and Technology: Water Supply,* 4(3):33-44.			Not an outdoor savings study.

Topic Area 5 – Monitoring and Evaluation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Hughes, S. 2012. Voluntary Environmental Programs in the Public Sector: Evaluating an Urban Water Conservation Program in California. *The Policy Studies Journal,* 40(4): 650-673.	Uses a new dataset from California to examine how political institutions affect decisions by local governments and public agencies to participate in a voluntary urban water conservation program and whether this program has improved the water conservation performance of its members.	The results show that special district governments, private utilities, and water suppliers dependent on purchased water are more likely to participate in the program and to join early. However, urban water agencies that have joined the program have not reduced their per capita water use more than those that have not.	Not an outdoor savings study. However, this study demonstrates the importance of accountability through monitoring and enforcement. The purpose of implementing a voluntary conservation program needs to be clearly focused on reducing water use. Absent monitoring and enforcement, other considerations for implementation overtake the conservation effort. In order for voluntary programs to be credible, they must be accountable for achieving a conservation goal.
Kleiman, D.G., R.P. Reading, B.J. Miller, T.W. Clark, J.M. Scott, J. Robinson, R.L. Wallace, R.J. Cabin and R. Felleman. 2000. Improving the Evaluation of Conservation Programs. *Conservation Biology,* 14(2):356-365.	Routine evaluation of program goals and processes (organization & function) are critical to improve the effectiveness of programs. Criteria for success should be based on program goals, but should also include social criteria; e.g. public support, public education outcomes. Evaluations should be institutionalized and routinely conducted as part of the program.	RECOMMEND *annual internal reviews* to improve the organization and function of programs and support team learning; and *5-year external reviews* should be conducted to evaluate the broader goals of the program.	Synthesis of lessons from the field of conservation biology can be applied to the development of water conservation program evaluations. Water conservation programs usually measure the end-users success in implementing recommendations. However, programs themselves would benefit from evaluation to ensure they meet the needs of program participants.
Knight, A.T., R.M. Cowling, and B.M. Campbell. 2006. An Operational Model for Implementing Conservation Action. *Conservation Biology,* 20(2):408-419.			Not an outdoor savings study.

Topic Area 5 – Monitoring and Evaluation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Price, J.I., J.M. Chermak, and J. Felardo. 2014. Low-flow appliances and household water demand: An evaluation of demand-side management policy in Albuquerque, New Mexico. *Journal of Environmental Management,* 133:37-44.	Considers the effects of rebates from the Albuquerque Bernalillo County Water Utility Authority (ABCWUA). Using panel regression techniques with a database of rebate recipients, we estimate the marginal effects of various low-flow devices on household water demand.	Results indicate a negative correlation between household water use and the presence of most low-flow devices, after controlling for water price and weather conditions. Low-flow toilets have the greatest impact on water use, while low-flow washing machines, dishwashers, showerheads, and xeriscape have smaller but significant effects. In contrast, air conditioning systems, hot water recirculation, and rain barrels have no significant impact on water use. The xeriscape rebate exhibits the largest decline, approximately 33%, between pre- and post-rebates periods. Declines in water use for the remaining rebates range from 17% to 24%.	Included xeriscape rebates in the analysis, but the methods were not sufficiently robust.
Pullin, A.S. and G.B. Stewart. 2006. Guidelines for Systematic Review in Conservation and Environmental Management. *Conservation Biology,* 20(6):1647-1656.	The authors use systematic review guidelines established by health services sector and modified them for application to conservation and environmental management. They argue that once established, reviews will provide evidence-based support of conservation outcomes.		A different subject (but quite interesting). This paper addresses the quality of systematic review ***papers*** in the field of conservation and environmental management. The authors assert that ecological practice would benefit from a more formalized set of guidelines of what constitutes a rigorous review paper, like those used in medicine where reviews are used to ensure uniform practice of medicine across the country.

Topic Area 5 – Monitoring and Evaluation			
BIBLIOGRAPHIC REFERENCE	**ABSTRACT**	**KEY FINDINGS**	**REVIEW COMMENTS**
Stem, C., R. Margoluis, N. Salafsky, and M. Brown. 2005. Monitoring and Evaluation in Conservation: a Review of Trends and Approaches. *Conservation Biology,* 19(2):295-309.	A review of monitoring and evaluation approaches in conservation and other fields including international development, public health, family planning, education, social services, and business. Here, we present our results for the field of conservation. We categorized the considerable variety of monitoring and evaluation approaches into four broad purposes: basic research; accounting and certification; status assessment; and effectiveness measurement. We focus here on status assessment and effectiveness measurement.	Specific lessons that emerged follow: different monitoring and evaluation needs require different approaches; conceptual similarities are widespread among prevailing approaches; inconsistent language impedes Communication; confusion among monitoring and evaluation components hinders practitioner ability to choose the appropriate component; and monitoring only quantitative biological variables is insufficient. We suggest that the conservation community continue support of collaborative initiatives to improve monitoring and evaluation, establish clear definitions of commonly used terms, clarify monitoring and evaluation system components, apply available approaches appropriately, and include qualitative and social variables in monitoring efforts. Table 1 list the many types of monitoring and evaluation approaches, their strengths and weaknesses.	A broad scale paper providing a historical review of various monitoring and evaluation approaches. Not a water conservation study.
Sutherland, Wm.J., A.S. Pullin, P.M. Dolman, and T.M. Knight. 2004. The need for evidence-based conservation. *TRENDS in Ecology and Evolution*, 19(8):305-308.	The authors promote a "systematic review" process to verify conservation effectiveness based on evidence. They suggest a framework for incorporating program evaluation into research practice. Effectiveness of conservation interventions matters for the future of scientific practice, policy formation, and allocation of funding.		Companion article to Pullen et al. The AWWA guidance report is a step towards providing a robust, evidence-based reporting system for the water conservation field.
Waller, D.H. and R.S. Scott. 1998. Canadian Municipal Residential Water Conservation Initiatives. *Canadian Water Resources Journal*, 23(4):369-406.			Not an outdoor savings study.
White, S., G. Milne, and C. Riedy. 2004. End use analysis: issues and lessons. *Water Science and Technology: Water Supply*, 4(3):57-65.			Discusses the use and importance of end use analysis as an analytic tool for water utilities.