2009 Literature Review to Assist in Quantification of Expected Benefits of Landscape Water Conservation Best Management Practices (BMPs)

Prepared for
Colorado Water Conservation Board

Prepared by
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Project Purpose

As communities develop and implement Water Conservation Plans to meet the requirements of the Colorado Water Conservation Board (CWCB), significant opportunities for outdoor water conservation exist. While most agree that landscape water conservation opportunities are plentiful, the magnitude of water conservation achievable through various practices is not currently quantified in a manner that is consistently transferable to Water Conservation Plans. In 2008, the Colorado Water Conservation Board (CWCB) provided a grant to the Green Industries of Colorado (GreenCO) to update its landscape best management practices (BMP) manual titled "Green Industry Best Management Practices for the Conservation and Protection of Water Resources in Colorado – Moving Towards Sustainability." This manual provides information on 39 BMPs that support landscape water conservation objectives; however, water conservation benefits of these practices are not quantified in the BMP Manual. (Attachment 1 summarizes the GreenCO BMPs.) Given CWCB's desire to quantitatively assess the role that conservation measures can play in statewide water supply planning and to see landscape water conservation better integrated into Water Conservation Plans, CWCB has provided support for a targeted literature review, which is the subject of this report. The goals of this review are as follows:

- Identify literature potentially useful in quantifying the water conservation benefits associated with various landscape BMPs.

- Assess usefulness of literature in developing a range of quantitative estimates for various practices under a given set of conditions.

- Summarize findings in a manner that is transferable to future Colorado Water Conservation Board (CWCB), GreenCO and local water provider projects.

- Determine whether available literature provides a reasonable basis for estimating water conservation benefits of various landscape practices and, if so, identify next steps in this process.

This project is intended as a fundamental step needed to bridge the gap between identified landscape water conservation BMPs and quantification of the benefits of these practices. This project will provide a common base of information for use in future projects by CWCB, water utilities and GreenCO, as well as identify information gaps that should be included in future efforts and research.

Project Approach

A variety of literature sources describe and identify landscape water conservation practices, with expected benefits of such practices quantified or estimated to various extents under varying site conditions. The first step in this project was to identify literature sources likely to provide quantitative water conservation data. "Literature" potentially includes the following information sources:

1. Published academic research in peer-reviewed journals (e.g., American Water Works Association [AWWA] Journal, Colorado State University Extension) or text books.

2. Published reports sponsored by independent organizations (e.g., U.S. Bureau of Reclamation, Irrigation Association, Northern Colorado Water Conservancy District, Western Resource Advocates, Center for ReSource Conservation).

3. Published or unpublished data compiled and analyzed by water providers (in-state and out-of-state) and Green Industry professionals. Priority was given to water providers within Colorado, followed by those in semi-arid or arid neighboring states (e.g., New Mexico, Arizona, Utah, Nevada, California).

4. Other "grey" literature including periodicals (e.g., *Water Efficiency*) and general website searches.

The initial reference list was developed from the GreenCO BMP Manual Bibliography (Attachment 4) and solicitation of references via email and direct requests from Colorado WaterWise Council members.

Based on preliminary review of literature compiled, a standard reporting framework for summarizing the available data was developed and agreed upon with CWCB staff and project advisors. Literature sources that appeared to be potential sources of quantitative data were reviewed, with notes taken on a standard form. The completed review forms are provided in Attachment 3. Attachment 2 contains a condensed summary of quantitative water savings reported in the literature reviewed. The findings of the review were then synthesized according to extent of knowledge for various BMP groups and are discussed. Based on these findings, an assessment of the extent to which existing knowledge is adequate to develop quantitative estimates of water conservation practices was completed, and recommendations regarding "next steps" in developing such estimates and/or needed research to fill data gaps was provided.

Scope Limitations and Excluded Literature

This literature review was focused primarily on demand-side physical practices associated with landscape water conservation and efficiency. There are a number of related supply side and behavioral measures that could have been included in this literature review, but that have not been included at this time, including:

- **Water Rate Structures/Pricing**: This topic has been covered in multiple publications such as Klein et al. (2007), Western Resource Advocates (2003, 2004, 2007, 2008), Mayer et al. (2008), Kenney et al. (2008), and others. From a landscape design and planning perspective, a closely related topic is water budgeting. To the extent that literature was available on establishing water budgets, this information has been included; however, pricing issues have not been addressed, other than a brief synopsis of the findings of Kenney at al. (2008) in Aurora.

- **Reclaimed Water**: Use of reclaimed water in the landscape is an important supply-side tool to help stretch potable water supplies and is a practice included in the GreenCO

BMP Manual. Much literature is available regarding the benefits of reclaimed water in the context of landscape irrigation. For example, Sharvelle et al. (2009) have estimated that reclaimed water used for irrigation of a typical residential landscape could supply about 30% of the demand. They further note that "…with increasing emphasis on xeriscape in the semi-arid West, it has the potential to supply 100% of the irrigation demand in some areas."

- **Rainwater Harvesting**: Currently, rainwater harvesting is not legally viable at a significant level in Colorado. Many other states have substantial guidance available promoting and facilitating use of rainwater harvesting, both as a water supply supplement and as a stormwater management tool. If rainwater harvesting becomes viable on a more widespread scale in Colorado at some point in the future, it would be appropriate to further evaluate the literature available on this topic, particularly from other semi-arid and arid states such as Texas and Arizona.

- **Utility-mandated Water Restrictions/Drought Response:** Watering restrictions are not considered to be a day-to-day landscape water conservation practice since they are artificially imposed to achieve utility objectives, regardless of the agronomic water requirements of the landscape. Many utilities in Colorado reported water savings of 30% or more during the peak of the recent Colorado drought, with Kenney et al. (2004) documenting a range of 13% to 56%. Nonetheless, these water savings may provide some type of benchmark or reality check on what could potentially be achievable through water conservation practices. These estimates, however, do not typically separate indoor and outdoor savings and are generally perceived as short-term.

- **Behavioral Studies**: A large factor influencing landscape water conservation is human behavior. Both price and non-price factors affect water conservation. Behavioral studies are not a central focus of this literature review, but are a fundamental factor in determining market penetration. Several studies associated with public behavior were identified during the course of this literature review, but were not reviewed in detail.

- **Other Literature Sources:** The focus of journal reviews was primarily in the arena of water resources engineering and management. An additional body of scientific literature that could also be reviewed in the future is in the realm of horticultural sciences. This body of literature could prove to be useful in the context of turf management, plant selection and soil preparation, as several examples. Exclusion of this literature was purely due to project scope limitations. Representative literature sources not included in this review, but that should be reviewed in the future, include the following:

  Agricultural Water Management
  Agronomy Journal
  Crop Science
  Horticultural Science
  International Turfgrass Research Journal
  Journal of Environmental Horticulture
  Journal of the American Society for Horticultural Science

Previous Work

Estimating the role of water conservation in water supply planning is not a new topic, although the role of conservation has consistently been a topic of debate. Several previously developed statewide water conservation estimates are summarized below. Additionally, two literature reviews conducted in the last several years by Colorado researchers are also summarized, in order to avoid "reinventing the wheel."

Previous Estimates of the Role of Water Conservation

During the course of the literature review, various estimates and projections regarding the role of water conservation in meeting the state water supply needs were identified. Some of these estimates include:

- Rozaklis (1997) at the 8th Annual South Platte Forum in Longmont estimated: "Currently anticipated conservation efforts will reduce future demand by about 17 percent compared to what it otherwise would be…there are still additional savings that could be gained from water conservation. My estimate is that additional "reasonable" water conservation efforts can reduce M&I demand by an additional 10 to 15 percent basin-wide. And of all six categories of water supply sources, conservation probably has the least impact to other resource interests—to West Slope supplies, to stream flows for endangered species, and to continuance of irrigated agriculture."

- SWSI (CDM 2004, p. ES-37) notes, "It is estimated that by 2030, Level 1 conservation will result in demand reduction in Colorado of approximately 101,900 AF…SWSI estimates these current active conservation programs [beyond Level 1] could result in additional water demand savings ranging from 3 to 14 percent by basin, or an estimated 231,000 AF statewide by 2030." (The landscape component of this estimate is not broken out separately.) "Also, as Colorado water providers and water customers continue to implement long-term water conservation, it may be harder to expect the 20 to 30 percent demand reductions that were seen in recent drought years in future drought years."

- In SWSI II (CDM 2007, pp. 2-6 & 2-7), the Conservation and Efficiency Roundtable further refined estimates of projected potential long-term savings from conservation alternatives. Based on information provided in a summary table from several sources, the group concluded, "the various conservation measures, if fully and successfully implemented, represent a range of potential demand reduction from 287,000 AF to 459,000 AF per year (AFY) by 2030 with a mid-point estimate of these potential statewide savings of 372,000 AF." The group further concluded, "The level of penetration, which can be defined as the extent to which the conservation measure is implemented or adopted, is the most sensitive variable that affects the amount of reduction in water demand (conservation) that may be achieved…. This point is central to the debate over how far conservation measures can go in reducing current and future water demand." Estimated savings associated with various landscaping conservation/efficiency measures are included in the summary of General Conservation Programs in Attachment 2.

Previous Literature Reviews

Two previous literature reviews conducted in Colorado closely relate to this project, including:

- Barta, R., Ward, R., Waskom, R., & Smith, D. (2004). *Stretching Urban Water Supplies in Colorado, Strategies for Landscape Water Conservation.* Special Report Number 13. Fort Collins: Colorado Water Resources Research Institute. http://www.cwi.colostate.edu/publications/sr/13.pdf

- Klein, B., Kenney, D., Lowrey, J., & Goemans, C. (2007). *Factors Influencing Residential Demand: A Review of the Literature (Updated 1/20/07).*

It is recommended that users of this literature obtain both Barta et al. (2004) and Klein et al. (2007) because the focus of the reviews is slightly different, and the reviews are complementary. The scope of this literature review is more narrowly defined regarding landscape conservation BMPs in terms of physical actions taken in the landscape, whereas the Barta et al. (2004) review is broader and the Klein et al. (2007) review focuses more in depth on price-related and behavioral aspects of residential demand. Key conclusions and highlights of these literature reviews are briefly provided as general background. Additionally, work by Kenney et al. (2007) in Aurora ties in closely to the Klein et al. (2007) literature review and is also discussed.

Barta et al. (2004)

Barta et al. (2004) focuses on conservation strategies categorized according to the general categories of price and non-price strategies. Non-price strategies are considered to include outreach and education as well as policy and regulation. Price strategies include inclining block rates, water budget based rate structures, and seasonal rate structures. A review of these strategies and an analysis of the advantages, disadvantages, and effectiveness of strategies are provided in the literature review. Perhaps one of the most important findings of the review was: "There is not sufficient peer-reviewed literature to scientifically evaluate the effectiveness of urban landscape water conservation strategies." Specific conclusions, which are largely consistent with the findings of the current literature review, include:

- Overall, there is a lack of information available regarding the implementation of non-price conservation programs and a lack of detail and consistency of water use information necessary to evaluate changes in demand.

- More research is needed to understand how the interaction of conservation strategy incentives influences the overall reduction in water consumption.

- Failure to account for non-price conservation efforts, primarily outreach and education programs, may result in an overestimation of the effectiveness of price strategies for conservation.

- Education and outreach conservation programs tend to be a part of all conservation efforts and are generally believed to be very important in all conservation programs.

- A majority of conservation studies are site-specific and are not necessarily applicable in all settings.

- There is very little consistency in terminology used by various water managers and members of the green industry regarding water conservation for landscapes.

Klein et al (2007) and Kenney et al. (2007)

Klein at al. (2007) focused primarily on pricing factors, but divided the literature review into factors utilities can control (e.g., price, policies) and factors that they cannot control (e.g., weather, household characteristics, behavior). The literature review also discusses two historical approaches to evaluating water demand: a water requirements approach (how much water is needed) and an economics approach (how people make decisions about water consumed). The overall literature review should be accessed for more in-depth information, but selected conclusions extracted from the report (*quoted directly*) that are relevant to this literature review include:

- A consistent point in the literature is the need to understand how price influences demand (price elasticity). Multiple studies confirm the hypothesis that raising prices reduces demand, albeit only modestly (i.e., demand is largely price inelastic), with estimates of price elasticity varying widely.

- A key research question that remains is the extent to which individuals understand their rate structure and water bill, raising difficult research issues about which price signals customers actually respond to.

- It is also clear that price elasticity can vary significantly among seasons, uses, regions, and various social/economic conditions. A more sophisticated understanding of these influences is key to translating a general understanding of price elasticity into effective demand management policies.

- Similarly, the interaction of price and non-price demand management programs is of particular concern, as many utilities employ multi-faceted programs to manage consumer demand for water. The range of non-price strategies for managing water demand can generally be grouped into three categories: water restrictions, public education, and technological improvements.

- Research into the first category, water restrictions, generally focuses on the comparison of voluntary versus mandatory programs, usually focused on outdoor water uses during drought emergencies. The literature is consistent in showing significant (often 30 percent or more) savings from mandatory restrictions; findings regarding voluntary restrictions are much more variable, but with savings estimates generally lagging far behind the mandatory programs. Part of the challenge in assessing the impact of restrictions programs is that they are usually combined with other efforts, particularly public information campaigns.

- Research into these educational efforts generally shows them to be modestly beneficial, especially in the short-term. Research seems to suggest that a certain "critical mass" of educational programs are necessary to generate significant benefits, but that utilities soon reach a point of declining returns as additional efforts are implemented thereafter.

- Less confusion generally surrounds efforts focusing on technological changes, such as household-level retrofitting of water-using devices such as toilets, showerheads, and washing machines. Among these approaches, the significant water-saving benefits of toilet retrofits are best documented. Technological upgrades regarding outdoor sprinkler systems do not appear to offer similar conservation benefits.

- It is well documented that weather can impact short-term water demand decisions (particularly for landscape irrigation), and for this reason, weather variables are typically controlled for in studies focused on price and non-price tools. But beyond the intuitive conclusion that hot-dry weather generates higher demands than cool-wet conditions, the exact nature of the weather/water demand relationship has several areas of uncertainty.

- Research is often frequently constrained by the fact that household-level consumption data is typically only available at a monthly scale while weather variables change daily.

- Data limitations are also a common impediment to assessing the impact of demographic characteristics on residential water demand, as researchers rarely have data sets that allow them to match household level consumption data with demographic data about the people and house associated with a residential water account.

- Nonetheless, research that distinguishes water demand trends between single-family versus multi-family dwellings, between urban and suburban settings, and between purely residential and mixed residential/commercial regions can provide useful information, especially since it may influence the types of management options (e.g., customer-specific water billing) available to the utility, and may help illuminate how a community (and its water demand) will evolve over time. Even in a community dominated by single family homes that is not undergoing a transformation regarding the types or mix of dwellings, the addition of new homes and the aging of the preexisting housing stock is important.

- Generally, new homes are shown to consume less water than older homes… On the other hand, to the extent that newer homes are more likely to have automatic in-ground sprinkler systems, these technologies generally increase water demand when compared to homes reliant on hose-based irrigation technologies. The relative size of lots and homes is an important consideration, especially if these averages are changing as a community builds out and matures. As expected, larger lot sizes tend to be correlated with higher water demands; however, establishing a similar correlation between house size and demand has proven elusive.

- Overall, the literature is clear in showing that residential water demand is largely a function of water price, the impact of non-price demand management programs, weather

> (and climate), and demographic characteristics of households and the homes they occupy. To the extent that this research is being pursued with the ultimate aim of informing and empowering water managers to better predict and manipulate demand, future investigations will need to better illuminate the interplay among these factors. This suggests a need to better understand water-use decision-making processes at the household level, which in turn will require the assembly of datasets featuring multiple, customer-level observations across time to augment citywide (aggregated) data. This seems particularly important as water utilities adopt dynamic, customer-specific water budgets, with the competing aims of managing water demand (and water revenues), encouraging economic efficiency in water use, all within a framework that customers can understand and endorse as equitable. To achieve these goals, in both "normal" and drought years, is a formidable challenge, and is deserving of the same level of intellectual effort as has traditionally been devoted to understanding and managing water supplies.

Closely related to the work by Klein et al (2007) as part of the Western Water Assessment, is the *Residential Water Demand Study in Aurora* (Kenney et al. 2009) where over 10,000 water billing records covering multiple years were reviewed with regard to changes in water use, straddling the 2002 drought. Key landscape-related findings from the Aurora study, extracted and quoted directly from a recent presentation by (Kenney & Reidy, 2009) include:

- Overall price elasticity of demand: -0.60 (10% price increase reduces demand by 6%)
- High-volume users are most responsive to price (-0.75) (7.5% decrease)
- Low-volume users are least responsive to price (-0.34) (3.4% reduction)
- Water Use Restrictions: -0.12 (12% reduction) assuming average prices
- Pricing-Restrictions Interactions. Savings from pricing and restrictions are not fully additive: people respond to one or the other
    - Overall price elasticity declines when restrictions are in effect (from 6% to 3.7%)
    - The effect of pricing on the high-volume users is significantly constrained when restrictions are in effect (7.5% to 2.4% decrease)
- Block Rate: -0.05 (5% reduction) [controlling for price and other factors]
- WaterSmart Readers. For those households that have a WaterSmart Reader:
    - Use actually went up 16% overall
    - However, the frequency that these households went into the second or third pricing tier dropped
- The effectiveness of demand management policies is mostly determined by how they influence the behavior of the high-volume users, who are:

  - Highly responsive to price in non-drought periods
  - Highly responsive to restrictions during drought periods

- Increasing block rate structures work (even if the pricing tiers are only modestly punitive). (Reduce demand 5%, irrespective of pricing)

- Customers will hit water-use targets if you provide them with proper incentives (via rate structures) and information (via a Water Smart Reader)

Summary and Evaluation of Literature Sources

Literature Sources

During April-June 2009, the following literature sources were reviewed:

- GreenCO BMP Manual references (Attachment 4). The majority of these references provided information on how to implement a wide range of landscape BMPs, but did not quantify the expected water savings of each practice.
- Colorado State University (CSU) and CSU Extension research
- Northern Colorado Water Conservancy District (NCWCD) (and other conservancy districts) research
- Western Resource Advocates publications (e.g., *Water Meter*, *Smart Water*)
- Center for ReSource Conservation (Slow the Flow Colorado)
- CWCB resources
- EPA WaterSense website
- U.S. Bureau of Reclamation (USBR)
- Irrigation Association website
- Peer-reviewed journals (representative examples)
  - *Journal AWWA*
  - *Journal of the American Water Resources Association*
  - *Journal of Irrigation and Drainage Engineering*
- Conference Proceedings (representative examples)
  - *2008 Sustainable Sources Conference* in Reno, NV by AWWA
  - *WaterSmart Innovations '08* in Las Vegas, NV
  - *2009 EWRI Congress* in Kansas City, MO
  - Water Environment Federation (WEF) conference proceedings (various years)
- Other periodicals:
  - *Colorado Water*, newsletter of Colorado Water Resources Research Institute
  - *Water Efficiency* Magazine
  - *Colorado Green* Magazine
  - *Water Wise,* newsletter of the Colorado WaterWise Council
  - *Headwaters*, magazine of the Colorado Foundation for Water Education
- Various state conservation related websites (e.g., California, Arizona, Nevada, Texas, New Mexico, Florida)

Interviews and Correspondence

In addition to review of published literature, numerous phone calls and emails were initiated to identify key literature sources. The following individuals provided valued input on the literature review, whether it was identifying leads, emailing studies, or providing recommendations or direction in phone interviews.

- Drew Beckwith, Western Resource Advocates
- Tracy Bouvette, Great Western Institute
- Bill DeOreo, Aquacraft
- Kristen Fefes, Associated Landscape Contractors of Colorado (ALCC)
- Stu Feinglass, City of Westminster
- Ram Dhan Khalsa, U.S. Bureau of Reclamation
- Doug Kenney, University of Colorado Natural Resources Law Center
- Larry Lesser, ASLA, ISA, The Laughing Earth
- Tim Lipan, Denver Water
- Dan Matsch, EcoCycle, Inc.
- Peter Mayer, Aquacraft
- Brent Mecham, Irrigation Association
- Donna Pacetti, Denver Water
- Alison Peck, Matrix Gardens
- Dick Ruppel, Horizon Turf
- Don Schlup, Scienturfic
- Jeanine Shaw, Denver Water (formerly Center for ReSource Conservation)
- Scott Winter, Colorado Spring Utilities
- Reagan Waskom, Colorado Water Resources Institute
- Jill Wuertz, Denver Water

A number of additional Green Industry members were also pursued; however, the short timeframe associated with the literature review, which corresponded to the peak of the landscaping season, limited the information obtained from these individuals. Similarly, several professors at Colorado universities active in horticultural research were pursued, but the timing of the study may have conflicted with priorities at the close of the academic year. Finally, requests for information were submitted to a broader range of Colorado WaterWise Council members several times via email distribution and via the June 2009 Board meeting. A group discussion regarding availability of quantitative landscape water conservation information at the June 2009 Board meeting, but did not result in additional data. In general, it appears that utility records associated with landscape conservation practices may be limited, possibly due to conservation historically being lower priority than other water utility issues.

Water conservation leaders and researchers in several states were also pursued, with the following individuals providing helpful information:

- Doug Bennett, Southern Nevada Water Authority
- Christina Bickelmann and Marjie Risk, Arizona Department of Water Resources
- Michael Dukes, University of Florida

- Garry Grabow, North Carolina State University
- Kelly Kopp, Utah State University (*via request from Reagan Waskom*)

Assessment and Findings

After completion of the literature review, a key objective was to answer the questions: 1) "what do we know" and 2) "how can we use it." At the initiation of the project, several possible project outcomes were envisioned, including:

1) Quantification of water conservation benefits for certain BMPs based on a significant base of literature.

2) Identification of BMPs for which literature is currently inadequate to develop quantifiable water conservation estimates.

3) Identification of BMPs for which literature is not currently available, but scientific understanding is adequate to calculate expected water conservation estimates.

As the literature review evolved, a relatively large number of potentially useful information sources was identified. This resulted in a coarser review of the studies, as opposed to a detailed processing of the study information. In general, a very strong base of information on "how to" implement landscape water conservation practices was available. Virtually every state website in arid/semi-arid climates has this type of information available; however, significantly less quantitative information regarding water savings was readily available. Nonetheless, the following general categories of BMP practices have quantitative information to varying extents:

- Xeriscape
- Irrigation Technology
- Irrigation Efficiency Audits
- Plant Selection
- Turf Management
- Soil Preparation/Amendment
- Water Budgeting

Although some of these practices have moderate amounts of information available (e.g., Xeriscape, irrigation practices), the findings are reported in an inconsistent manner, may be located in other climates or may be limited to the science behind the practice, without accounting for the behavioral variables in real-world applications. A summary of findings based on the literature reviewed follows, along with recommendations for additional research and next steps regarding quantifying various landscape water conservation practices.

General Water Conservation Planning

As an initial step in assessing literature available for landscape water conservation planning, several summary-level documents were reviewed to develop a sense of the range of water

savings associated with landscape conservation practices and programs reported by others. Key documents reviewed included:

- *Water Conservation Programs- A Planning Manual, Manual of Water Supply Practices M52* (AWWA 2006)
- *Water Conservation Plan Guidelines* (EPA 1998)
- *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities* (Western Resource Advocates 2007)
- *Colorado's Water Supply Future, Statewide Water Supply Initiative, Phase II* ("SWSI II")(CDM 2008)

These and other general water conservation planning estimates from others as summarized in Attachment 2. Additional discussion of AWWA M52 and the EPA Planning Guidelines follows.

AWWA M52

As a general starting point, the American Water Works Association (2006) guidance manual titled *Water Conservation Programs- A Planning Manual, Manual of Water Supply Practices M52* was reviewed for water savings estimates for various landscape practices. While specific numeric estimates were provided for many forms of indoor and commercial conservation/efficiency measures, the only landscape irrigation measure with a quantitative estimate provided was evapotranspiration (ET) irrigation controllers, with an estimated water savings of 18-22%. Other landscape water conservation/efficiency practices with savings identified as "varies" in terms of end-use reductions, included these practices: drip systems, micro-spray systems, hose timers, trigger shut-off valves on hoses, irrigation system moisture sensors, rainwater tanks, native plants and mulch. "Varies" was defined as "depending on the amount of water used outside and interaction with other outdoor measures." Public education, inclusive of overall general household water use, was estimated to provide a 1-5% reduction in end-use.

In terms of calculating water savings, AWWA (2006) notes that baseline water use must first be determined for the targeted group of users. Water savings will depend on 1) reduction in water use as a result of implementing the measure; and 2) the degree of coverage that the measure can achieve (i.e., market penetration). The general formula to estimate how effective a specific efficiency measure is in a given year is:

$$E = R \times C \times V$$

Where:

E = estimated reduction in water use (million gallons/year)

R = percent reduction in water use as a result of the measure if all customers implemented the practice (entered as a fraction of 1)

C = percent coverage of the measure of the group water users (entered as a fraction of 1)

V = volume of water use without the water-efficiency measure in million gallons/year

Based on the literature review conducted, for some landscape BMPs, the "R" (technical) part of the equation can be calculated, but the "C" (behavioral) part of the equation is much more challenging. AWWA (2006) notes that for mandatory measures, the C factor is considered 100%, whereas for voluntary measures, the C factor is much lower. Most landscape water conservation practices in Colorado are voluntary under non-drought conditions, with a few exceptions such as soil amendment and penalties for blatant water waste in some jurisdictions. AWWA notes that the experience of other utilities may be useful in developing C factor estimates. This literature review may be helpful in developing estimates for the "R" and "C" factors.

EPA Landscape Water Conservation Benchmarks

Appendix B of *Water Conservation Plan Guidelines* (EPA 1998) summarizes water savings estimates from a broad range of indoor and outdoor practices, as "compiled from various sources." EPA provides a footnote stating: "Actual water savings can vary substantially according to a number of factors. These data are provided for illustrative purposes only and may not be current or applicable. To the extent practical, planners should regionally appropriate or system-specific assumptions and estimates." A subset of findings related to landscape measures is provided in Table 1 below.

Table 1. Landscape-related Excerpts from EPA's Benchmarks for Savings from Selected Conservation Measures (Table B-4) (Source: EPA 1998)

Category and Implementation Level (1-3)	Conservation Measure	Estimated Reduction in End Use
Universal metering (1)	Connection metering	20 percent
	Submetering	20 to 40 percent
Water accounting and loss control (1)	System audits and leak detection	Based on system
Costing and pricing (1)	10% increase in residential prices	2 to 4 percent
	10% increase in nonresidential prices	5 to 8 percent
Information and education (1)	Public education and behavior changes	2 to 5 percent
End-use audits (2)	Outdoor residential use	5 to 10 percent
	Large landscape water audits	10 to 20 percent
Pressure management (2)	Pressure reduction, system	3 to 6 percent of total production
	Pressure-reducing valves, residential	5 to 30 percent
Outdoor water-use efficiency (2)	Low water-use plants	7.5 percent
	Lawn watering guides	15 to 20 percent
	Large landscape management	10 to 25 percent
	Irrigation timer	10 gpcd
Water-use regulation (3)	Landscape requirements for new developments	10 to 20 percent in sector
	Graywater reuse, residential	20 to 30 gpcd

Xeriscape

The U.S. Bureau of Reclamation sponsored five field demonstration projects as part of its decade-long National Xeriscape Demonstration Project (NXDP), which began in 1996. Partnering communities included Fargo, North Dakota; Austin, Texas; Phoenix, Arizona; Las Vegas, Nevada; and Denver, Colorado. The most comprehensive Colorado-based Xeriscape study reviewed was the Yield and Reliability Demonstration in Xeriscape (YARDX) study conducted along the Colorado Front Range (Medina and Gumper 2004) as part of the NXDP program. Table 2, reproduced below directly from the Medina and Gumper (2004) report, demonstrates statistically significant saving from implementation of Xeriscape. The study also recognizes differences in water savings among new installations, retrofits and older existing Xeriscape sites. Information on participation, cost and maintenance are also provided in the study. The standardized and statistically designed study methodology enables comparison of the Denver results to other studies participating in the NXDP studies, as summarized in Table 3. Medina and Gumper (2004) provide the following observations from the YARDX report:

- "Computation of water use savings between Xeriscape samples and respective control properties ranged from 18 percent savings in the Colorado Springs new start demonstration (28 percent in data without year 2002 water use values) to 63 percent water savings in the Highlands Ranch new start demonstration. All comparisons tested with the Wilcoxon method yielded P-values less than 0.01. The retrofit demonstration in Colorado Springs yielded a water savings of 23 percent (32 percent excluding year 2002 data) while the Denver retrofit demonstration ("hose drag") produced a 28-percent savings. The new start demonstration in Fort Collins, consisting of large area, and more expensive properties, produced a 36-percent savings." (p. 5-4)

- "The retrofit demonstrations did not achieve water savings levels consistent with expected savings from the Xeriscape design developed for retrofits. This design called for Xeriscape plant area according to⅓ low (or no), ⅓ moderate, and ⅓ high water use, and overall water savings of about 60 percent. Water savings may have been negatively impacted by some participants employing greater than⅓ high water use area (of total landscape)." (p. 5-5)

- "Plausible explanations for the Colorado Springs year 2002 results include unrestricted watering regulation of Xeriscapes during the drought year. Xeriscape owners apparently hand watered their plants or used their drip irrigation systems allowable under the restrictions. Watering turf was more restricted and thus affected the controls more severely." (p. 5-4)

It is anticipated that additional statistical analysis of this data set could be beneficial. In the report, Metro Water Conservation Incorporated (MWCI) indicated willingness to share the data set with others for additional data exploration.

Table 2.
Water Use Comparisons Between Xeriscape and Traditional Landscape Samples
Source: YARDX Final Report, Table 5-1 (Medina and Gumper 2004)

	Seasonal (Apr-Oct) water use savings (%) per square foot of landscapable area, using growing season values adjusted for winter[1] average use[2]			Seasonal savings without adjustment for area	Winter[1] median daily water use (gal/day) N=number of properties Landscape average area (A) in square feet	
Demonstration	All project years	Years except 2002	Year 2002 only	All years	Xeriscapes	Control group
Colorado Springs new start	18 savings P<0.01	28 savings P<0.01	50 increase	22 savings P<0.01	169 (N=27) A=4608	182 (N=37) A=5190
Colorado Springs retrofit	23 savings P<0.01	32 savings P<0.01	34 increase	24 savings P<0.01	194 (N=27) A=5374	191 (N=32) A=5472
Denver retrofit	28 savings P<0.01	26 savings P<0.01	33 savings	17 savings P<0.01	146 (N=34) A=3047	152 (N=31) A=2537
Fort Collins new start	36 savings P<0.01	39 savings P<0.01	29 savings	32 savings P<0.01	191 (N=34) A=7583	182 (N=38) A=8859
Highlands Ranch new start	63 savings P<0.01	69 savings P<0.01	63 savings	50 savings P<0.01	165 (N=13) A=3971	218 (N=17) A=3576
Greeley retrofit	54 savings	56 savings	30 savings	40 savings	130 (N=6) A=9290	185 (N=4) A=9348
Wheat Ridge & Arvada pre-existing Xeriscapes	1 savings P>0.05	1 savings P>0.05	3 savings	25 savings	164 (N=26) A=4068	198 (N=28) A=5558

[1] Winter months included January, February, March, November and December.
[2] P-values (probability that sample differences could have occurred by chance) are not given for small samples.

Table 3. Results from other National Xersicape Demonstration Project (NXDP) Studies

Location	Study Name	Savings Relative to Control Group
Colorado Front Range (YARDX)	Medina, J. & J. Gumper (2004). *YARDX: Yield And Reliability Demonstrated in Xeriscape: Final Report*. Metro Water Conservation, Incorporated, Littleton, CO, 140 p. www.coloradowaterwise.org Includes studies in Denver, Fort Collins, Greeley, Highland Ranch, Colorado Springs, Wheatridge and Arvada. See Table 2.	18-63% (Approx 30%- range expected)
Phoenix, AZ	Stinnett, R. (2003). *Landscape Trends and Water Use in the Phoenix Metropolitan Area.* Available from the Bureau of Reclamation, Phoenix Area Office. This project was similar to a YARDX pre-existing Xeriscape landscape study conducted in Arvada/Wheat Ridge neighborhoods, except for lack of an observation period. The Phoenix study involved selecting, acquiring, and evaluating landscape historical water use data.	53%
Las Vegas, NV	Sovocool, A.K, and J.L. Rosales. (2003). *A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert*. Las Vegas, Nevada: Southern Nevada Water Authority.	39%
Austin, TX	Gregg, Tony, J. Curry, and C. Grigsby. (1994). *Xeriscaping: Promises and Pitfalls.* Report for the Texas Water Development Board. City of Austin.	31%
Fargo, ND	Medina, J., & Lee, A. (2006). *FX Project, Fargo Xeriscape Project, Final Report*. Bureau of Reclamation and City of Fargo.	29% (new starts) 10-50% (retrofits)
Other Xeriscape Studies Cited in the NXDP Studies:		
North Marin	Nelson, J. (1994). "Water Saved by Single Family Xeriscapes." Preliminary Draft for AWWA National Conference. New York, June.	25%
Mesa, AZ	Testa, A., and A. Newton. 1993. "An Evaluation of a Landscape Rebate Program." AWWA Conserv'93 Proceedings. December.	33%

In summary, both data within and outside of Colorado indicate that Xeriscape can produce considerable water savings. Priority should be given to Colorado-based studies, given that landscape retrofits in more arid communities such as Phoenix and Las Vegas involved desert landscaping, which differs from the natural ecological communities associated with Colorado's Front Range. Additionally, a key long-term issue with regard to Xeriscape evaluations is the durability of savings achieved over time. This is one of the reasons that it is important to emphasize all seven principles of Xeriscape, which include efficient irrigation and proper

maintenance. In other words, Xeriscape and turf replacement are not synonymous terms, although some literature treats them synonymously.

Finally, it is anticipated that more Xeriscape case studies within Colorado exist, but perhaps have not been formally documented. An example is a recent Denver Parks and Recreation (2009) fact sheet regarding retrofitting medians along Martin Luther King Boulevard, which has shown an estimated water savings of approximately 48% in initial estimates comparing 2001/2002 data to 2007/2008 data. The new median design included combinations of turf, planting areas, hardscape and mulched tree beds, combined with a significant irrigation system upgrade. This, once again, emphasizes that plant selection is only one part of a Xeriscape retrofit.

Irrigation Technology/Retrofits

A number of irrigation-related studies are available, typically either controller technology or overall irrigation system retrofits. The largest group of studies is associated with evaluation of "smart" irrigation controllers, either weather-based or soil moisture-based. Irrigation controller testing has been conducted by both the U.S. Bureau of Reclamation and the Irrigation Association through its Smart Water Application Technology (SWAT) program. Multiple studies have shown statistically significant savings associated with smart irrigation control technology.

In Colorado, several small-scale studies have been conducted by City of Boulder (1998), Aquacraft (2001, 2002), Mecham and Boyd (2004) and Keesen (2004) that demonstrated water savings associated with irrigation controller technology. The Mecham and Boyd (2004) study combined a soil preparation variable with several types of irrigation controller technologies at their study of nine model homes. Attachment 2 reports water savings associated with these and other studies, but additional standardization of the savings metrics is needed, since the results range from percent of water applied relative to a water budget, gallons saved, or percent water savings. Range of savings is quite variable and more processing of this data set is needed.

In 2009, Mayer et al. released a large-scale ET controller study based in California. Although the study was not located in Colorado, the study is particularly important due to the very large sample size and the strong experimental design basis associated with the project, enabling meaningful statistical analysis at a more robust level than is typically found. Additionally, the study is important because it demonstrates the difference between technologically achievable water savings versus real-world water savings when the human behavior factor is considered. A brief summary of this study follows.

The California Weather-Based Irrigation Controller (WBIC) study (Mayer et al. 2009) presents empirical data on the performance of smart controller products distributed and installed through different methodologies in a wide variety of settings over a four-year time period. The study was completed in cooperation with the California Department of Water Resources, the California Urban Water Conservation Council, the Metropolitan Water District of Southern California and their 26 member agencies, and a consortium of six water agencies in northern California led by the East Bay Municipal Utility District. Utility partners were able to provide the necessary data for 2,294 sites with 3,112 smart controllers. Fourteen different brands of controller were included in the analysis portion of this study, with varying installation conditions (owner versus

professional). Overall, outdoor water use was reduced by an average of 47.3 kgal per site (-6.1% of average outdoor use) across the 2,294 sites. This reduction was found to be statistically significant at the 95% confidence level. Multiple nuances and community specific findings were also presented. The report should be referenced for more detail, with the following findings and conclusions briefly quoted directly from the Executive Summary prepared by Mayer et al. (2009):

- On average smart controllers are a moderately effective measure for reducing the amount of water applied by automatic irrigation systems, while maintaining the health, and appearance of landscapes.

- When seeking irrigation water savings, the pre-existing level of excess irrigation at the site is the most important factor to consider.

- The water savings achieved through installation of smart controllers can be maximized by targeting the technology to irrigators with historically high irrigation application rates, not simply customers with high irrigation use.

- The many irrigators who historically apply less than the theoretical irrigation requirement for their landscape are likely to increase their irrigation application rate after installing a smart controller.

- Survey results indicate that smart controllers are likely to achieve a high degree of customer acceptance once they more broadly penetrate the consciousness of irrigation contractors and the general public.

- The utility programs implemented through the Division of Water Resources grant have succeeded in raising public awareness of this technology, but survey results suggest most consumers have no knowledge of smart irrigation control.

- Smart controllers can achieve cost effective water savings for utilities and irrigators under some cost and pricing scenarios, however this technology will not be cost effective for all utilities and customers.

- Most of the smart controller brands and technologies evaluated in this study reduced irrigation demands on average, but not all of these reductions were statistically significant.

Additionally, Keesen (2004) has calculated savings associated with overall irrigation retrofits at several locations in Colorado, demonstrating significant water savings associated with retrofits and providing cost data and return on investment calculations. More information on irrigation retrofits in Colorado is believed to be available; however, it appears that data compilations are often not completed. Denver Parks and Recreation is a likely source of future information as a number of large irrigation retrofits of Denver parks have either been completed or are planned.

Several additional behavioral observations related to irrigation technology identified in the literature that were noteworthy include:

- Mayer et al. (2009) state, "The irrigation controller is important, but only one piece of the puzzle. Even the best, most water efficient controller cannot make up for poor system design, installation, and maintenance. The focus of [the California WBIC] report is on irrigation controllers, but a holistic approach to irrigation systems and landscape design and maintenance is required to achieve the full potential of water savings in the urban irrigation sector."

- Kenney and Reidy (2009) posed the following question, which may warrant additional study: "To what extent is outdoor water use a function of the types of irrigation technologies in use (e.g., hoses, sprinklers, timers), and what opportunities exist to strategically manipulate this as part of demand management programs?"

- Barnes et al. (2008) identified some issues with residential rebate programs or distribution of ET controllers in California that fall in the "behavioral" category:

    - Controllers not in ET mode
    - Weather monitors installed improperly (upside down, under roof, near heat source)
    - Incorrect programming (plant type, sprinkler type, etc.)
    - Lack of fine-tuning of programming after installation
    - Initial starting point as "deficit irrigators"

Irrigation Efficiency Audits

Several studies documenting the effectiveness of irrigation efficiency audits in semi-arid and arid locations were identified. All of these studies demonstrated or estimated water savings, but once again, results vary and are reported according to varying performance metrics.

A study of particular interest is the Center for ReSource Conservation (CRC)'s Slow the Flow Colorado Program, which included performing 1,256 irrigation inspections across Colorado's Front Range in 2007. As part of the inspection, a CRC auditor tested a property's irrigation system for efficiency and recommended an irrigation schedule, as well as other improvements that could improve the system's efficiency. Common problems identified included poor distribution uniformity and systems operating at incorrect pressure, with only 12 percent of inspections showing systems considered to be operating efficiently. Following the inspections, 79% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection.

A similar "Water Check" program has been conducted by Utah State Center for Water Efficient Landscaping. Annual reports include water use analysis compared to a baseline year, property characteristics, irrigation system characteristics, and cost data. Table 4 summarizes study results from the 2008 annual report (Waters et al. 2009). This table is also important because it shows variability over time, emphasizing the importance of long-term data collection in terms of assessing durability of conservation measures.

Table 4.
Average Annual Water Savings (kgal) per Household for Sandy, West Jordan, and Salt Lake City Water Check Participants Over the Course of the Water Check Program
(Source: Waters et al. 2009)

	Water Service Area Savings in Kgal/year/household		
Year	**Sandy**	**West Jordan**	**Salt Lake City (based on available data)**
2002	78.72	40.40	60
2003	32.49	5.63	27
2004	22.40	6.45	33
2005	2.23	-20.14	-
2006	-11.76	-17.63	-
Average Annual Savings per Household (kgal) (excluding Salt Lake City)	**13.88****		

Waters et al. (2009) provided these broad-scale observations:

- To date, 6,325 residential Water Checks have been completed along with 286 large Water Checks.
- The main techniques by which Water Check Program effectiveness has been evaluated is the comparison of water use and billing data from Program participants to matched control groups and also to the participants themselves over time.
- When averaged over all post water check years per household, Salt Lake City Program participants conserved the most (40,000 gallons/year in years with available data), West Jordan the least, (3,000 gallons/year to date), and Sandy at an intermediate level (25,000 gallons/year to date).
- Analysis of individual household patterns of water use showed that 60-70% of Program participants had a high capacity to conserve, and most of them reduced their water use as a result of program participation.
- The increased water use observed statewide in 2006 (and 2007) may indicate that desensitization to the conservation message of the Slow the Flow program occurred during those years. However, the climatic conditions of 2007—the hottest summer on record—should have led to an increased, not decreased, conservation response by Utahns. The decreased water use observed statewide in 2008 may indicate that Utahns response to conservation as a result of climatic conditions shows a predictable delay. With further observation of statewide trends and the water savings of Water Check participants, these responses may be quantifiably determined.

- To date, large water check participants within the Jordan Valley Water Conservancy District's retail service area (n=7) have shown approximately 5 million gallons of savings over the baseline year. This represents an average of 16,500 gallons of water saved per acre audited.

- Large water check participants within West Jordan City's retail service area (n=28) have shown an approximate savings of over 31 million gallons of savings over their respective baseline years. This represents an average of 319,000 gallons of water saved per acre audited.

Soils

Proper soil preparation and amendment is the top issue cited by turfgrowers as a reason for poor turf establishment and shallow rooting. Multiple cities across the Front Range have also recognized this and are now requiring soil amendment at new turf installations. The only control and test case study related to soil preparation identified during this literature review was conducted by Mecham and Boyd (2004) at nine model homes in Loveland. The study concurrently evaluated performance of two different types of ET controllers. Additional studies are believed to exist in the horticultural literature, but were not obtained during the course of this review. One related study by Johnson et al. (2006) showed that topdressing turf with compost extended the number of days between watering.

Plant Selection

From the scientific side of water conservation, it is important to have an understanding of how much water plants require. A reasonable base of scientific information regarding expected plant water requirements is available through the X-rated Gardening program, the 2004 GreenCO/Colorado State University (CSU) Crop Coefficient Survey (Kc) Survey and an ongoing CSU shrub water requirement study. Multiple CSU professors such as Dr. Jim Klett and others continue research in this area. Dr. Tony Koski has conducted significant research on water requirements and selection considerations for numerous turfgrass varieties. The research should be used as a scientific basis to separate plant requirements from behavioral water application practices.

Actual water savings are dependent on education regarding water needs, irrigation scheduling, etc. Unless plant choice is combined with good cultivation practices, water savings will be less than potentially achievable. A lesson from nursery professionals during the development of the GreenCO BMP Manual is that the most common reason that failing plants are returned to nurseries is overwatering. This is important in the context of turf replacement programs, where replacement of turf with other plants may or may not result in significantly reduced water application.

Turf Management

Good Colorado-based turf-related scientific data are available from the Colorado Turf Research directed by Tony Koski. Table 5 provides a summary prepared by Barta et al. (2004) that

integrates data from Koski (2004) and Denver Water's experience (Gardner 2004). See the "General Turf Management References" on the Colorado Turf Research program website for over 175 sources related to turf and golf courses. Using this research, water budgets for turf are relatively straightforward to develop, with many tools available such as the Turf Irrigation Management System (TIMS) program at Northern Water Conservancy District.

Table 5.
Water Needs for a Variety of Landscape Conditions
(as summarized by Barta et al. 2004)

Landscape Type/Condition	Annual Water Need [inches]
Koski (2004) Recommendation	
Adequate for healthy bluegrass	24
Maintenance level for healthy bluegrass	18
Denver Water Experience (Gardner 2004)	
Recommended amount for healthy bluegrass	29
Single Family Residential (SFR) average	35
Average for SFR with clock-controlled sprinkler	39
Average for SFR with manual watering (hose)	32

In the literature review by Barta et al. (2004), the following observations regarding turf water requirements are noteworthy:

- "Cool season grasses do require more water than many common landscape plants, but it is not for this reason alone that landscapes constitute a majority of our urban water uses. Mismanagement and uninformed decisions about landscapes are as much a reason for high water use as is cool season turfgrass. There is often little consideration put into limiting turfgrass to practical turf areas, or those areas where lawns serve a functional or practical use. Instead society tends to place turfgrass throughout cities, even on medians and along roadways because it aesthetically appealing and is relatively inexpensive to install. In addition, very few people are informed about how much water turfgrass needs to maintain a healthy, green lawn." (p. 7)

- "A significant conservation issue associated with using water for turfgrass and landscapes is that they tend to be overwatered. Poor irrigation scheduling, or watering too often or for too long, is the primary source of water waste in landscapes. It has been suggested that the average landscape is overwatered by more than 10% to 50% (Reed, 2002; Ash, 2002; Kjelgren et al., 2002). A majority of overwatering occurs through the mismanagement of some of the more technically advanced irrigation systems." (p. 7)

Echoing these findings, Wright Water Engineers has compiled irrigation usage data at several locations along the Front Range. This work was completed as part of data collection efforts related to work for insurance companies for claims associated with building foundation

damage/wet basements. Overwatering at several homeowner's associations ranged from 220 to 275 percent of irrigation requirements based on an estimated water budget (Clary et al. 2004).

In addition to current research at the CSU Turfgrass Research Center, several Colorado Water Resources Research Institute studies from the late 1970s and early 1980's provide some historical context on conservation and urban lawn care. (These studies were not evaluated in Attachment 3, but can be downloaded from http://www.cwi.colostate.edu/publications.asp.) A few selected notes include:

- In "The Effect of Conservation Programs on the Quality of Urban Lawns," Winje and Flack (1986) conducted a study of 209 properties along the Front Range and found that good lawn quality can be achieved along with moderate water conservation and that conservation education leading to good maintenance habitats can actually lead to high quality lawns. The study findings were in contrast to their survey findings where water utilities and homeowners expressed concerns regarding brown lawns anticipated due to conservation. The study also showed that water is probably over-applied to lawns in most communities and that water conservation can be achieved when the public is informed that water conservation is in their best interest.

- In "Water Requirements for Urban Lawns in Colorado," Danielson et al. (1980) conducted studies in 1977 and 1978 regarding irrigation application rates to lawns in Fort Collins and Northglenn. The study found that irrigation application rates in Fort Collins were appreciably higher than in Northglenn, even though the lawn water requirements were higher in Northglenn. Total water application in Fort Collins was 135% of potential ET, whereas water application in Northglenn was about 80% of potential ET. The pricing in Fort Collins at that time was a flat rate system, whereas Northglenn charged for the amount of water delivered. The study also found that lawn quality ratings reflected the amount of water being applied to the lawn. Because lawn quality is not assessed based on yield (as are crops), the amount of water to be applied is more subjective in terms of achieving a desired aesthetic. As a result of the study, irrigation guidelines were developed to maintain a high, medium and low quality lawn for various cities in Colorado based on historic precipitation, temperature and solar radiation.

- In "Urban Lawn Irrigation and Management Practices for Water Savings with Minimum Effect on Lawn Quality," Danielson and Feldhake (1981) reported research findings from research conducted at CSU during 1979 and 1980. Lysimeters were used to measure the effect of various lawn management practices on maximum water use and the response of turf to limited irrigation levels. Maximum water use was influenced by these factors: mowing height, nitrogen fertility, shade level, grass species and soil properties. The study found that proper management can minimize the loss of quality in turfgrass. The study also noted the ability of bluegrass to go dormant during drought and that regular periods of mild water stress help promote soil aeration and growth of a vigorous root system, increased drought tolerance and water conservation without greatly reducing quality. The study also presents some perspectives on the values of lawns in urban areas.

SWSI II (CDM 2007) places significant emphasis on turf replacement as a landscape water conservation measure (40% of overall conservation savings); however, proper management of turf (e.g., irrigation scheduling, water budgeting) is not included. Reduction of overwatering of turf and proper soil preparation prior to turf installation may also provide measurable conservation benefits, particularly in existing developments. Additionally, the long-term irrigation practices associated with non-turf replacements are not clearly defined. During the development of the GreenCO BMP manual, nursery professionals noted that the most common reason for return of failing plants to nurseries is overwatering.

Water Budgeting

Although this literature review has not focused on price-related aspects of landscape water conservation, the concept of developing a landscape water budget (and following it) is closely tied to tiered rate structures based on water budgets. The Irvine Ranch Water District model is likely the most well known of these approaches. Within Colorado, the City of Boulder and Centennial Water and Sanitation District are two utilities to continue following with regard to the effectiveness of water budget-based rate structures. In support of this literature review, Centennial Water and Sanitation District (Klassen 2009) provided a summary of findings related to implementation of a water budget based rated structure. A few highlights include:

- For the purpose of estimating water savings due to the implementation of the water budget rate structure, the District uses 2001 as a benchmark. It is estimated that the water budget rate structure has helped achieve a 21 percent savings compared to projected demand numbers prior to implementation.

- Approximately 75 percent of residential and multi-family customers are at or under water budget annually. Water use as a percentage of water budget is typically around 85 to 90 percent. Residential water use has decreased from 126 gpcd in 2001 to 102 gpcd in 2007.

- Non-residential irrigation customer water use is typically over water budget. Water use as a percentage of water budget for this customer class is around 110 percent. Centennial will continue to focus additional efforts towards this customer group to help reduce their water usage.

See Klein et al (2007) for more detailed exploration of water budgeting in the context of water rate structures.

Education/Outreach

Quantifying the benefits of education/outreach is challenging. The Seattle 1% Annual Conservation report provides some insight into possible approaches (Seattle Public Utilities 2009). Of particular interest to the Green Industry is the partnering that Seattle Public Utilities has done with regard to contractor training and offering programs in Spanish. This may provide a model for CWCB to encourage, working with GreenCO, ProGreen and other Green Industry programs already established in Colorado. The Town of Castle Rock and the City of Boulder

both have implemented landscape-training education programs. It would be instructive to obtain an assessment of the expected benefits achieved by these local efforts.

A key finding of several of the National Xeriscape Demonstration Project (NXDP) studies was the challenge of getting people to participate in programs. Recent literature regarding conservation and social marketing Silva (2008) and studies documenting property owner perception of Xeriscape such as the NXDP studies, studies by Atwood et al. (2008) reporting residential assessments of outdoor conservation program, and others may useful in identifying social and behavioral parameters to track when evaluating potential effectiveness of water conservation programs. Hanak (2007) and Gleick et al. (2003) note that there may be considerable educational, political, and social barriers to achieving conservation savings, even when the savings should be achievable from a scientific/technology perspective.

Monitoring and Evaluation

While monitoring and evaluation are not specifically identified as a landscape BMP (i.e., a physical practice applied to the landscape), these activities are fundamental to developing the state of the science regarding water conservation practices throughout the U.S. and in Colorado. A handful of monitoring and reporting requirements associated with conservation programs in western and southwestern states were briefly reviewed, including Texas (TWDB 2009), Arizona (2009), New Mexico and others. Although covered entities in Colorado with Water Conservation Plans are also required to monitor and evaluate progress, the guidelines and requirements are general. A more systematic review of monitoring and reporting requirements in other states would be helpful as part of a follow-up to this literature review.

As an example of requirements in other states, Texas Water Development Board requires entities receiving financial assistance of more than $500,000 to implement a water conservation program for the life of the loan and report annually on the progress of program implementation. This reporting includes estimated savings associated with conservation measures. TWDB provides a standard reporting format to assist in this effort, although the landscaping reporting component is brief and narrative.

Arizona also has a standard form for reporting conservation efforts. In Arizona, "A Summary of Water Conservation Programs in Active Management Areas" (ADWR 2007) provides a publically accessible summary of conservation and educational measures, ordinances, etc., in place in these Active Management Areas.

Of particular interest, in Oregon, the "Statewide Conservation Inventory, Oregon Water Supply and Conservation Initiative" (HDR 2008) is conducting a conservation inventory for these purposes:

- Help the State better understand the nature and magnitude of conservation opportunities and how they might serve as solutions to supply shortfalls by reducing out of stream demands.

- Provide a data source for the state to use when identifying and prioritizing projects for possible state funding.

Based on a survey of utilities in Oregon, an inventory of parameters useful in data reporting on conservation measures has been developed to promote transfer of knowledge. A spreadsheet of conservation projects has also been developed. (Although this may have some similarities to the "Identified Projects and Processes" database already underway for CWCB, the Oregon database is more oriented to documenting study variables/data.)

The need for systematically collected landscape water conservation data in Colorado has been a common recommendation for over a decade, recurring in several key Colorado reports, including these representative findings by Colorado researchers:

- Michelson et al. (1998) stated: "A significant finding of this study is the overall lack of information available regarding the implementation of non-price conservation programs and the lack of detail and consistency of water use information necessary to evaluate changes in demand. With improved information, combinations of programs, proven to be successful in reducing water-use levels in one city, could be applied to cities with similar characteristics …"

- Heaney et al. (1998) further recommended, "A concerted effort is needed to devise more effective ways to reduce outdoor water use in urban areas. Intensive monitoring is needed to evaluate how irrigation water is actually used in urban areas."

- Barta (2004) echoed the same finding: "…in general, there is not sufficient peer-reviewed literature to scientifically evaluate the effectiveness of urban landscape water conservation strategies. While there have been studies of basic urban water conservation principles, applications of water conservation practices by municipalities are highly site-specific, are often inconclusive due to confounding factors, and a lack of strong backing of scientifically defensible information."

- Waskom (2008) states, "The question is not whether water conservation is achievable or desirable, but whether it can be a viable, long-term substitute for new water storage projects or agricultural transfer."

In summary, monitoring and reporting guidance from other states should be reviewed in more detail for potential application in Colorado. Guidance provided by CWCB could help facilitate standardized reporting of conservation measures. Additionally, studies conducted and water demand models developed previously by Michelson et al. (1998), Heaney et al. (1998), Kenney et al. (2008), and other studies (Colorado-based, whenever available) should be considered in developing such guidance and identifying parameters that should be reported in water conservation studies and assessments. With input from water utilities, it is possible that some standard reporting guidelines that are not overly burdensome could be helpful to providing a common base of knowledge for use by water providers throughout the state. This appears to be needed, in part, due to the difficulty experienced in trying to obtain this type of data from Colorado water providers (even those who are actively engaged in and committed to meaningful conservation).

Use of Data in Projecting Water Conservation Savings

In order to develop and apply estimates in longer term planning, several factors need to be taken into consideration:

- **Quality, scope and location of the study.** Studies based on statistically valid sample sizes and study designs should be given preference, as would Colorado-based studies. Other estimates of water savings may be useful as general benchmarks or "reality checks." An example would be the U.S. EPA benchmarks included in EPA (1998). Presumably, these estimates have an underlying data source, but there is not enough information to translate how applicable those benchmarks are for a particular utility. Additionally, as noted by Heaney et al. (1998) and many others, irrigation water use varies widely across the United States from little use to being the dominant use.

- **Demographics/User Profile**. Multiple studies have shown that expected savings are contingent on "the starting point." As an example, Kenney et al (2009) found that comparison of data during pre-drought and drought conditions varied according to general water user type. High water users saved roughly 15%, mid-level water users saved 5-7% and low water users saved 1-2%. In order to apply savings data, it is important to understand the demographic base of the literature (e.g., were the participants randomly selected or targeted at high water users?) This phenomenon is one of the reasons that weather-based irrigation controllers show increased water usage in some cases: if the property owner was already a low-water user or under-irrigator, there is not much room for savings (Mayer et al. 2009). Similarly, Heaney et al. (1998) and CDM (2007) noted the relationship between housing density and irrigable area per capita. In the late 1990s, lower density housing was the trend, but more recent trends associated with Green Building programs such as LEED are promoting densification and redevelopment within cities. Additionally, people vary in how they use water outdoors, whereas indoor water use is more constant.

- **Performance Benchmarks**. The studies reviewed assess the performance of the BMPs using three basic approaches, affecting transferability of findings:

    - Volume Saved
    - Percent Savings
    - Percent (or Volume) Above or Below Water Budget

    In order to use these varied performance measures to develop estimates in Colorado, results would need to be standardized according to a single metric or set of metrics. From a technical perspective, the most meaningful is calculation of volume of water per landscaped area compared to a target water budget. (This was the approach used by Mecham and Boyd 2004.) Nonetheless, percent savings is the most common value reported in the literature. These are some significant data transferability issues with percent savings because it begs the question: "percent of what?" For example,

implementation of a weather-based irrigation controller on a property that already applies minimal irrigation will show a low percent savings, whereas installation of the same controller on a property originally over-irrigating will show a high percent savings. The more meaningful measure would be percent of properties meeting a water budget. In terms of CWCB's desire to forecast percent savings attributable to landscape water conservation, it may be more desirable to estimate the current landscape water budget and compare it to a target landscape water budget. As examples, Denver Parks and Recreation has used 30 inches as a comparison benchmark, and the Water-Efficient Landscape Design Model Ordinance (Department Office of Smart Growth of the Colorado Department of Local Affairs 2004) recommends 15 gallons per square foot.

- **Market Penetration**. Closely related to the demographic information described above, the reasonably attainable market penetration for conservation practices is a challenging variable to define, particularly at a statewide level. Relatively little information on market penetration estimates was discussed in the literature reviewed, although some case studies provide numbers of participants in various programs. Other arid/semi-arid states may also have better developed market penetration information that could be pursued.

Lessons from Other Water Resources Disciplines

During the course of the literature review, several parallels between indoor/outdoor water use and the wastewater/stormwater disciplines emerged that may be worth further consideration in terms of next steps in quantifying or refining estimates of the potential savings associated with landscape water conservation. These are discussed briefly below.

Indoor/Outdoor Parallels to Wastewater/Stormwater: Development of a Stormwater BMP Database

Evaluation of outdoor water conservation potential is unquestionably more complex than indoor conservation, in part because it is not a matter of simply replacing old technology with new technology mandated under plumbing codes. Effective outdoor water conservation requires on-going maintenance and continual adjustment to variables. To some extent, these challenges have parallels in the water quality arena where installation of treatment technologies in wastewater treatment plants is much more controllable than performance of best management practices for stormwater treatment. In the stormwater arena, a significant problem has been reporting of pollutant removal efficiencies using differing assumptions and inadequate documentation of variables. As a result, a national stormwater BMP performance database (www.bmpdatabase.org) was established to provide standardized guidance on 1) parameters to report to evaluate BMP performance, 2) a standardized database where studies could be submitted for use by the broader technical community and 3) development of standardized performance analysis protocols, using statistically valid techniques. Development of a similar approach in the landscape conservation arena could be beneficial to Colorado in moving from a "fruit basket" of studies to a more standardized accounting of variables.

Use of GIS to Effectively Integrate Local Government Data for Planning Purposes

GIS appears to be an underutilized tool with regard to landscape water conservation planning. Although some communities such as Boulder and Centennial Water and Sanitation District have used GIS to develop customer-specific water budgets, there appears to be opportunity for broader, general planning application, as well. Utilities are increasingly using GIS to map and plan for system infrastructure, but more opportunity is believed to be present in terms of conservation planning and subsequent tracking of the effectiveness of conservation measures. As an example, in stormwater drainage planning, a common first step is to combine aerial photography (up-to-date coverage is available for the metro-Denver area) with tax assessor database records to generate impervious area coverage estimates based on zoning data. This information is then used as a key component in modeling existing and future runoff conditions to size drainage improvements. Additionally, in some areas, the impervious component of the landscape has already been calculated or estimated in support of stormwater utility fees. Whereas drainage planning focuses on impervious area, the reverse would be true for landscape water conservation planning. This type of land use information could be combined in conjunction with water billing records (subtracting estimating annual indoor use from winter billings) to target areas most likely to be sources of landscape water waste, using some basic water budgeting benchmarks. Once this information is known, more reasonable estimates of water conservation potential could be developed in a targeted manner that moves beyond "who has the largest water bill." Socioeconomic factors identified in the literature could be linked to surrogates such as home age and square footage and lot size. Using GIS in combination with basin round tables, it could be possible to develop an approach to refine estimates at a statewide level, although it is recognize that this would be a substantial undertaking at a statewide scale. A pilot project could be useful in determining whether a GIS-based approach could be effectively extrapolated to a larger statewide scale.

Conclusions and Recommendations

1. A wide range of literature confirms that landscape water conservation can play a meaningful role in demand management to stretch limited water supplies. Specific practices documented with an initial base of information include: Xeriscape, irrigation audits, and irrigation technology. Much more information is currently available in several other states than in Colorado. The tabulated information in Attachment 2, although imperfect, provides an additional resource for utilities developing conservation estimates for planning purposes. Statewide water supply planning efforts would be well-served to continue sponsoring and promoting studies within Colorado. Locally based studies are important due to both climate and social values influencing behavior.

2. A limitation of the compilation of data in this literature review is that it requires further processing to normalize the data in a manner that can be applied to utility or statewide landscape conservation projections. An important follow-up step to make the most use of this literature review would be to review site-specific studies reporting landscape savings in more detail, according to an established set of minimum reporting parameters that would enable some normalization of the data. More refined estimates of water conservation savings could potentially be developed from this process. It is clear from the available literature that expected savings would vary according to the distribution of users with existing high, moderate and low water usage categories within a service area.

3. Many of the literature sources reported cost data in terms of water savings, cost of implementation and return on investment. This information is informally noted on the reporting forms in Attachment 3 of this literature review. Further compilation and processing of this information is needed for it to be effectively used.

4. Information developed in other states in terms of volumes or percent savings is less transferable than their general conclusions confirming that water savings occurred when certain practices were implemented. For example, percent savings associated with replacing turf with desert landscaping, as is done in Arizona, Nevada and other arid states, are not directly transferable to the Front Range of Colorado, where landscaping associated with a plains ecosystem is more consistent with the natural environment. On the other hand, more arid portions of Colorado may be able to draw more directly upon experiences in such states. Rainfall, temperature and other climatological data could be further examined to normalize data from other arid and semi-arid locations. On a related note, significant climatic differences within Colorado reinforce the importance of the basin roundtable approach to statewide water supply planning (e.g., Denver has nearly twice the annual precipitation of Grand Junction and Alamosa; therefore, a one-size fits-all approach with regard to expected landscape water conservation is unlikely).

5. Estimating the magnitude of water savings through landscape conservation/efficiency measures is highly dependent on site-specific factors, some of which are physically based and others which are behaviorally based. Some literature exists documenting the relationship of both types of factors into predictive models to estimate water

conservation. Additional research is needed in these areas. This relates directly to the SWSI II debate regarding extent of penetration of conservation measures.

6. Development of a standard set of reporting and performance assessment protocols for landscape water conservation studies would enable collection of more meaningful data useful at a statewide level. These reporting protocols may need to be developed at both the macro (utility-wide) and micro (site-specific) scales. These protocols could also be used for reporting associated with Water Conservation Plans submitted to CWCB by covered entities. If such protocols were developed and accepted, development of a landscape conservation practice database could be developed that would be extremely valuable to developing a more refined assessment of landscape BMP performance.

7. Additional exploration of water conservation data tracked by Colorado utilities is needed and is a significant limitation of this literature review. Although data relating rebate programs to water savings was pursued from several water providers, this information was not successfully obtained. For covered entities, it would be expected that this information would be available under measurement and verification tasks specified in Water Conservation Plans. It is unclear whether: 1) the information exists, but was not able to be provided within the short turn-around time of this project, 2) the information is being tracked, but water utilities are reluctant to release it due to billing privacy and other issues, or 3) the information is not being systematically tracked. This issue warrants further follow-up and discussion with the Colorado WaterWise Council members to develop a better understanding of these issues. Tracking this information should be "low-hanging fruit" in terms of assessing effectiveness of water conservation efforts in Colorado. Additional efforts to assess the type and extent of data potentially attainable from Colorado utilities could be accomplished by additional follow-up interviews and possibly through review and assessment of the approved Water Conservation Plans.

8. Opportunities to fund studies of landscape water conservation practices should continue to be pursued in Colorado. Criteria for study designs should be developed to enable transferability of data to other utilities. Example studies from this literature review serving as a starting place include: YardX (Medina and Gumper 2004), California WBIC (Mayer et al. 2009), Kenney et al. (2008), Mecham and Boyd (2004), etc.

9. With regard to monitoring and evaluation needs for specific landscape conservation BMPs, it would be beneficial to monitor the following practices, following experimental design principles leading to statistically meaningful results:

    - Continued monitoring of Xeriscape, particularly over the long-term. Follow-up with the YardX sites would be a logical starting point. (Sidenote: When the term Xeriscape is used, it is intended to reflect implementation of all seven principles, not simply "turf replacement.") There may be opportunity to conduct some neighborhood-based studies where similar demographics are present, but significant variation in landscape practices (e.g., Xeriscape retrofits) is present.

- Effectiveness of real-time water use technology that enhances customer knowledge and decision making related to water use. The Aurora Water Smart reader study is one such example. Other technologies such as Geosyntec's Ambient Water Beacon also exist. These types of studies may be particularly beneficial in developing a better understanding of the behavioral/social component of water conservation.

- Weather-based irrigation controllers in Colorado (e.g., a Colorado-based "WBIC" study).

- Test plots of turf under various soil preparation scenarios (if it is confirmed that such research has not already been completed at CSU).

- Overall irrigation system retrofit performance (e.g., more examples similar to those developed by Keesen and Denver Parks and Recreation). This goes beyond ET controllers, which alone cannot correct existing irrigation system deficiencies. A starting point would be to document case studies already existing within utilities.

- Effectiveness of landscape contractor education programs (e.g., Castle Rock model) and public education programs.

- Continued socioeconomic/behavioral research with regard to landscape conservation practices and values is important, since this information affects the durability of landscape conservation savings and market penetration estimates. Several of the existing literature sources provide initial insights that could be further processed and evaluated, as a starting point.

- Refinement of understanding of water usage patterns associated with varied irrigation approaches (e.g., hose, drip, automated) (recommended by Kenney et al. 2009).

10. Explore enhanced multi-disciplinary/interdepartmental dialogue to determine how landscape water conservation objectives may support other community goals related to sustainability, stormwater management and wastewater management. Although this is a somewhat vague recommendation, there appears to be untapped opportunity for better integration between multiple water disciplines. For example, communities pursuing Low Impact Development strategies or encouraging LEED certified developments may have synergistic opportunities providing multiple community benefits of reduced water use or water waste (runoff). For example, where preservation of natural areas/riparian buffers, preservation of undisturbed soils and mature trees, and use of bioretention (rain gardens) for stormwater management are objectives, these practices can positively reduce landscape irrigation requirements.

Recommended Near-term Actions

1. Convene an advisory committee comprised of utilities and Green Industry representatives to review and refine the findings of this initial literature review and prioritize areas in need of follow-up.

2. Further process the data collected in this initial literature review into a more standardized format, normalizing data, if possible. Concurrently, provide additional follow-up in several areas of the literature review: 1) available utility landscape water conservation data, 2) horticultural literature sources, particularly related to turf and soils, and 3) more in-depth review of conservation-related conference proceedings over the past decade. (*Although many studies were identified during the course of this literature review, more are known to be available, but excluded due to scope limitations.)*

3. Develop a set of standardized monitoring and reporting protocols for large-scale and site-specific landscape water conservation studies.

4. Assess interest in a statewide database to store conservation studies (following a standard format from #3 above). Such a database would need to be kept as simple as possible to encourage participation and use. It may also be worthwhile to discuss pursuing funding at a national scale from EPA and professional organizations, following a model similar to that used for stormwater BMPs.

5. Develop a pilot-scale GIS-based tool to better integrate landscape water conservation and land use/demographics. Potential benefits include targeting of rebate programs in areas of high water use, assessment of effectiveness of various conservation measures at the neighborhood scale and eventual development of a statewide model that could be useful for longer range planning.

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Attachment 1. GreenCO BMPs and Relationship to Water Conservation Planning

GreenCO BMP			CWCB Conservation Measures and Goals	Literature Review Priority
General Category	**GreenCO BMP Name**	**Brief BMP Description**	**Relation to Demand Side Measure or Program to Reduce Peak Seasonal Demand**	
Sustainability	Sustainable Landscaping	This BMP introduces basic sustainability and energy conservation concepts that Green Industry professionals can consider integrating into their professional practice.	Landscape Efficiency	Low
Xeriscape	Xeriscape	Implement the seven basic landscape principles of Xeriscape: planning and design, soil improvement, zoning of plants, practical turf areas, efficient irrigation, mulching and appropriate maintenance.	Landscape Efficiency Xeriscape ordinances, rebates/incentives; landscape standards	High
Water Budgeting	Water Budgeting	Calculate the water needs of irrigated landscapes based on plant types, land area and irrigation system efficiency. Use the calculated water budget to apply water according to the needs of the plants and manage irrigation.	Landscape Efficiency Water Budgets (also relates to Conservation Pricing)	High
Design	Landscape Design (including Plant Selection & Placement and Hardscapes)	Plan and design landscaping comprehensively to conserve water and protect water quality.	Landscape Efficiency Landscape Standards, Drought Resistant Vegetation, Xeriscape	Medium
Landscape Installation: General	Landscape Installation/Erosion and Sediment Control	Minimize erosion and control sediment leaving the construction site during landscape installation.	Landscape Efficiency	Low
Soils	Soil Amendment/Ground Preparation	Evaluate soil and improve, if necessary, to promote efficient water usage and healthy plants.	Landscape Efficiency Soil amendment ordinances and rebates/incentives	High
Trees	Tree Protection	Identify trees suitable for preservation and implement measures to protect these trees during construction activities.	Landscape Efficiency	Low
Trees	Tree Placement in Urban Landscapes	Trees must be placed in the urban landscape so that adequate soil and space for root growth are provided for the long-term growth and health of the tree.	Landscape Efficiency	Low
Trees	Tree Planting	Properly plant trees, shrubs and other woody plants to promote the long-term health of the tree.	Landscape Efficiency	Low
Irrigation	Irrigation Efficiency	Properly design, install and maintain irrigation systems to ensure uniform and efficient distribution of water, thereby conserving water and protecting water resources.	Landscape Efficiency/ Irrigation System Standards	High
Irrigation	Irrigation System Design	Design the irrigation system for the efficient and uniform distribution of water.	Landscape Efficiency/ Efficient Irrigation; Irrigation System Standards	High
Irrigation	Irrigation System Installation	Install the irrigation system according to the irrigation design specifications, which should be in accordance with manufacturer's specifications, local code requirements and sound principles of efficient and uniform water distribution.	Landscape Efficiency/ Efficient Irrigation; Irrigation System Standards	High
Irrigation	Irrigation System Maintenance	Maintain the irrigation system for optimum performance, ensuring efficient and uniform distribution of water. Modify the irrigation system as needed to provide supplemental water for maintaining healthy plants without wasting water.	Landscape Efficiency/ Efficient Irrigation; Irrigation System Standards; Water Waste Ordinance	High
Irrigation	Irrigation Efficiency Audits	Auditing existing irrigation systems to identify needed improvements is a key tool in reducing landscape water waste and improving irrigation efficiency.	Landscape Efficiency/ Efficient Irrigation; Irrigation Audits	High
Irrigation	Irrigation Technology and Scheduling	Irrigation systems can be equipped with a variety of water conserving devices such as soil moisture sensors, rain sensors and shutoff devices, weather stations, high wind shutoff devices, freeze protection devices, and advanced, automated, "Smart" control systems that incorporate evapotranspiration (ET) conditions. Because one of the key benefits of advanced irrigation technology with regard to controllers (clocks) is increased ease of scheduling and more precise scheduling, irrigation scheduling is also discussed as part of this BMP.	Landscape Efficiency/Irrigation Efficiency Measures (rebates/incentives for a variety of devices such as rainfall, soil moisture and ET sensors); alternative irrigation systems (e.g., subsurface drip)	High
Irrigation	Irrigation Using Nonpotable Sources	Nonpotable water may be used for irrigation purposes as a method to conserve potable or higher quality water sources for human consumption (drinking water).	Supply Side Measure: Source Substitution (Reuse)	Need to Discuss

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Maintenance: General	Landscape Maintenance	Practice landscape maintenance appropriate for the site including practices such as pruning, weeding, mulching, fertilization and attention to the irrigation system.	Landscape Efficiency	Need to Discuss
Maintenance: Trees	Tree and Other Woody Plant Care	Properly plant and maintain prune or trim trees, shrubs and other woody plants to maximize the plants' health.	Landscape Efficiency	Low
Maintenance: Herb. Plants	Herbaceous Plant Care	Properly plant and maintain herbaceous plants to maximize plant health and conserve water.	Landscape Efficiency	Low
Maintenance: Turf	Turf Management	Plan, properly install and maintain practical turf areas.	Landscape Efficiency Turf Rebates/Incentives*	High
Maintenance	Fertilizer Application	Properly apply fertilizers, based on the specific needs of plants, particularly as identified by appropriate soil or plant tissue tests.	Landscape Efficiency	Low
Maintenance	Pesticide and Herbicide Application	Apply pesticides and herbicides at minimal levels in accordance with the label and targeted to specific disease and weed problems.	Landscape Efficiency	Low
Maintenance	Pesticide, Fertilizer and Other Chemical Storage, Handling and Disposal	Pesticides, herbicides, fertilizers, fuel and other maintenance chemicals must be properly applied, stored, handled and disposed of to prevent contamination of surface water and groundwater.	**	N/A
Maintenance	Lawn Aeration	Aerate lawns to reduce thatch, thereby improving nutrient and water uptake, reducing runoff and reducing compaction.	Landscape Efficiency	Medium-High
Maintenance	Lawn Waste Disposal/Composting	Dispose of yard waste to minimize adverse impacts to the environment by keeping waste out of storm drains. Recycle and compost organic materials whenever possible.	**	Low-Medium
Maintenance	Mowing	Mow lawns to the proper height and at the proper frequency to maintain turfgrass health, thereby minimizing the need for pesticide and fertilizer application and reducing water usage.	Landscape Efficiency	Medium-High
Maintenance	Mulching	Use organic mulches to reduce water loss through evaporation, to reduce soil loss due to exposure to wind and runoff, to suppress weeds, and to provide a more uniform soil temperature.	Landscape Efficiency Rebates/Incentives	Medium-High
Maintenance	Drought and General Water Conservation Practices for Landscapes	Manage landscapes using the most water-efficient techniques during drought conditions.	Landscape Efficiency/Irrigation Efficiency	N/A (individual practices split out separately)
Snow	Snow Removal	Snow removal practices should be conducted in a manner that minimizes adverse impacts to vegetation, soils and water quality.	**	N/A
Production	Production Practices for Nurseries, Greenhouses, and Sod Growers	Nurseries, greenhouses and other growers should implement a variety of source, structural, cultural and managerial controls to minimize pollution of water resources. Irrigation practices that minimize off-site transport of pollutants also typically conserve water.	Industrial/Commercial Irrigation Efficiency Measures	Out of Scope
Production	Water Management Practices for Nurseries, Greenhouses, Sod Growers and Holding Yards	Manage production and holding areas to promote the efficient use of water..	Industrial/Commercial Irrigation Efficiency Measures	Out of Scope
Retail	Retail Practices for Nurseries, Greenhouses and Garden Centers	Retail businesses should operate in a manner to maintain the health of plants, to conserve water and to promote water conservation and water resource protection to the general public.	Industrial/Commercial Irrigation Efficiency Measures	Out of Scope
Large Landscapes	Park, Golf Course and Other Large Landscape Design and Management	Large landscaped areas such as parks and golf courses should be well designed and properly managed to be an environmental amenity and to minimize runoff to waterbodies.	Landscape Efficiency/ Irrigation Efficiency Measures	Need to Discuss

Attachment 1. GreenCO BMPs and Relationship to Water Conservation Planning

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Drainage	Landscape Features in Low Impact Development	Properly design, install and maintain landscape features serving stormwater runoff water quality treatment and volume reduction functions. Low Impact Development (LID) designs seek to approximate pre-development runoff hydrology by allowing storm runoff to infiltrate into the landscape rather than routing urban runoff directly into the storm sewer.	Landscape Efficiency (Alternative to Rainwater Harvesting)	Medium
Drainage	Revegetation of Drainageways	Establishment of a robust cover of vegetation is critical to the proper functioning of engineered drainage structures such as grass-lined channels, detention basins, retention ponds, and wetlands.	**	N/A
Drainage	Riparian Buffer Preservation	Preserve wide, undisturbed natural riparian areas along streams.	Landscape Efficiency Natural Landscaping	Low-Medium
Education	Employee Education	Educate industry employees on water quality and water conservation practices.	Education/Information	Medium-High
Education	Public Education	Model and teach water conservation and water pollution prevention to the general public and consumers of green industry products.	Education/Information	Medium-High
Education	Regulatory Awareness	A variety of local, state and federal environmental regulations impact landscaping and nursery operations. Green industry professional should be aware of these regulations and comply with their requirements.	**	N/A

Other Practices Not in GreenCO Manual
Cash for Grass

Attachment 2.
Initial Tabulation of Estimated or Measured Water Savings due to Landscape Water Conservation and Efficiency Practices

This tabulation provides estimated water savings associated with various landscape water conservation BMPs included in the 2009 WWE/GreenCO literature review conducted for CWCB. This tabulation should be viewed as a "big picture", interim summary to give a general sense of the types of information reported in the literature and variation in how conservation savings are reported. This information is intended to be useful in shaping subsequent efforts needed to better quantify landscape conservation practices.

Scope and timeline associated with the literature review limited follow-up on some of these studies, which could be reviewed in more detail and summarized in a more standardized manner in the future. Additionally, more information is known to exist for various water utilities in Colorado, but was not attainable within the timeline of the project. Similarly, additional horticultural research associated with turf, soils and plant selection is also believed to exist and should be integrated in the future.

Category: Xeriscape

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Denver Parks and Recreation. (2009). Martin Luther King Jr. Boulevard Post-Construction Analysis. Fact Sheet provided by Jill Wuertz. June. Denver, CO.	Denver	Xeriscape AND Irrigation Retrofit	The project converted original 1950s-60s turf medians into combinations of turf, planting areas, hardscape and irrigated mulched tree beds. Old irrigation systems completed replaced.	48% savings, comparing an average of 2001 and 2002 versus an average of 2007 and 2008. Results not adjusted for ET/rainfall variations.
Medina, Jonnie G., and Julia Gumper, 2004: YARDX: Yield And Reliability Demonstrated in Xeriscape: Final Report. Metro Water Conservation, Incorporated, Littleton, CO, 140 p. www.coloradowaterwise.org	Fort Collins-Loveland, Highlands Ranch, Arvada, East Larimer County, Denver, Colorado Springs, Wheat Ridge, Greeley	Xeriscape YARDX NXDP	The YARDX project is one of five field projects of Reclamation's National Xeriscape Demonstration Program (NXDP) established to study the benefits of installing Xeriscape under differing climatic and other potentially impacting conditions. Seven municipalities from Fort Collins, Colorado, to Colorado Springs, Colorado, participated in the study. YARDX was conducted from 1997 through 2002 Most design schemes included 25% low water plants, 25% moderate water use plants and 50% turf.	New Homes: 18 to >50% relative to control samples (with 30% range typically attainable for new homes with a long-term commitment to maintenance) Higher savings possible with a 1/3-1/3-1/3 design scheme. Retrofits: 28-32%. "Water savings appeared to vary with the amount of turf left in the lawn." The target of 50% savings was not reached. Older existing Xeriscapes (previously installed) in the study did not show water savings and more study regarding why this was the case was recommended. Ownership turnover was one hypothesis.
Stinnett, R. (2003). *Landscape Trends and Water Use in the Phoenix Metropolitan Area.* Available from the Bureau of Reclamation, Phoenix Area Office.	Phoenix, AZ	Xeriscape NXDP	This project was similar to a YARDX pre-existing Xeriscape landscape study conducted in Arvada/ Wheat Ridge neighborhoods, except for lack of an observation period. The Phoenix study involved selecting, acquiring, and evaluating landscape historical water use data.	53%
Sovocool, A.K, and J.L. Rosales. (2003). *A Five-Year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert*. Las Vegas, Nevada: Southern Nevada Water Authority.	Las Vegas, NV	Xeriscape NXDP	Las Vegas NXDP study.	39%
Gregg, T., Strub, D., & Gross, D. (2007). Water Efficiency in Austin, Texas, 1983-2005, An Historical Perspective. Journal AWWA, 99 (2), pp. 76-86.	Austin, TX	Xeriscape	This Journal AWWA article summarizes the successes of the Austin water conservation program over time. Cost data are provided. (Noted: This entry is copied into irrigation technology and irrigation audit tables with all of the landscape measures entered together for comparison.)	**1984 Xeriscape Ed. Program**: Peak Day Savings: 1 gpd/person; Savings through 2005: 4,676 gpd **1992 Irrigation Audits**: Peak Day Savings: 100 gpd/SF; Savings through 2005: 483,500 gpd **1994 Incentives for Waterwise plants**: Peak Day Savings: 100 gpd/property; Savings through 2005: 75,900 gpd **1994 Revised Commercial Landscape Ordinance**: Peak Day Savings: 100 gpd/property; Savings through 2005: 65,500 gpd **1987 Free Hose Timers**: Peak Day Savings: 5 gpd; Savings through 2005: 26,040 gpd
Medina, J., & Lee, A. (2006). *FX Project, Fargo Xeriscape Project, Final Report*. Bureau of Reclamation and City of Fargo.	Fargo, ND	Xeriscape NXDP	Reducing the amount of turf area has the highest impact on water usage per property, and when turf is limited to one-third to one-half of the landscape area, maximum results can be achieved.	31% (new starts) 10-50% (retrofits)
Nelson, John. (1994). "Water Saved by Single Family Xeriscapes." Preliminary Draft for AWWA National Conference. New York, June.	North Marin, CA	Xeriscape		25%
Testa, A., and A. Newton. (1993). "An Evaluation of a Landscape Rebate Program." AWWA Conserv'93 Proceedings. December.	Mesa, AZ	Xeriscape		33%
Galvin, K. (2008). Water Efficient Landscape Rebate Pilot Program. 2008 Sustainable Water Sources Conference. American Water Works Association. http://www.awwa.org/Resources/Waterwiser.cfm?ItemNumber=42265&navItemNumber=43381.	Santa Clara Valley, CA	Xeriscape	"Water Efficient Landscape Rebate Program" (WELRP). Essentially a turf removal project with requirements for project size, replacement plant list, irrigation system retrofit, mulch and 5-year requirements.	Only participant perception of reduced water use reported in presentation
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	Austin, TX Marin, CA	Xeriscape	"Studies of residential properties that have been partially or fully converted to water-wise landscape have for several years reported actual water savings of 20-50%, but savings can be even higher." (p. 162)	20-50%

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	Xeriscape "studies"	Xeriscape	"Studies have shown that implementing water-wise or Xeriscape landscaping practices can achieve at least a 50% reduction in water use compared with conventional landscaping practices."	50%
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	Phoenix, Arizona	Xeriscape	"A field study of 18 residential properties in Phoenix found that homeowners with Xeriscapes used 30% more water than those with conventional landscapes; all the properties had automatic irrigation systems. 'This is a behavioral issue, not a plant issue'…" (p. 162)	+30% (increase in water use)
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	Austin, Texas	Xeriscape	Residential xeriscapes on lots smaller than 9,000 square feet used an average of 43% less water than conventional landscapes according to a water–use study of more than 6,000 single-family residential landscapes by Austin's Environmental and Conservation Services Department. Specific findings: 1. Drought-tolerant turfgrass used 31% less water than traditional turf species 2. High income properties used significantly more water than low- and middle-income properties. (p. 162)	43%
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	East Bay Municipal Utility District, California	Xeriscape	A study of more than 1,000 single family homes found those with water-conserving landscapes used 42% less water than those with traditional landscaping at homes with turf comprising 70% or more of front yard. Amount of water saved increase proportionally with lot size. (p. 162)	42%
City of Henderson, Nevada. (2008). *Turf Removal Loan Program.* http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.	Henderson, Nevada	Xeriscape	The Southern Nevada Water Authority (SNWA) has a Water Smart Landscape Rebate Program	50-70 gallons per square foot of turf converted
Sovocool, K. A. (2005). *Xeriscape Conversion Study, Final Report* . http://www.snwa.com/assets/pdf/xeri_study_final.pdf.	Las Vegas Valley Water District, Henderson, North Las Vegas, and Boulder City	Xeriscape	Southern Nevada Water Authority conducted a study that involved recruiting hundreds of participants into treatment groups (a Xeric Study and a Turf Study Group and control groups), as well as the installation of submeters to collect per unit area application data.	Results show a 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.
Western Resource Advocates. (2008). Smart Savings Water Conservation: Measures That Make Cents.	Las Vegas, Nevada (builds upon Sovocool 2005)	Xeriscape	The Southern Nevada Water Authority's Water Smart Landscapes rebate program is designed to promote the conversion of seldom-used lawn areas into climate-appropriate, drought-tolerant landscaping.	The landscape conversion rebate program has cumulatively saved 18 billion gallons (55,327 acre-feet) of water from 2000 through the end of November 2007. This savings equates to an average of 199,008 gallons (0.61 acre-feet) saved per rebate participant per year. Each square foot of lawn replaced saves roughly 55.8 gallons annually.
Environmental Protection Agency. *Water-Efficient Landscaping: Preventing Pollution and Using Resources Wisely.* http://www.epa.gov/WaterSense/docs/water-efficient_landscaping_508.pdf.	Las Vegas, Nevada (builds upon Sovocool 2005)	Xeriscape	Local officials plan to reach the target with the assistance of incentive programs encouraging Xeriscape, a city ordinance limiting turf to no more than 50 percent of new landscapes, grassroots information programs, and a landscape awards program specifically for Xeriscaped properties.	Preliminary results of a five-year study show that residents who converted a portion of their lawns to Xeriscape reduced total water consumption by an average of 33 percent.

Category: Irrigation Technology

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
City of Boulder. (1998). *Soil Moisture Sensors: Are They a Neglected Tool, The Experience in Boulder, CO.* http://www.irrometer.com/pdf/smp98.pdf.	Boulder, Colorado	Soil Moisture Sensors	The City of Boulder, CO began studying Soil Moisture Sensors as a method of conserving outdoor use water in 1992. At considerable expense, the Office of Water Conservation and Department of Public Works installed and monitored over 50 Watermark Soil Moisture Sensors and Electronic Modules on existing irrigation systems throughout the City. These were installed on private homes, association common areas, and public street medians and parks.	This study has shown that even after five years in the field the sensors continue to successfully match irrigation applications to requirements with the seasonal applications during 1997 ranging from 52% to 124% of the theoretical, and the average application equaling 76% of the theoretical requirement.
Aquacraft, Inc.. (2003). *Report on Performance of ET Based Irrigation Controller.*	Boulder, Longmont, and Greeley, Colorado	WeatherTRAK ET signal controller	In the Spring of 2000, the cities of Boulder, Longmont, and Greeley, Colorado began a small pilot study of the reliability and effectiveness of the WeatherTRAK ET signal controller. The purpose of this study was to document the performance of the system in actual field conditions at homes of volunteer customers.	As a group, the seven sites saved an average of 35,000 gal of water per site compared to their historical use.
AquaCraft. (2002). *Performance Evaluation of WeatherTRAK Irrigation Controllers in Colorado.* http://www.weathertrak.com/pdfs/studies/Aquacraft_Colorado_WeatherTRAK_Field_Study_Year_1.pdf.	Boulder, Longmont, and Greeley, Colorado	WeatherTRAK Irrigation Controllers	A total of 10 sites were selected for the study from a combination of volunteers and high water using accounts. The actual irrigation applications of each system were tracked against the theoretical requirements for the 2001 season.	As a group, the ten sites saved an average of 26,000 gal of water per site compared to their historical use
Keesen, L. (2009). Next Steps After an Audit Are Implementing Changes for Less Water Use and Long Term Sustainability. Keesen Water Management.	East Cherry Creek Valley Water and Sanitation District, CO	Irrigation Audits with Retrofit	The ECCV Water District sponsored Greenfield/Liverpool Irrigation System Evaluations and Pilot Program. New spray heads were installed with 4-inch pop-up height, check valves and pressure control. New nozzles were installed to better control the spray. Check valves were installed in rotors. Rain and freeze sensors were installed on controllers.	Greenfield 2001 usage went down from 61.7 to 50.1 inches, three year savings of 2.7 million gallons or 8 acre-feet. Liverpool 2000 usage went down from 63.0 to 30.0 inches, four year savings of 4.5 million gallons or 14 acre-feet.
Keesen, L. (2009). Next Steps After an Audit are Implementing Changes For Less Water Use and Long Term Sustainability.	The Meadows Metropolitan District, Castle Rock, Colorado	Irrigation Audits with Retrofit	In 1994, Keesen Water Management, Inc. performed an irrigation system evaluation for The Meadow Metropolitan District 37-acre streetscape. In 1997 the irrigation system was renovated with conservation design and equipment.	Annual Savings: 25,449,000 gallons; 78 acre-feet; 28-inches; $51,407.00
Colorado Springs Utilities. (n.d.). Residential Irrigation Equipment Rebates. Retrieved June 15, 2009, from Colorado Springs Utilities: http://www.csu.org/residential/greenback/rebates/irrigation/item1117.html	Colorado Springs, CO	Various Irrigation Efficiency Measures	Estimated savings reported on website along with rebate information.	Weather-based irrigation controllers: …can reduce irrigation water usage by an average of 16%" Elsewhere, "Studies suggest irrigation savings of about 20 percent or more can be expected. Actual savings is dependent of previous watering habits and weather, but a reasonable range is 10 to 30 percent. It can also reduce runoff by more than 50 percent." Rain Shutoff Device: Savings is dependent on the frequency and volume of rainfall and watering, but a reasonable range in Colorado Springs is 5 to 10 percent of irrigation use. Sprinkler heads with check valves: Savings is dependent on a number of factors including the number of cycles run, but 5 to 10 percent of irrigation use is conservative. Matched precipitation nozzles: Savings is dependent on a number of factors, but research suggests that 10 to 20 percent is possible.
Keesen, L. (2004). The Economics of Water Conservation: Irrigation Technologies. *Water Wise* , Volume 10, Number 4, Page 9.	East Cherry Creek Valley Water District, Colorado	ET controllers, rain sensors, and soil moisture sensors	ET controllers were installed at 23 homes, rainfall sensors were installed at 28 homes, and soil moisture sensors were installed at 32 homes.	**ET Controllers:** **2001**: 1,081 total million gallons saved; **2002**: 760 total million gallons saved **Rain Sensors:** **2001**: 1,391 total million gallons saved; **2002**: 810 total million gallons saved **Soil Moisture Sensors:** **2001**: 1,606 total million gallons saved; **2002**: 837 total million gallons saved
Mecham, B., & Boyd, R. (2004). *Case Study: Landscape Irrigation Efficiency of Nine Model Homes.* Loveland: Northern Colorado Water Conservancy District.	Loveland, Colorado	Irrigation Technology AND Soil Preparation	Nine single-family model homes in an entry-level housing development were selected for a study to determine if changes in landscape maintenance would produce information on how to better manage lawn watering.	**4148 Florence**: Standard drip irrigation, soil prep of 3 cy/1000 sf & tillage, standard controller: Excess Water Use = 19% **4232 Florence:** Sprinkler system, no soil prep, Water Watcher soil moisture sensor: Excess Water Use = 41% **4225 Florence:** Sprinkler system, soil prep, Aqua Conserve ET Controller: Excess Water Use = 47% **4208 Florence:** Sprinkler system, no soil prep, Weather Reach ET Controller: Excess Water Use = 56% **4203 Florence: 4232 Florence:** Sprinkler system, no soil prep, Water Watcher soil moisture sensor: Excess Water Use = 41% **4196 Florence:** Sprinkler system, no soil prep, Aqua Conserve ET Controller: Excess Water Use = 96% **4189 Florence:** Sprinkler system, soil prep, standard controller: Excess Water Use = 47% **4180 Florence:** Standard drip irrigation, soil prep, Water Watcher soil moisture sensor: Excess Water Use = 33% **4164 Florence:** Standard drip irrigation, soil prep of 3 cy/1000 sf & tillage, Weather Reach ET Controller: Excess Water Use = 11%

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Rain Bird . (2003). *Irrigation for a Growing World.* http://www.rainbird.com/pdf/iuow/iuow_whitepapers.pdf.	Bakersfield, CA	Central control system, weather station, ET sensors, and other technologies	"The City of Bakersfield, CA, Parks Division upgraded its outdated, manually operated electromechanical controllers and replaced them with a sophisticated central control system, weather station, ET sensors and other technologies to irrigated the parks and street landscapes at the south end of the city."	"When compared against the older system still in use in other parts of the city, the upgraded irrigation system saved more than 10 million gallons in one year."
Zoldoske, D. F. (2003). Improving Golf Course Irrigation Uniformity: A California Case Study. Center for Irrigation Technology, California State University, Fresno. California Agricultural Technology Institute. http://cati.csufresno.edu/cit/Golf%20Course%20Irrigation%20Nozzle%20Study.pdf	CA: Los Angeles, Rancho Santa Fe, San Gabriel, Fairfax, La Jolla	Irrigation Nozzle Retrofits on Golf Courses	Five golf courses in California participated in this study during 1998-2002, including a total of 606 irrigated acres representing 108 holes of golf (six-18 hole courses). The time span of data collection was one year prior to the nozzle change and one year of operation post nozzle change.	Average of 6.5% of applied water The estimated total gross water savings for all the participants was 99.8 acre feet of water (32,519,304 gallons) or 6.5% of the applied water. Individual golf course gross water savings ranged from positive 21.4% to -11.3%. Adjusting for useful rainfall, the estimated savings falls to 82.9 acre feet (27,012,799 gallons) or 5.7% of the applied water. Individual golf course-adjusted water savings ranged from a positive 14.7% to -3.1%. Assuming the actual savings is somewhere in between, the total savings experienced may be nearer 91.4 acre feet (29,782,507 gallons) and an average savings of 6.1% per golf course of the applied water.
Mayer, P., Hayden, M., Davis, R., Caldwell, E., Miller, T., & Bickel, P. (2009). Evaluation of California Weather-based "Smart" Irrigation Controller Programs. Presented to the California Department of Water Resources by the Metropolitan Water District of South California and the East Bay Municipal District. California Urban Water Conservation Council. http://www.aquacraft.com/Download_Reports/Evaluation_of_California_Smart_Controller_Programs_-_Final_Report.pdf	California	Weather-Based Irrigation Controllers	This report presents an evaluation of the California Weather-Based Irrigation Controller (WBIC) programs. This project presents empirical data on the performance of smart controller products distributed and installed through different methodologies in a wide variety of settings. Data provided for 2,294 sites encompassing 3,112 smart controllers. Fourteen different brands of controller were included. Participants installed about 60%, with about 40% of the sites installed by a professional. This is a robust study; see report for details.	Overall, outdoor water use was reduced by an average of 47.3 kgal per site (**-6.1%** of average outdoor use) across the 2,294 sites. --1,300 (56.7%) of the 2,294 study sites had a statistically significant reduction in weather-normalized irrigation application ratio --959 (41.8%) sites had a statistically significant increase in application ratio. --35 (1.5%) of sites, there was not a statistically significant change in application. Factors determined to have a statistically significant impact on the change in application ratio: • Pre-smart controller Application Ratio – the application rate relative to the calculated theoretical irrigation requirement • Installation method (self vs. professional) • Participating agency (sometimes significant) Difference in performance of controller brands was also evaluated and reported.
State of California Department of Water Resources. (2008). *Urban Drought Guidebook.*	California	Irrigation System Design	State of California Department of Water Resources *Urban Drought Guidebook* provides various landscape irrigation tips and the estimated savings.	- Water only before 6 a.m. and after 8 p.m. to reduce evaporation and interference from wind: **20-25 gallons per day** **-**Reduce each irrigation cycle by 1-3 minutes, or eliminate one irrigation cycle per week: **15-25 gallons for each minute; up to 250 gallons per cycle** **-**Adjust sprinklers to prevent overspray and runoff: Estimated savings: 15-25 gallons per day -Repair leaks and broken sprinkler heads: **20 gallons per day per leak** -Add 2" to 3" of mulch around trees and plants to reduce evaporation: 20-30 gallons per day per 1,000 sq. ft. -Install water-efficient drip irrigation system for trees, shrubs, and flowers to get water to the plant's roots more efficiently: **20-25 gallons per day** **-**Upgrade to a "smart irrigation controller" that automatically adjusts watering times for hotter weather, and shuts down the system when it rains: **40 gallons per day** **-**Replace a portion of lawn with beautiful native and California-friendly plants: **33-60 gallons per day per 1,000 sq. ft. depending on climate**
Western Resource Advocates. (2003). *Smart Water: A Comparative Study of Urban Water Use Efficiency Across the Southwest.*	California	Irrigation Technology	"The California Irrigation Management Information System (CIMIS) is applicable to agricultural operations or other large-scale irrigation systems. It was designed to provide farmers and irrigators or large landscapes with accurate weather information so that levels of rainfall, temperature, wind speed and solar radiation could be incorporated into watering schedules."	CIMIS users reported an average of 13% reduction in applied water; some were as high as 20%. A landscaper was able to reduce applied water by 60% using CIMIS. Escondido Union School District began using CIMIS and an average of 32 million gallons has been saved annually. Some other school districts have reported 44% reductions in applied water to athletic fields because of CIMIS information.
AquaCraft, Inc. (2009). *California Single Family Water Use Efficiency Study.*	East Bay Municipal Utility District, California	Irrigation Management	"The East Bay Municipal Utility District (EBMUD) was one of 10 participants in the California Single Family Water Use Efficiency Study. Outdoor water use for the study home was characterized with respect to the total annual outdoor use, the actual application rate to the landscape in inches and the theoretical irrigation requirement for the home based on the irrigated area by plant type, the local ET and reasonable irrigation efficiencies based on the type of irrigation system."	"If these customers are typical of a single family customer in the counties, which the statistics show that they are, then the total potential savings in EBMUD from improved irrigation management would be 15 kgal x 306,950 (the number of single family customers in the system). This is equivalent to 4604 million gallons, or 14,135 acre feet of potential water savings per year from improving irrigation applications."
Diamond, R. A. (2003). *Project Review of the Irvine ET Controller Residential Runoff Reduction Study.*	Irvine, California	ET controllers	The study area included five similar neighborhoods in Irvine, California with its own single point of drainage in the urban storm drain system. The participating ET controller group homes received a site evaluation and an installation of an ET controller to manage the irrigation system. Additionally, residents of these homes received information regarding environmentally sensitive landscape practices. The second group was referred to as the education group. This group received the same environmental landscape practice information as the ET controller group, plus a suggested watering schedule each month. Both the ET controller and education groups received educational information monthly in the form of a letter, including tips to improve the appearance of their yards in an environmentally sensitive manner. The remaining three neighborhoods became control groups that were unaware of the study and served as a comparison during the testing period.	Water conservation savings from the typical participant in the ET controller group was 41 gallons per day or approximately 10% of total household water use. The education group residential customers saved 26 gallons per day, or about 6% of the total water use. The larger dedicated irrigation accounts (landscape sizes range from 0.14 acres to 1.92 acres) resulted in water savings of 472 gallons per day. The observed reduction in runoff from the controller test area was 49% when comparing pre and post intervention periods and 71% in comparison to the control group. In contrast, direct pre and post runoff from the education group increased 36% while runoff increased 72% in comparison to the control group.
American Water Works Association. (2006). Water Conservation Programs- A Planning Manual, Manual of Water Supply Practices M52.	Irvine, California and Seattle, WA	ET controllers	General estimate based on studies at Irvine Ranch and Seattle.	18-22%

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Municipal Water District of Orange County. (2008). Effectiveness of Runoff-Reducing Weather-Based Irrigation Controllers (Smartimers). Retrieved from http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008	Municipal Water District of Orange County, California	SmarTimer	Case study from 2004-2006 to promote technology, rebates, and water savings combined with runoff reduction and water quality improvement. Rebate-based participation in 3 different ET zones with 8 different brands of SmarTimers that were either homeowner or professionally installed.	Single Family Residential Installation: Net average savings of 35.7 gpd Commercial Installation: Net average savings of 460 gpd
Aquacraft, Inc, National Research Center, Inc, and Dr. Peter J. Bickel. (2009). *Evaluation of California Weather-Based "Smart" Irrigation Controller Programs.*	Northern and Southern California	Smart Controller programs	"Through this program more than 6,342 smart controllers have been installed in southern and northern California. This report presents results of the impact of 3,112 smart controllers (49.1% of the total) installed at 2,294 sites in northern and southern California."	In this study, smart controller sites changed demand by -316,407,600 gallons across California in one year.
Wells, O. (2007). Utilizing Best Management Practices in the Landscape for Water Conservation, University of Florida IFAS Extension and Florida Yards and Neighborhoods. AWWA's Water Conservation Workshop. American Water Works Association.	Florida	Irrigation Scheduling and Technology	Significant reductions in landscape water use achievable. Presentation describes overall Florida Yards and Neighborhoods program.	Savings Estimates Associated with Various Practices: 20% irrigation scheduling 40% irrigation scheduling and landscape changes 45% rain sensors 60-90% over time irrigation w/ rain sensors only
Haley, M., & Dukes, M. (2007). Evaluation of Sensor Based Residential Irrigation Water Application. 2007 ASABE Annual International Meeting (Paper No. 072251). Minneapolis: American Society of Agricultural and Biological Engineers. http://asae.frymulti.com/abstract.asp?aid=23040&t=2	Pinellas County, FL	Soil Moisture Sensors, Rain Sensors and Education	An irrigation study to determine the effects of sensor based irrigation controllers on residential irrigation water use is described in this paper. This project included 59 homes in Pinellas County, Florida, with automatic in-ground residential irrigation systems. Experimental treatments evaluated include: T1) an automatic time based irrigation controller, set and operated by the cooperator, with the integration of a soil moisture sensor, T2) a rain sensor with a timer-based irrigation schedule, T3) an automatic time based controller only, and T4) similar to T2 with educational material detailing seasonal irrigation recommendations based on historical climate data.	With a soil moisture sensors (T1), water savings of 51% have been recorded compared to homes with an irrigation time clock only (T3). With a rain sensor (T2): the water used was 19% lower than T3. A further decrease in the amount of water use occurred after the distribution of the educational materials, with a difference of 58% between the two rain sensor treatments (T2 and T4).
Shedd, M., Dukes, M. D., & Miller, G. L. (2007). *Evaluation of Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass.*	Plant Science Research and Education Unit in Citra, Florida	ET and Soil-Moisture Sensor Controllers	Research was done to evaluate the effectiveness of the various technologies for reducing residential irrigation water use based on irrigation applied and turfgrass quality measurements.	**Rain Sensors:** · Spring: Water savings ranged from 11 to 26% · Fall: Water use reductions ranged from 7% to 38% **Soil Moisture Sensors:** · Spring: Among the medium and high threshold treatments, the water savings were between 0% and 20%. · Fall: Reductions in water applications ranged from 0% to 49%. **ET Controllers:** ET based treatments managed to use between 36% and 59% less water than the control treatment
Dukes, M. D., Cardenas-Lailhacar, B. and Miller, G. (2008). Evaluation of Soil Moisture-Based on-demand Irrigation Controllers Final Report, August 8. Prepared for and funded by Southwest Florida Water Management District. http://www.acclima.com/08images/research/Dukes,_M._et_al_(2008)_Evaluation_of_Soil_Moisture-based_on-demand_Irrigation_Controllers.pdf	Southwest Florida	Soil Moisture Sensors	A four-year research project, was conducted to evaluate a SMS-based irrigation system. Four different SMS models/brands were initially tested and, later on, two more brands were included. The research was conducted at the Agricultural and Biological Engineering Department research facilities at the University of Florida, in Gainesville, Florida. The experimental area consisted of common bermudagrass plots (3.7 x 3.7 m).	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 turfgrass quality below acceptable levels.
American Water Works Association. (2006). Water Conservation Programs- A Planning Manual, Manual of Water Supply Practices M52.	Austin, TX	Multiple Conservation Program components	**Residentia**l: Irrigation Rebates Irrigation Audits Hose Timers Rain Shutoffs **Commercial:** Irrigation audits	**Residential:** 30 gpd 79 gpd 3 gpd 20 gpd **Commercial:** 250 gpd
Gregg, T., Strub, D., & Gross, D. (2007). Water Efficiency in Austin, Texas, 1983-2005, An Historical Perspective. Journal AWWA, 99 (2), pp. 76-86.	Austin, TX	Xeriscape	This Journal AWWA article summarizes the successes of the Austin water conservation program over time. Cost data are provided. (Noted: This entry is copied into irrigation technology and irrigation audit tables with all of the landscape measures entered together for comparison.)	**1984 Xeriscape Ed. Program**: Peak Day Savings: 1 gpd/person; Savings through 2005: 4,676 gpd **1992 Irrigation Audits**: Peak Day Savings: 100 gpd/SF; Savings through 2005: 483,500 gpd **1994 Incentives for Waterwise plants**: Peak Day Savings: 100 gpd/property; Savings through 2005: 75,900 gpd **1994 Revised Commercial Landscape Ordinance**: Peak Day Savings: 100 gpd/property; Savings through 2005: 65,500 gpd **1987 Free Hose Timers**: Peak Day Savings: 5 gpd; Savings through 2005: 26,040 gpd
Rain Bird . (2003). *Irrigation for a Growing World.* http://www.rainbird.com/pdf/iuow/iuow_whitepapers.pdf.	Fort Stockton School District-Texas	Automatic Irrigation System	"Water use on one football field in July 1996, when temperatures regularly simmer above the century mark, was measured at 1,373,000 gallons at a cost of 41,800 for the month. Despite the effort expended and amount of water consumed, it was impossible to irrigate an entire campus in one day and stubborn dry spots marred the fields and lawns."	"Following the installation of an automatic irrigation system that distributed water in a uniform and efficient manner, water use on the same football field was reduced by just over 1 million gallons, a 75% reduction in water use and a significantly lower water cost of $471 for the month."

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Smart Water Application Technologies. (n.d.). *"Smart" Controller Efficiency Testing for Climate-based Controllers.* Retrieved from http://www.irrigation.org/SWAT/Industry/default.aspx?pg=tested_climate.asp	Center for Irrigation Technology based at California State University, Fresno	Smart Controllers	"The Irrigation Association has developed an independent third party testing protocol specific to "smart" climatologically-based controllers. Each product evaluation is conducted by creating a six-zone virtual landscape subjected to real-time climate through monitoring of a selected weather station to evaluate the ability of individual "smart" controllers to adequately and efficiently irrigate that landscape."	Out of 18 smart controllers that were tested, the following controllers had 0% irrigation excess (how much irrigation water was applied beyond the needs of the plant material): · Calsense ET2000e-24-GR-RB with RB-1 Tipping Rain Bucket · Irritrol Smart Dial · Rain Bird ET Manager with ESP-TM Controller · Rain Master RME Eagle (RMEGEG) · SMG Superior Controls Sterling 8 Controller w/ Water2Save · Toro Intelli-Sense · Water Optimizer
Environmental Protection Agency WaterSense. (2007, July). Outdoor Water Use in the United States.	U.S.	Weather-Based Irrigation Controllers	"Weather-based irrigation controllers can reduce water by 20 percent compared to conventional equipment, potentially saving nearly 20 billion gallons per year across the United States- approximately equal to more than 7,000 hoses running non-stop for a year."	20% or 24 billion gallons per year
Environmental Protection Agency WaterSense. (2007, July). Outdoor Water Use in the United States.	U.S.	Soil Moisture Sensors	"Soil moisture sensors determine the amount of water in the ground available to plants. These sensors, when professionally installed and properly maintained, can potentially save a household more than 11,000 gallons of water used for irrigation annually."	11,000 gallons per year
U.S. Bureau of Reclamation. (2007). *Reclamation Managing Water in the West: Weather and Soil Moisture Based Landscape Irrigation Scheduling Devices.* http://www.usbr.gov/waterconservation/docs/SmartController.pdf.	U.S.	Smart Irrigation Control Products	This report includes information on smart irrigation control products by 28 companies that were available as of June 2007.	AccuWater: As of November 2005, AccuWater had accumulated over 700 controller-months of operating data. AccuWater reports its analysis of these data suggest that average water savings are in the 30 percent range, with individual controllers yielding savings as high as 55 percent. Aqua Conserve: Reported outdoor water use savings for pilot studies with Aqua Conserve controllers, which were performed by the City of Denver, Colorado, Sonoma, California, and the Valley of the Moon Water District in Northern California were 21, 23 and 28 percent, respectively. Cyber-Rain: Cyber-Rain reports systems installed during January through June 2007 reported an average water savings of 36%. ECO-100: ECO Research reports water savings of 20 to 40 percent with the ECO 100, based on its own pilot testing. ET Water Systems: ET Water reports overall average water savings in the range of 20 to 50 percent. Hunter: Although Hunter did not provide water savings data for this report, it reports an approximate water savings of 30 percent, which is similar to the study results for other weather based irrigation control products discussed in this report. WeatherTRAK: WeatherTRAK reports the overall results from these tests indicate significant water savings (16 to 58 percent) and reductions in runoff (64 to 71 percent). Irrisoft: Irrisoft reports the overall results from these projects indicate water savings of 20 to 50 percent. Rain Master: Although water savings data were not available for this report, Rain Master reports average water savings of 25 to 40 percent. Water2Save: The City of Los Angeles, California Department of Water and Power recently performed a pilot study of Water2Save over a one-year period. Water2Save reports the average percentage water savings achieved for the properties installed with its system was over 28 percent. Weathermatic: Weathermatic reports that in 2002, sites installed with the Weathermatic ET controller saved 26%. In 2003, the water savings climbed to 32%. Weathermiser: Weathermiser reports the results of these studies indicated an average savings between 34 and 52 percent after four years of formal testing between 2000 and 2004.
Grabow, G. L., Dukes, M., & Thapa, B. (2009). *The Use of Soil-water Sensors in Turf Irrigation Control- How Effective are they?*	Utah and Florida	Soil-water sensor controllers	"Soil-water sensor controllers have been used since the mid 1990s to manage turf irrigation. While evapotranspiration (ET) based controllers have been widely adopted for turf and landscape irrigation, soil-water-sensor based systems hold some distinct advantages, particularly in humid regions where rainfall contributes significantly to turf water requirements and is highly spatially variable."	· In a study conducted in Utah, the use of a simple automated device for overriding a standard electronic irrigation clock by monitoring soil-water can result in an average of 10% savings in water use and can still maintain healthy green lawns compared to a system without a rain sensor. · In Florida, most SMS systems saved significant amounts of water when compared to time-based irrigation schedules typically used by homeowners. They recorded "wet weather" savings of 69% to 92% for three of the four systems tested and "dry weather" savings of 28% to 83% while maintaining turfgrass quality at acceptable levels. · In a study that evaluated three commercially available ET controllers, found water savings as much as 40% compare to the theoretical gross irrigation requirement, and water wastage by as much as 63% depending upon the season.
Seattle Public Utilities. (2009). Water Smart Technology, Irrigation Case Study, Shoreline School District. Retrieved June 2009 from the Saving Water Partnership: www.savingwater.org	Seattle, WA	Weather-Based Irrigation Controllers and Other Irrigation Technology	• Moved toward 'scientific scheduling' of irrigation, based on actual irrigation system performance, soil characteristics, plant water needs and climatic data. Site audits showed that this alone decreased water use by 30 percent with no adverse effects. • Installed rain sensors and widespread use of sprinklers with in-head check valves.	30% from "scientific scheduling" (assumed to be primarily using ET controller) with over 50% reduction in water cost

Category: Water Efficiency Audits

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Center for ReSource Conservation. (2007). *Irrigation Inspection Program: Impacts of Slow the Flow Colorado on Outdoor Water Use.*	Colorado Front Range	Irrigation Audits	Slow the Flow Colorado is a program that strives to reduce outdoor water waste by improving upon the efficiency of landscape irrigation systems and educating property owners on landscape best management practices. This is accomplished by providing irrigation system inspections at no charge to properties along the Front Range. In 2007, the Center for ReSource Conservation's Slow the Flow Colorado Program performed 1256 irrigation inspections across Colorado's Front Range.	- Only 25% of all zones inspected met the distribution uniformity (DU) standard of 70%. - 61% of residential and 68% of larger property spray zones had high pressure. - Of the inspected zones, only 12.31% were found to be efficient. - Results showed that in 2004, 75% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection. - In 2005, 79% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection.
Vickers, A. (2001). *Handbook of Water Use and Conservation.* Amhurst: Water Plow Press.	California	Irrigation Audits	"Programs that educate customers one-on-one about water-wise concepts, recommend site-specific conservation measures, and provide or install an efficiency device along with back-up technical support should result in at least a 10 to 15% reduction in landscape water demand." (p. 152)	10-15%
Western Resource Advocates. (2008). *Smart Savings Water Conservation: Measures That Make Cents.*	Albuquerque, New Mexico	Irrigation Audits	The Albuquerque Cernalillo County Water Utility Authority (ABCWUA) offers free water audits to industrial, commercial, and institutional water customers. These audits identify opportunities for increasing water efficiency and implementing water conservation measures.	The industrial, commercial, and institutional water audit program cumulatively saved 867 AF from 1999 to 2003.
Ewing Irrigation Products. (2008). *Action Audits! What You Don't Understand Can Save a Significant Amount of Water.* Retrieved from http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.	Las Vegas, NV	Irrigation Audits	Audits determine uniformity and net precipitation rate which are used to determine a watering schedule.	With a weekly water requirement of 2.17"/week, the savings on 1 acre of turfgrass = 38,340 gallons/week if the distribution uniformity is increased from 48% to 70%
GDS Associates. (2002). *Quantifying the Effectiveness of Various Water Conservation Techniques in Texas* . Texas Water Development Board. http://www.twdb.state.tx.us/assistance/conservation/gdsstudy.asp.	Texas	Irrigation Audits	Estimates calculated for irrigation audits for high-use SF, MF and commercial sites. Other conservation measures also estimated.	SF Irrigation Audits – High Users: 50 gpd with 5% participation rate; avg. audit savings 10% MF Audits:125 gallons per day with 50% participation rate; avg. audit savings 15% Commercial Audits: 125 gallons per day; average audit savings 15%; overall commercial water used estimated to be reduced by 1%

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Gregg, T., Strub, D., & Gross, D. (2007). Water Efficiency in Austin, Texas, 1983-2005, An Historical Perspective. Journal AWWA, 99 (2), pp. 76-86.	Austin, TX	Xeriscape	This Journal AWWA article summarizes the successes of the Austin water conservation program over time. Cost data are provided. (Noted: This entry is copied into irrigation technology and irrigation audit tables with all of the landscape measures entered together for comparison.)	**1984 Xeriscape Ed. Program**: Peak Day Savings: 1 gpd/person; Savings through 2005: 4,676 gpd **1992 Irrigation Audits**: Peak Day Savings: 100 gpd/SF; Savings through 2005: 483,500 gpd **1994 Incentives for Waterwise plants**: Peak Day Savings: 100 gpd/property; Savings through 2005: 75,900 gpd **1994 Revised Commercial Landscape Ordinance**: Peak Day Savings: 100 gpd/property; Savings through 2005: 65,500 gpd **1987 Free Hose Timers**: Peak Day Savings: 5 gpd; Savings through 2005: 26,040 gpd
Utah State University Extension Center for Water Efficient Landscaping. (2008). *Water Check Report and Summary: 2008.*	Salt Lake County, Utah	Irrigation Audits	Water Checks were conducted seasonally beginning in 2002. The checks were conducted throughout Salt Lake County for customers of Jordan Valley Water Conservancy District, their member agencies, Salt Lake City Public Utilities, Sandy City, and Murray City. Both residential and commercial Water Checks were conducted. To date, 6,325 residential Water Checks have been completed along with 286 large Water Checks.	Average annual savings/household = 13.8 kgal/household/yr, excluding Salt Lake City Water Savings/Year in kgal/household by location: Year Sandy W. Jordan Salt Lake City 2002 78.72 40.40 60 2003 32.49 5.63 27 2004 22.40 6.45 33 2005 2.23 -20.14 - 2006 -11.76 -17.63 -

Category: Soils, Plant Selection, Turf Management

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation/ Findings
Drought Tolerance of Bedding Plant Annuals. (n.d.). Retrieved from Colorado State University Horticulture and Landscape Architecture: http://www.specialtycrops.colostate.edu/grower_grants/2003/2003_gg_drought_tol.htm	Welby Gardens, Denver, Colorado	Drought Tolerant Plants	The objective of this experiment is to determine how much irrigation water is necessary to maintain healthy bedding plants. Plants were irrigated at five different levels, 100% Et (blue grass), 75% ET, 50% ET (X-rated), 25% ET (XX-rated), and 0% ET (XXX-rated).	Annuals were classified as requiring 100%, 75%, 50% Et (X-rated), 25% Et (XX-rated) and 0% Et (XXX-rated) of grass reference ET.
Wright Water Engineers, Inc. and Green Industries of Colorado. (2008). Green Industry Best Management Practices for the Conservation and Protection of Water Resources in Colorado – Moving Towards Sustainability. Denver: GreenCO. http://www.greenco.org/bmp_list.htm	Statewide, CO	Relative ET Requirements of Plants	Results of CSU and GreenCO 2004 Crop Coefficient Survey	Appendix in GreenCO Manual provides relative ET requirement of a broad range of annuals, perennial, shrubs and trees based on a state-wide survey.
Colorado Department of Local Affairs. 2004. Water Efficient Landscape Design Model Ordinance. Web site: www.dola.state.co.us/smartgrowth/. Denver, CO: Colorado Department of Local Affairs, Office of Smart Growth.	Front Range, CO	Water Budgets/Relative ET Requirements of Plants		Appendix provides relative ET requirement of a broad range of annuals, perennial, shrubs and trees.
Koski, T. (2005). Turfgrass Species/Variety Selection Guidelines. Retrieved from www.csuturf.colostate.edu.	Colorado	Turf Management	Provides list of cultivation requirements for various turfgrass species.	Relative irrigation requirements by selected species: Tall Fescue: often lower than bluegrass, but can be the same or higher Buffalograss: very low to none required Kentucky bluegrass: low to high, depending on soil
Merkl, C. (2005). Good Soil A Key to Water Conservation. *Water Wise* , Volume 11, Number 2, Page 6.	Colorado	Soil Amendments	When compost is mixed into the top 4-10 inches of the soil, it improves the physical, chemical, and biological characteristics of the soil in ways superior to any other single product.	Compost increases the ability of the soil to absorb water. As a general rule, 100 pounds of compost can hold 195 pounds of water.
Johnson, G. A., Qian Y.L., Davis J.G. (2006). Topdressing Kentucky Bluegrass with Compost Increases Soil Water Content and Improves Turf Quality during Drought. Obtained from original manuscript. Fort Collins: Colorado State University. (final publication location unknown).	Fort Collins, CO	Soil Amendment, Core Cultivation, Turf Management	Following core cultivations in May and September 2003 and May 2004, compost treatments [0 (control), 33, 66, and 99 m3 ha-1] were topdressed onto established 'Nuglade' and 'Livingston' Kentucky bluegrass in the field (Experiment I). In Experiment II, 'Kenblue' Kentucky bluegrass was topdressed with 0 (control), 66, and 99 m3 ha-1 compost after core-cultivation. In addition, a non-core-cultivated and no-compost-topdressed treatment was included. Three 10-d dry down periods were imposed during the summers.	Results suggested that compost topdressing after core cultivation is a management practice that could reduce turfgrass irrigation requirements. The experiment indicated that core cultivation could help Kenblue Kentucky bluegrass maintain its turf quality 3 days longer during the 10-day-period without irrigation or precipitation. Compost topdressing (at 66 and 99 m3 ha-1) after core cultivation could help Kentucky bluegrass maintain acceptable turf quality 2-3 days longer compared to the core cultivated but no-compost-topdressed control.

Category: Water Budgeting (*this list is not comprehensive since the focus of this literature review was not on rate structures***)**

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation/ Findings
Klassen, J. (2009). Water Budget Summary for Centennial Water and Sanitation District. Unpublished written communication.	Centennial Water and Sanitation District, Colorado	Water Budgeting	In the spring of 2003, the water budget rate structure was adopted as a means to encourage water conservation through water rates. This new rate structure provided individualized water budgets for all accounts and emphasized the importance of staying within that budget with a financial impact on customers who used more water than their allocated water budget. The water budget rate structure has played an important role in the water savings that Centennial Water has experienced through its conservation program.	For the purpose of estimating water savings due to the implementation of the water budget rate structure, the District uses 2001 as a benchmark. It is estimated that the water budget rate structure has helped achieve a 21 percent savings compared to projected demand numbers prior to implementation. Approximately 75 percent of residential and multi-family customers are at or under water budget annually. Water use as a percentage of water budget is typically around 85 to 90 percent. Residential water use has decreased from 126 gpcd in 2001 to 102 gpcd in 2007. Non-residential irrigation customer water use is typically over water budget. Water use as a percentage of water budget for this customer class is around 110 percent. Centennial will continue to focus additional efforts towards this customer group to help reduce their water usage.
Taylor, L. (2005). Evolution of a Water Budget at Centennial Water and Sanitation District. *Water Wise* , Volume 11, Number 4, Page 5.	Centennial Water and Sanitation District, Colorado	Water Budgeting	The Centennial Water and Sanitation District introduced a water budget system to their residential and commercial customers in 2003. The budget is based on individual customer lot size, not on historical usage or tap size.	**2003:** Usage at 100% of water budget amounts; Usage 17% less than historical usage per tap **2004:** Usage at 79% of water budget amounts; 11% reduction estimated from mild weather patterns **2005:** Usage through August approximately 103% of water budget due to dry July, Single family residential at 99% of water budget, Commercial irrigation (not including Parks District) at 105% of budget with significantly higher overages in dry weather. Observation is that commercial irrigators do not respond to rates in the short term, rather, they are motivated to maintain landscape appearance at any cost.
Western Resource Advocates, Colorado Environmental Coalition, and Western Colorado Congress. (2004). *Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool.*	Front Range, Colorado	Water Budgeting	In late June of 2004, water rate data was gathered from twelve municipal water utilities along the Front Range of Colorado and fourteen municipal water utilities on the Western Slope.	- Many cities with water rate structures that accurately reflect the value of water and the costs of obtaining new water supplies have lower per capita water use and can stretch existing water supplies further. - The increasing block rate structure most effectively encourages efficient water use.
Environmental Protection Agency. (2002). *Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs.*	Irvine Ranch Water District, California	Water Budget/ Rate Structure	Irvine Ranch Water District (IRWD) adopted a five-tiered rate structure to reward water efficiency and identify areas where water is being wasted. IRWD individualizes rates for each account based on landscape square footage, number of residents, and additional needs of the individual customers (such as for medical uses), and daily evapotranspiration rates.	IRWD believes that the implementation of incentive pricing, especially the individualized customer water budget, made their other conservation programs more effective. Between 1991 and 1997, savings in landscape water totaled 61,419 acre-feet, valued at $26.5 million. Landscape water usage dropped from an average of 4.11 acre-feet of less than 2 acre-feet per year.

Category: Water Conservation Programs				
Reference	**Location**	**Category**	**Practice Implemented**	**Saving Attributed to Landscape Water Conservation**
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Aurora, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Irrigation Efficiency Rebate - Ordinances (Lawn Permit, Irrigation Standard, Landscape) - Xeriscape (Education, Demonstration Gardens, Rebate Programs) - Education/Outreach Programs (School Programs, Community Outreach)	Stated Goals: Aurora Water estimates that the current conservation program will save an estimated 83 AF (27 million gallons) of water in 2007 and a cumulative total of 2,450 AF (798 million gallons) if continued at the same intensity through the planning period to 2030.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Boulder, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Customer Rebates/Giveaways (Smart Irrigation Controller rebate, MP-Type Rotator Heads or Nozzles rebate, Drip Irrigation System rebate) - Ordinances (Soil Amendment, Landscape, Irrigation) - Xeriscape (Education, Demonstration Gardens) - Education/Outreach Programs (Informational Website, School Programs, Community Outreach)	Stated Goals: Boulder has set a goal to reduce total system demands by build-out, expected in 2025. The target includes a 22% reduction for the single-family residential sector and a 26% reduction for multifamily residential. For the C&I and the municipal sectors, Boulder aims to reach a 14% and 1% reduction, respectively, from current per capita. The city has also set a goal to achieve a 15% reduction in unaccounted for water. Overall, Boulder has set a goal to have a total demand reduction goal of 19% below the current (2006) per capita water use. If Boulder were to achieve an equal savings every year from now until the reduction goal at 2025, the equivalent 10-year savings goal would be 10.5%.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Broomfield, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Ordinances (Soil Amendment, Turf Restriction, Irrigation) - Xeriscape (Education, Demonstration Gardens) - Education Programs (Informational Website)	Stated Goals: Broomfield has an annual 10% voluntary conservation savings goal, with no goals set for per capita reduction. Broomfield successfully met or exceeded the 10% goal in 2003 and 2004 — during both those years, total water use also declined throughout the city and county. Since that time, it has not reached the 10% goal, achieving 8.5% in 2005 and exceeding projected demand in 2006 by 0.2%.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Colorado Springs, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Customer Rebates/Giveaways (Rotating Multistream Nozzle Retrofit rebate, Spray Head w/ Check Valve rebate, Irrigation Controller rebate, Rain Sensor rebate, Free Automatic Sprinkler Timers, Free Garden Hose Nozzles) - Ordinances (Soil Amendment, Slope, High-Water Turf Restriction) - Xeriscape (Demonstration Gardens, Clinics) - Education Programs (Informational Website, School Programs, Community Outreach)	Stated Goals: Colorado Springs Utilities' current conservation plan draft states a goal of 7.5% sustained demand reduction now through 2046, in addition to 9.4% reduction for natural replacement of inefficient fixtures. Total conservation savings from both demand management and natural replacement is 15.6% through 2046. CSU anticipates a 3.8% savings due to natural replacement by 2017, in addition to a sustained conservation program savings goal of 7.5%. The total savings in 2017 from both is 10.7%.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Denver, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Customer Rebates (ET Irrigation Controller rebates, Wired/Wireless Rain Sensor rebates) - Rules (Time-of-Day Watering, Irrigation) - Xeriscape (Demonstration Gardens, Education) - Education Programs (Informational Website, Community Outreach) - Additional Incentives (Water Use Audits, Irrigation Incentive Program)	Stated Goals: Denver Water has set a goal to reduce system-wide treated water consumption to 165 GPCD by 2016, a 10% decrease from current system-wide treated water consumption.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Erie, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Ordinances (Waste of Water) - Educational Programs (Informational Website, School Programs) - Additional Incentives (Free Irrigation Audits)	Stated Goals: Erie's current conservation plan states a system-wide goal of 190 GPCD by 2014. Erie plans to reduce the expected potable demand of 230 GPCD in 2014 by reusing 28 GPCD (12.5% of projected demand) and reducing demand by 11.3 GPCD (4.9% of projected demand).71 Erie also plans to reduce water use on all existing city irrigated parks and landscaping 15% by 2014.

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Evans, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Ordinances (Time-of-Day Watering, Soil Amendments) - Education Programs (Community Outreach)	Stated Goals: Evans has set a goal to achieve a 5% city-wide savings from the previous year's water use for the summer months of June, July, August, and September.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Fort Lupton, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Ordinances (Time-of-Day Watering, Waste of Water Prohibited)	Stated Goals: Fort Lupton has set a goal of a 5% reduction in water demand for the next 10 years and a 7% long-term reduction. Specifically, the city plans to reduce water usage from 173 GPCD to 161 GPCD within the next 10 years. Fort Lupton has also set a goal to reduce the current city irrigation water of 460 AF (150 million gallons) by 5% by 2030.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Longmont, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Customer Rebates (Soil Amendment) Xeriscape (Demonstration Gardens) - Ordinances (Soil Amendment, Waste of Water Prohibited) - Education Programs (Informational Website) Additional Measures (Free Irrigation Audits)	Stated Goals: Longmont has set a goal to achieve water conservation that results in water demands at build-out of the Longmont Planning Area that are 10% lower than the current demand projections of 32,950 AF per year. Residential build-out of 104,000 is projected to occur in 2024 and build-out of nonresidential land is projected to occur in 2048. Over a 10-year period, Longmont expects to achieve roughly one-third of that 10% savings.
Western Resource Advocates. (2007). *Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.*	Louisville, Colorado	Water Conservation Programs	Landscape Conservation Measures Include: - Customer Rebates (Buffalo Grass, Soil Moisture Sensor, Drip Irrigation System) - Xeriscape (Demonstration Gardens) - Ordinances (Waste of Water Prohibited) - Education Programs (Informational Website)	Stated Goals: Louisville has set a 5% water savings goal, with no timeframe for meeting this.
SWSI 2	Colorado Statewide Planning Estimates	Overall Landscape Water Conservation Potential	a) Turf replacement b) Rebates for landscape retrofits other than turf replacement c) Residential landscape audits (includes irrigation system upgrades, shutoff devices, weather-based controllers, other new technology) d) Commercial landscape audits (includes irrigation system upgrades, shutoff devices, weather-based controllers, other new technology)	a) 25% of single family (SF) residents with no more than 60% turf: 30 to 60 kgal/yr per customer; 41,000,000 to 69,000,000 kgal/yr entire program b) 2.0 - 2.5 % of residential customers, 15 to 20% of irrigation, 11 to 36 kgal/customer, 1,000,000 to 6,000,000 kgal/yr entire program c) 25 % of all residential customers - targeted at high users, 5 to 15 kgal/customer, 1,250,000 to 3,750,000 kgal/program by 2030 d) 25% of all commercial irrigators - targeted at high users, 20 to 75 kgal/customer, 500,000 to 1,875,000 kgal by 2030

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
Environmental Protection Agency. (2002). *Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs.*	Albuquerque, New Mexico	Water Conservation Programs	**Water Rates:** The city applies a summer surcharge of 21 cents per ccf (100 cubic feet) when customers' use exceeds 200 percent of their winter average. On May 1, 2001, the commodity rate increased to $1.07 per ccf ($1.43 per 1,000 gallons) including an additional state surcharge of 2.44 cents per ccf. **Public Education:** Education programs consist of running public relations campaigns, including water usage information on water bills, and organizing cooperative programs with schools and community organizations. **Landscaping/Outdoor Water Use:** In 1995, the city adopted the Water Conservation Landscaping and Water Waste Ordinance. The ordinance includes strict requirements for landscaping new developments, such as prohibiting the use of high-water-use grasses on more than 20 percent of the landscaped area. It also includes restrictions for landscaping on city properties, along with watering and irrigation regulations. Since 1996, the city has offered tools to assist property owners in converting to Xeriscape landscapes. In addition to how-to videos and guides, homeowners can choose from six professionally designed xeriscape plans.	By 2001, its landscaping program and rate structure had helped reduce peak water use by 14 percent from its high point in 1990.
Environmental Protection Agency. (2002). *Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs.*	Tampa, Florida	Water Conservation Programs	Outdoor irrigation is limited to one day per week and prohibited between 8 a.m. and 6 p.m., and all new irrigation systems must have rain sensors. The city also provides homeowners with free Sensible Sprinkling irrigation evaluations and distributes free rain sensors. The landscape code limits the amount of irrigated turfgrass to 50 percent in new developments and encourages the use of Florida-friendly plants and low-volume irrigation methods.	The Sensible Sprinkling irrigation evaluation program resulted in a 25 percent drop in water use.
U.S. Environmental Protection Agency. (1998). Water Conservation Plan Guidelines. Washington, DC.: Office of Water. http://www.epa.gov/WaterSense/pubs/guide.htm.	Compiled from Various Sources (only measures pertaining to landscape water conservation are included in this summary)	Universal metering	Connection metering	20 percent
			Submetering	20 to 40 percent
		Water accounting and loss control	System audits and leak detection	Based on system
		Costing and pricing	10% increase in residential prices	2 to 4 percent
			10% increase in nonresidential prices	5 to 8 percent
		Information and education	Public education and behavior changes	2 to 5 percent
		End-use audits	Outdoor residential use	5 to 10 percent
			Large landscape water audits	10 to 20 percent
		Pressure management	Pressure reduction, system	3 to 6 percent of total production
			Pressure-reducing valves, residential	5 to 30 percent
		Outdoor water-use efficiency	Low water-use plants	7.5 percent
			Lawn watering guides	15 to 20 percent
			Large landscape management	10 to 25 percent
			Irrigation timer	10 gpcd
		Water-use regulation	Landscape requirements for new developments	10 to 20 percent in sector
			Graywater reuse, residential	20 to 30 gpcd
Seattle Public Utilities. (2009). Seattle Water Supply System Regional 1% Water Conservation Program, Saving Water Partnership 2008 Annual Report.	Seattle, WA	Overall Landscape Water Conservation Program includes Irrigation Technology	**2008 Landscape Rebates**	**New 1-year Savings (gpd)**
			Single Family Homes (108 participants)	9600 gpd
			Single Family Non-Rebate	21055 gpd
			Commercial (Including Multifamily) (44 participants)	16506 gpd
			Commercial Non-Rebate	28243 gpd
			Total 1-year Savings	75404 gpd

Reference	Location	Category	Practice Implemented	Saving Attributed to Landscape Water Conservation
http://www.savingwater.org/docs/2008%20Annual%20Report.pdf.		Rebates and Education	ET Controllers Estimated Savings	30%
			Overall *Behavioral* Savings Estimate	0.26 MGD
			8-year overall Reduction due to Conservation	Approx. 8.4 MGD
American Water Works Association. (2006). Water Conservation Programs-A Planning Manual, Manual of Water Supply Practices M52.	Austin, TX	Multiple Conservation Program Components	**Residential**:	**Residential:**
			Irrigation Rebates	30 gpd
			Irrigation Audits	79 gpd
			Hose Timers	3 gpd
			Rain Shutoffs	20 gpd
			Commercial:	**Commercial:**
			Irrigation audits	250 gpd

Attachment 3.

Literature Review to Assist in Quantification of Expected Benefits of Landscape Water Conservation Best Management Practices (BMPs)

This attachment provides "working notes" and summaries compiled during the literature review effort and are intended to be used as general supplemental information for those desiring more information on various references. In some cases, text was copied electronically from the source document's Executive Summary or Abstract as a means to efficiently and accurately transfer data.

DRAFT--INTERNAL WORKING NOTES

1. **Mecham, B., & Boyd, R. (2004).** ***Case Study: Landscape Irrigation Efficiency of Nine Model Homes.*** **Loveland: Northern Colorado Water Conservancy District.**

General Category: Irrigation, Soils

GreenCO BMP Category: Irrigation Technology, Irrigation Efficiency, Soil Amendment/Ground Preparation

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: Nine single-family model homes in an entry-level housing development were selected for a study to determine if changes in landscape maintenance would produce information on how to better manage lawn watering.

Year(s) Data Collected: Spring 2003

Quantitative/Qualitative: Provides *quantitative* findings of study but with multiple BMPs in place (drip irrigation, soil preparation, and irrigation technology). Provides good background information regarding basis of study

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Drip irrigation and soil preparation had the least amount of excess water usage.
- Improved sprinkler system installation helped conserve
- Landscape appearance began to override the concept of water conservation (looks vs. conservation)
- Lack of communication between all parties involved provided an obstacle to achieving the desired results or reducing water usage.

Limitations: Limited sample size.

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

DRAFT - INTERNAL WORKING NOTES

2. ***Drought Tolerance of Bedding Plant Annuals.*** **(n.d.). Retrieved from Colorado State University Horticulture and Landscape Architecture: http://www.specialtycrops.colostate.edu/grower_grants/2003/2003_gg_drought_tol.htm**

General Category: Plant Selection, Water Budgeting, Irrigation, Soils Amendment/Ground Preparation

GreenCO BMP Category: Irrigation System Design, Soil Amendment/Ground Preparation

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: As an association of many independently owned garden centers, the Garden Centers of Colorado initiated the X-rated Program to give their customers solutions to drought related problems. The X-rated List is a list of annual, perennials, shrubs and trees that are able to tolerate lower levels of water. The objective of this experiment was to determine how much irrigation water is necessary to maintain healthy bedding plants by being irrigated at five different levels: 100% ET, 75% ET, 50% ET, 25% ET, and 0% ET.

Year(s) Data Collected: Spring and Summer 2003

Quantitative/Qualitative: Provides *quantified* information regarding at what level (100% ET, 75% ET, 50% ET, 25% ET, and 0% ET) certain plants can survive.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A
Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides information on how much irrigation water is necessary to maintain healthy bedding plants.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

DRAFT--INTERNAL WORKING NOTES

3. **Center for ReSource Conservation. (2007).** ***Irrigation Inspection Program: Impacts of Slow the Flow Colorado on Outdoor Water Use.***

General Category: Irrigation, Soils

GreenCO BMP Category: Irrigation System Design, Soil Amendment/Ground Preparation, Irrigation System Installation, Irrigation Efficiency Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: In 2007, the Center for ReSource Conservation (CRC)'s Slow the Flow Colorado Program performed 1256 irrigation inspections across Colorado's Front Range. In an irrigation inspection, a CRC auditor tests a property's irrigation system for efficiency, and recommends an irrigation schedule as well as other improvements that can improve the system's efficiency.

Year(s) Data Collected: 2007

Quantitative/Qualitative: Qualitative information with regards to landscape BMPs. Gives detailed quantitative information regarding before and after audit water usage.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Distribution Uniformity and system operating at incorrect pressure
- 79% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection.
- Of the inspected zones, only 12.31% were found to be efficient.

Limitations:

- Does not quantify conservation benefits of individual BMPs.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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4. Aquacraft, Inc.. (2003). *Report on Performance of ET Based Irrigation Controller.*

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: In the Spring of 2000, the cities of Boulder, Longmont, and Greeley, Colorado began a small pilot study of the reliability and effectiveness of the WeatherTRAK ET signal controller. The purpose of this study was to document the performance of the system in actual field conditions at homes of volunteer customers.

Year(s) Data Collected: Between 2000 and 2002

Quantitative/Qualitative: *Quantitative* information regarding how the WeatherTRAK controller works

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- The four participants that saved water with the WeatherTRAK system also saved an average of $190 per year in water charges. This was based on the weighted average water rates of $2.40 per kgal in effect in the three cities during 2002.

Summary of Findings Related to Landscape Water Conservation BMPs:

- As a group, the seven sites saved an average of 35,000 gal of water per site compared to their historical use.
- If only the four participants who saved significant amounts of water were included, their average annual savings were 64,000 gallons per site. This shows greater savings potential if the program focuses on high users.

Limitations:

- Some of the study was conducted during the 2002 drought

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

DRAFT - INTERNAL WORKING NOTES

5. **Barta, R. (2004).** ***Stretching Urban Water Supplies in Colorado, Strategies for Landscape Water Conservation.*** **(Barta, 2004)**

General Category: Irrigation, Water Budgeting

GreenCO BMP Category: Irrigation Scheduling, Water Budgeting

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: In response to the suggestion for a consistent comparison of urban landscape water conservation practices, this study examines commonly accepted and emerging strategies for landscape water conservation. The study attempts to enhance the dialogue between the landscape industry in Colorado and the municipalities that supply water for urban landscapes by systematically, and where possible, scientifically defining options for managing urban landscape water use. The study synthesizes existing knowledge on the range of options available for reducing landscape water use; reviews the literature regarding the advantages and disadvantages of each option; and attempts to define a Colorado context for examining urban landscape water conservation strategies.

Year(s) Data Collected: Prior to February 2004

Quantitative/Qualitative: Primarily qualitative

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- "There is not sufficient peer-reviewed literature to scientifically evaluate the effectiveness of urban landscape water conservation strategies."

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

- Use bibliography for additional references
- Summary data provided from other reports

DRAFT - INTERNAL WORKING NOTES

6. **Western Resource Advocates. (2003).** ***Smart Water: A Comparative Study of Urban Water Use Efficiency Across the Southwest.***

General Category: Xeriscape, Irrigation

GreenCO BMP Category: Xeriscape, Irrigation Technology and Scheduling

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: Western Resource Advocates distributed a comprehensive Smart Water survey to 32 urban water providers throughout the Southwest. The survey contained several dozen questions related to retail water demand in calendar years 1994 and 2001 and asked for water management plans and related materials. A total of 13 water providers including those for major urban areas in Arizona, Colorado, New Mexico, Nevada, Texas, and Utah participated by submitting survey data during the summer and fall of 2002.

Year(s) Data Collected: 2001, 2002

Quantitative/Qualitative: Mostly *qualitative* with a little information describing the quantitative effects of drought restrictions. It does not provide quantitative results for xeriscape and irrigation technology.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- While gathering conservation program data for this report, WRA discovered a distinct lack of analyses by water providers related to water savings effectiveness and cost-effectiveness of specific conservation programs. Although benefit/cost analysis is a common tool for justifying structural water supply improvements and planning in other areas, this tool is rarely applied to assess the cost-effectiveness of water conservation measures.
- Michelson (1998) conducted a study for AWWARF that reached a similar conclusion. A lack of detailed and consistent program monitoring makes it extremely difficult to perform an objective analysis of program effectiveness.
- The majority of water providers have not assessed the cost-effectiveness of their particular conservation programs. Although detailed benefit/cost analyses are often conducted to justify structural water supply improvements, this level of analysis for water use efficiency measures is virtually non-existent.
- Rebate and retrofit programs:

DRAFT - INTERNAL WORKING NOTES

- Cash for grass: $1.00 per square foot of landscape converted from turfgrass to Xeriscape
- $50 rain sensor rebate
- $200 soil moisture sensor rebate
- $50 multi-setting irrigation clock rebate
- 50 percent reimbursement of cost for drip irrigation materials and installation

Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides basic climate data for urban areas included in Smart Water report

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

DRAFT--INTERNAL WORKING NOTES

7. **State of California Department of Water Resources. (2008). *Urban Drought Guidebook.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology and Scheduling

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: To help local agencies and communities prepare for the possibility of another dry year and possible water supply interruptions, the Department of Water Resources is pleased to publish this updated version of the Urban Drought Guidebook. Drought, climate change, natural disasters, and environmental protections can all affect water supplies. Good planning and preparation can help agencies maintain reliable supplies and reduce the impacts of supply interruptions. We, the U. S. Bureau of Reclamation, and the California Urban Water Conservation Council worked together on the guidebook to provide technical assistance to local water suppliers.

Year(s) Data Collected: Prior to 2008

Quantitative/Qualitative: Primarily qualitative

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Provides table of water conservation alternatives with the cost-effectiveness on a scale of 1 to 3

Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides estimated savings for certain landscape BMPs, but does not provide basis of savings
- Appendix H: Water Efficient Landscape Websites may be helpful

Limitations:

- Majority is a California based study, but it does reference Denver, Colorado in it as well.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

DRAFT-INTERNAL WORKING NOTES

8. **DeOreo, W. B., Lander, P. W., Qualls, R. J., & Scott, a. J. (1998).** ***Soil Moisture Sensors: Are They A Neglected Tool?***

General Category: Irrigation Technology: Watermark Soil Moisture Sensors and Electronic Modules

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: The City of Boulder, CO began studying Soil Moisture Sensors as a method of conserving outdoor use water in 1992. The Office of Water Conservation and Department of Public Works installed and monitored over 50 Watermark Soil Moisture Sensors and Electronic Modules on existing irrigation systems throughout the City. These were installed on private homes, association common areas, and public street medians and parks. To date, a total of four project reports, three papers and one master thesis have been prepared on the studies.

Year(s) Data Collected: 1997

Quantitative/Qualitative: A quantitative report based on the Watermark irrigation control technology in Boulder, Colorado

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- The results of this study were quite encouraging from the standpoint of both irrigation efficiency and cost effectiveness. On a seasonal basis, the systems limited applications to an average of 76% of theoretical requirement when all sites are combined.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

DRAFT-INTERNAL WORKING NOTES

9. **AquaCraft. (2002).** ***Performance Evaluation of WeatherTRAK Irrigation Controllers in Colorado.*** **http://www.weathertrak.com/pdfs/studies/Aquacraft_Colorado_WeatherTRAK_Field_Study_Year_1.pdf.**

General Category: Irrigation Technology: WeatherTRAK Irrigation Controllers

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: Beginning in 2000, the Cities of Boulder, Longmont and Greeley Colorado began a field study aimed at determining the performance of the WeatherTRAK system in actual field use within their service area. A total of 10 sites were selected for the study from a combination of volunteers and high water using accounts. A total of nine residential and 1 office accounts were included in the study. The actual irrigation applications of each system were tracked against the theoretical requirements for the 2001 season, and the results are summarized in this report.

Year(s) Data Collected: 2000-2002

Quantitative/Qualitative: A quantitative report based on the WeatherTRAK Irrigation Controllers

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- The 5 participants that saved water with the Weather TRAK system also saved an average of $197 per year in water charges. This was based on weighted average water rates of $2.40 per kgal.

Summary of Findings Related to Landscape Water Conservation BMPs:

- As a group, the 10 sites saved an average of 26,000 gal of water per site compared to their historical use.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

DRAFT - INTERNAL WORKING NOTES

10. Colorado State University Cooperative Extension. (1994). *Best Management Practices for Irrigation Management.* http://www.ext.colostate.edu/Pubs/crops/xcm173.pdf.

General Category: Irrigation

GreenCO BMP Category: Irrigation System Design

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: Best Management Practices (BMPs) for the use of irrigation water can help increase efficiency and uniformity and reduce contamination of water resources. Because each farm is unique, producers must evaluate their systems to determine which BMPs are suitable for their operations. Irrigation management BMPs include irrigation scheduling, equipment modification, land leveling, tailwater recovery, proper tillage and residue management, and chemigation safety.

Year(s) Data Collected: Prior to 2004

Quantitative/Qualitative: A qualitative report with a little quantitative research

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Table 3. Estimated seasonal consumptive water use for selected crops and sites
- Table 5: Approximate Efficiency of Various Irrigation Application Methods

Limitations:

- Targets agricultural applications rather than urban landscapes

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

DRAFT - INTERNAL WORKING NOTES

11. Colorado Water Resources Research Institute. (2004). *Colorado High Plains Irrigation Practices Guide: Water Saving Options for Irrigators in Eastern Colorado.* http://digitool.library.colostate.edu/view/action/singleViewer.do?dvs=1240332311084~872.

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: The Colorado state office of the USDA Natural Resources Conservation Service (NRCS) asked Colorado State University faculty in 2003 to summarize irrigation practices that offer potential water savings at the field or farm level. The purpose of this report is to provide a summary of the documented water savings options for irrigators in Colorado. The report provides a significant amount of detail regarding what options are available for water conservation, how these options are used to conserve water, and expected water savings that can be achieved through various irrigation conservation practices.

Year(s) Data Collected: Prior to 2004

Quantitative/Qualitative: A qualitative report with a large portion of quantitative information

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides potential field efficiency ranges for different irrigation techniques

Limitations:

- Targeted to agriculture rather than urban landscapes

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☐ Medium ☒ Low

DRAFT - INTERNAL WORKING NOTES

12. Colorado State University Extension. (2005). *Irrigation Scheduling: The Water Balance Approach.* http://www.ext.colostate.edu/pubs/crops/04707.html.

General Category: Ways to determine irrigation needs

GreenCO BMP Category:

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description:

Year(s) Data Collected:

Quantitative/Qualitative: A quantitative report that supplies lots of information on how to estimate soil water content.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides information regarding crop coefficients; typical available water holding capacities based on soil texture; rooting depths, effective cover and allowable depletion for selected crops

Limitations:

- Agriculturally targeted, as opposed to urban landscape oriented

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☐ Medium ☒ Low

DRAFT INTERNAL WORKING NOTES

13. Bauer, J. (2008). ***Lessons Learned from Field Monitoring of Customer-led Programming of SMART Irrigation Controllers .*** **http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.**

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A Powerpoint presentation by the East Bay Municipal Utility District that focuses on how necessary and how effective water agency intervention is in the programming and monitoring of the controllers to achieve successful water savings and customer satisfaction

Year(s) Data Collected: July 2006 - June 2007

Quantitative/Qualitative: A qualitative presentation with basic water saving quantification.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- Incentive offer based on the account's average irrigation water use over the past three years.
- Moved to a fixed rebate program that is paid after the inspection.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Customer programmed: 41% water savings
- Gardener programmed: 18% water savings
- Contractor programmed: 41% water savings

Limitations:

- PowerPoint presentation so it lacks detailed background information

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

DRAFT - INTERNAL WORKING NOTES

14. City of Henderson, Nevada. (2008). *Turf Removal Loan Program* . http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A PowerPoint presentation by the City of Henderson Department of Utility Services that describes the components of the turf removal loan program.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative presentation with basic water saving quantification.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Up front cost: $2-$5 per square foot
- 3-5-7 Plan
  - 3% interest
  - $5000 maximum loan
  - 7 year deferred payment schedule

Summary of Findings Related to Landscape Water Conservation BMPs:

- Southern Nevada Water Authority (SNWA) Water Smart Landscape Rebate Program: Reduce water consumption by 50-70 gallons per square foot of turf converted

Limitations:

- PowerPoint presentation so it lacks detailed background information

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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15. New Mexico State University. (2008). ***Crop Coefficients for Scheduling Irrigations on Drought Tolerant Landscapes.*** **http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.**

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A Powerpoint presentation describing a project study with these objectives:

- Establish and maintain a live exhibit of various native or drought tolerant plants that have potential for use in urban landscapes of the western U.S.
- Evaluate the growth and quality of each species under variable levels of irrigation in an effort to formulate (crop) coefficients for these landscapes.

Year(s) Data Collected: 2003-2007

Quantitative/Qualitative: A qualitative presentation with good quantitative study results.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Valuable exhibit of drought tolerant species that have potential for western, semi-arid urban landscapes
- Some valuable insight into the water requirements of xeric adapted species including estimates of baseline K_Ls that can be used for efficient irrigation scheduling

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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16. Municipal Water District of Orange County. (2008). *Effectiveness of Runoff-Reducing Weather-Based Irrigation Controllers (Smartimers)*. Retrieved from http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008

General Category: Irrigation
GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A PowerPoint presentation describing a project study of 4,100 SmarTimers installed in residential and commercial settings throughout Orange County with these objectives:

- Determine effectiveness of SmarTimers
  - across brands
  - Overall-residential and commercial
- Reduce outdoor water use
- Maintain healthy and attractive landscaping
- Reduce runoff and improve water quality

Year(s) Data Collected: 2004-2006

Quantitative/Qualitative: A qualitative presentation with good quantitative study results.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Single Family Residential Installation
  - Savings of 18.3 gpd for 899 water accounts –
  - 439 water accounts (49%) not significantly different
  - 460 water accounts (51%) had significant different water usage – 294 saved, 166 used more
  - Net average savings of 35.7 gpd for SFR participants
- Commercial Accounts:
  - 189 accounts (59%) not significantly different
  - 134 accounts (41%) had significantly different water usage: 98 saved, 36 used more
  - Net average savings of 460 gd

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Limitations:

- The data for this study were not normalized for weather with advanced statistical modeling.
- The results obtained from the retrofit participants in this study were not compared to a control set of similar participants.

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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17. Maddaus, M., Maddaus, W., Torre, M., & Harris, R. (2008). Innovative Water Conservation Supports Sustainable Housing Development. *Journal AWWA,* May. 100 (5), pp. 104-111. http://www.awwa.org/WaterWiser/watch/AWWA_Orlando_PaperonWaterEfficient%20Development.pdf

General Category: Xeriscape, Irrigation

GreenCO BMP Category: Xeriscape, Irrigation System Design

Study Type: ☒ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: To meet stringent regulations on water usage by its residents due to long-term water supply limitations, the developer of the new 600-acre Alamo Creek community in Danville, CA was faced with the challenge of how to build and market a new community while dramatically reducing the amount of water that would normally be consumed. The concept used for the development was a "zero water footprint," essentially offsetting new water requirements by funding water conservation in another part of the EBMUD service area. Plans call for minimizing water use on new lots, while paying a fee to EBMUD to facilitate conservation in other parts of the service area. This is a similar concept to pollutant trading.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A quantitative, planning-level study.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data: Developer pays EBMUD $6,000 per new home to fund conservation projects in another part of the service area, offsetting new demand on a 2:1 basis. Plan is to invest about $ 9 million to save 0.9 mgd from program that EBMUD will undertake that are over and above the current aggressive conservation plan.

Summary of Findings Related to Landscape Water Conservation BMPs:

- An average water usage budget established per lot (for each home) of 320 gallons of water per day, with most of the water reductions coming from lower water usage for landscaping. By comparison, most customers in EBMUD's service area use in excess of 500 gallons of water per day, per residence.

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- The aggressive water savings of 27% will be accomplished through multiple measures indoor and outdoor measures, including these landscape measures:
    - Covenant-required Xeriscape landscaping (estimated overall single family savings 22,000 gal/day, relative to 207,000 gal/day baseline)
    - Low water use landscaping on common areas and street medians
    - Use of ET controllers
    - Use of artificial turf on a soccer field
    - Use of recycled water for all large turf irrigation (much of the savings is due to use of recycled water)
    - Extensive training programs for landscape contractors and home owners
    - Surcharge premiums enforced by the Alamo Creek Homeowners Association to home owners who use more water than budgeted for their individual homes
- A portion of the off-site measures implemented by EBMUD include ET irrigation controllers, with an expected savings of 25%.
- Water savings (indoor and outdoor) are estimated at 20-30%.

Limitations: Data not yet available; planning level information only. In 2007, an 8-10 year buildout was planned.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low (*at present time*)

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18. Ewing Irrigation Products. (2008). ***Action Audits! What You Don't Understand Can Save a Significant Amount of Water.*** **Retrieved from http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008.**

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency Audits, Irrigation System Design

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer (Irrigation Distributor)

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: PowerPoint presentation with general information about irrigation efficiency audits and distribution uniformity.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative presentation with basic quantitative information about water savings with improved irrigation efficiency.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Replace spray nozzles with MP Rotator type technology at $12/head

Summary of Findings Related to Landscape Water Conservation BMPs:

- Audits determine uniformity and net precipitation rate which are used to determine a watering schedule
- Las Vegas, NV: Savings on 1 acre of turfgrass = 38,340 gallons/week if DU is increased from 48% to 70% with a weekly water requirement of 2.17”/week

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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19. Rain Bird . (2003). *Irrigation for a Growing World.* http://www.rainbird.com/pdf/iuow/iuow_whitepapers.pdf.

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency, Irrigation System Design

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____ (Provides case studies throughout the U.S.)

Study Description: At Rain Bird, we feel it is our responsibility to increase awareness of the growing threats posed by global water scarcity. Our white papers, entitled *Irrigation for a Growing World*, are just that, an effort to educate readers on the importance of using water efficiently and ways to incorporate these practices into their daily lives.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative white paper with brief summaries about various case studies with improved irrigation efficiency.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- Fort Stockton School District-Texas: 75% reduction in water use and a significantly lower water cost of $471 for the month.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Fort Stockton School District-Texas: Following the installation of an automatic irrigation system that distributed water in a uniform and efficient manner, water use on the football field was reduced by just over 1 million gallons, a 75% reduction in water use.
- The City of Bakersfield, California, Parks Division upgraded its outdated, manually operated electromechanical controllers and replaced them with a sophisticated central control system, weather station, ET sensors and other technologies to irrigate the parks and street landscapes at the south end of the city. When compared against the older system still in use in other parts of the city, the upgraded irrigation system saved more than 10 million gallons in one year.

Limitations: N/A

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Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low
Need to research individual case studies

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20. Aquacraft, Inc, National Research Center, Inc, and Dr. Peter J. Bickel. (2009). ***Evaluation of California Weather-Based "Smart" Irrigation Controller Programs.***

General Category: Irrigation
GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: Through this program more than 6,342 smart controllers have been installed in southern and northern California. This report presents results of the impact of 3,112 smart controllers (49.1% of the total) installed at 2,294 sites in northern and southern California. These sites met the fundamental data requirements established for inclusion in this study- 1 full year of pre- and post-installation billing data, corresponding climate data, a measurement of the landscape area at the site, and basic information about the site, controller, and installation.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A quantitative report with detailed background information.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product.

Summary of Findings Related to Landscape Water Conservation BMPs:

- The overall results are impressive. In this study, the smart controller sites changed demand by -316,407,600 gallons across California in one year.
- All but one participating water agency achieved overall water savings.
- In this study, 41.8% of the study site increased their irrigation water use after installation of the smart controller. Deficit irrigators are poor candidates for smart controllers and should be pre-screened from utility distribution programs.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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21. Aquacraft, Inc. (2006). ***Post Drought Changes in Residential Water Use.***

General Category: Irrigation, Water Budgeting

GreenCO BMP Category: Irrigation Technology, Water Budgeting

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: During the summer and fall of 2005, Aquacraft was hired by Denver Water to collect water use data in a sample of approximately 100 single-family customers in the Denver Water service area. These data provide important findings about how single-family water demands have changed in Denver between the mid 1990's and 2005.

Year(s) Data Collected: 2005

Quantitative/Qualitative: A quantitative report that provides information about indoor and outdoor water usage.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Annual outdoor use dropped between 1994 and 2004 by an average of 54 kgal. This represents a 53% reduction in outdoor use.
- Prior to the drought, the typical customer irrigated to approximately 85% of net ET, but during the first drought year (2002) this dropped to 70% of net ET, and in 2003, the average irrigation application rate dropped to 50% of net ET.

Limitations:

- It is not clear if the observed reduction in irrigation application rates are durable or will gradually rise to pre-drought levels, but an analysis of the survey results suggest that a portion of these savings may be long lasting.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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22. Merkl, C. (2005). Good Soil A Key to Water Conservation. *Water Wise* , Volume 11, Number 2, Page 6.

General Category: Soils

GreenCO BMP Category: Soil Amendment/ Ground Preparation

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: Generic magazine article about soil preparation with compost.

Year(s) Data Collected: N/S

Quantitative/Qualitative: A qualitative report explaining the benefits of using compost.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- When compost is mixed into the top 4-10 inches of the soil, it improves the physical, chemical, and biological characteristics of the soil in ways superior to any other single product.
- Compost increases the ability of the soil to absorb water. As a general rule, 100 pounds of compost can hold 195 pounds of water.
- Compost also improves water infiltration.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☐ Medium ☒ Low

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23. AquaCraft, Inc. (2009). *California Single Family Water Use Efficiency Study.*

General Category: Water Budgeting

GreenCO BMP Category: Water Budgeting

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: The East Bay Municipal Utility District (EBMUD) was one of 10 participants in the California Single Family Water Use Efficiency Study. The goal of this study was to obtain a detailed analysis on the indoor and outdoor water use patterns of a random sample of single family homes in each of the participating agencies. Outdoor water use for the study homes was characterized with respect to the total annual outdoor use, the actual application rte to the landscape in inches and the theoretical irrigation requirements for the home based on the irrigated area by plant type, the local net ET and reasonable irrigation efficiencies based on the type of irrigation system. 83 homes were included in the outdoor analysis.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative report comparing the actual application rate to the landscape in inches and the theoretical irrigation requirements.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- There is a definite relationship between landscape requirements and actual use.
- There is also a great deal of scatter in the data, and many customers are not adjusting their irrigation to ET requirements.
- People often do not have the information or the interest to spend time calibrating their irrigation systems.
- The average excess over-irrigation use was 15 kgal per lot for the 83 study homes, and 35 kgal for the 35 homes that are over irrigating.
- If these customers are typical of single family customers in the counties, which the statistics show that they are, then the total potential savings in EBMUD from improved irrigation management would be 15 kgal x 306,950 (the number of single family customers in the system). This is

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equivalent to 4604 million gallons, or 14,135 acre-feet of potential water savings per year from improving irrigation applications.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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24. Center for ReSource Conservation. (2007). *Irrigation Inspection Program: Impacts of Slow the Flow Colorado on Outdoor Water Use.*

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer ☒ Non-profit

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: This report is intended to summarize the impacts of the Slow the Flow Colorado Irrigation Inspection program on the outdoor (landscape) water use of program participants in the years 2004 and 2005. This report details the methodology and results of the analysis.

Year(s) Data Collected: 2004 and 2005

Quantitative/Qualitative: A quantitative report that compares water usage before the inspection and after the inspection.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- The cost of conducting the number of inspections in the 2005 group (751) was approximately $57,000. Current estimates for the cost of infrastructure associated with the development of water range from $12,000 to $17,000 per acre foot (at a minimum).
- This would indicate that this conservation program is a cost effective method of meeting water supply needs.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Results showed that in 2004, 75% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection.
- In 2005, 79% of participants that watered at rates above ET prior to the inspection reduced their water usage after the inspection.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☒ High ☐ Medium ☐ Low

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25. Taylor, L. (2005). Evolution of a Water Budget at Centennial Water and Sanitation District. *Water Wise* , Volume 11, Number 4, Page 5.

General Category: Water Budgeting
GreenCO BMP Category: Water Budgeting

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: The Centennial Water and Sanitation District introduced a water budget system to their residential and commercial customers in 2003. The budget is based on individual customer lot size, not on historical usage or tap size.

Year(s) Data Collected: 2003 - 2005

Quantitative/Qualitative: A brief article demonstrating the impacts of introducing a water budget.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- **2003**: Usage at 100% of water budget amounts; Usage 17% less than historical usage per tap
- **2004**: Usage at 79% of water budget amounts; 11% reduction estimated from mild weather patterns
- **2005**: Usage through August approximately 103% of water budget due to dry July, Single family residential at 99% of water budget, Commercial irrigation (not including Parks District) at 105% of budget with significantly higher overages in dry weather. Observation is that commercial irrigators do not respond to rates in the short term, rather, they are motivated to maintain landscape appearance at any cost.

Limitations:

- Throughout the years, there are customer complaints about large lots with small house, large households, winter irrigation of trees, customers in new homes moving from areas of traditional water rates and those installing new lawns.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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26. Keesen, L. (2004). The Economics of Water Conservation: Irrigation Technologies. *Water Wise* , Volume 10, Number 4, Page 9.

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: In looking for hard data on cost-effective conservation strategies for outdoor irrigation, the East Cherry Valley Water District sponsored an irrigation system evaluation and renovation program in 1999. The District wanted to find ways to solve water waste from irrigation at a cost that would be appealing to its customers.

Year(s) Data Collected: 1999 - 2000

Quantitative/Qualitative: A brief article with good quantitative information.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

-

Summary of Findings Related to Landscape Water Conservation BMPs:

- ET controllers were installed at 23 homes, rainfall sensors were installed at 28 homes, and soil moisture sensors were installed at 32 homes.
- Savings from ET controllers: 2001: 1,081 total million gallons saved; 2002: 760 total million gallons saved
- Savings from rain sensors: 2001: 1,391 total million gallons saved; 2002: 810 total million gallons saved
- Savings from soil moisture sensors: 2001: 1,606 total million gallons saved; 2002: 837 total million gallons saved

Limitations:

- Water use and water bills were tracked for two years, 2001 and 2002, which was a serious drought year for many water districts.

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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27. Trout Unlimited, Western Resource Advocates, and Colorado Environmental Coalition. (2005). *Facing Our Future: A Balanced Water Solution for Colorado.*

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: Facing Our Future offers a strategic model that will help satisfy the competing demands for water along the Front Range, including those of the environment and river-based recreation, while minimizing reliance on large new dams and projects that divert more water from the West Slope. This strategic model is distinguished from other water management approaches in two primary aspects: (1) it places a higher priority on boosting rates of water conservation and efficiency in water use and management; and (2) it incorporates protection- and even improvement- of environmental values into any and all actions that would boost water supplies.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative report with quantitative outdoor conservation potential estimates.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- The Technical Appendix shows the savings potential for limited xeriscaping, or full coverage of efficiently-watered bluegrass; moderate xeriscaping; and substantial/full xeriscaping

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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28. Western Resource Advocates. (2008). *Smart Savings Water Conservation: Measures That Make Cents.*

General Category: Xeriscape, Irrigation

GreenCO BMP Category: Xeriscape, Irrigation Efficiency Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: This report provides water utility managers and the public with information that can be utilized to gauge the likely effectiveness of water conservation measures, including the diversity of water conservation measures available, the variety of programs to encourage customers to save water, the water savings that have been achieved, and utility program costs.

Year(s) Data Collected: Varies

Quantitative/Qualitative: A qualitative report with different case studies that demonstrate quantitative water savings and cost.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Synthetic turf installation in Irvine, CA: Approximate average of $4 per square foot
- Water audits in Albuquerque, NM: assuming the installed water-saving equipment has a life span of 10 years, the utility program cost over the device life span is $42 per cumulative AF saved.
- Xeriscape in Las Vegas, NV: From 2000 to end of November 2007, Southern Nevada Water Authority spent roughly $89 million on incentives for landscape rebates.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Synthetic turf installation in Irvine, CA: Replacing 7,837 square feet of high-water-use grass with synthetic turf saves a total of 149,917 gallons per year.
- Water audits in Albuquerque, NM: The industrial, commercial, and institutional water audit program cumulatively saved 867 AF from 1999 to 2003.
- Xeriscape in Las Vegas, NV: From 2000 to end of November 2007, the cumulative water savings in gallons is 18,028,229,480.

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Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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29. Utah State University Extension Center for Water Efficient Landscaping. (2006). ***Water Check Report and Summary: Summer 2006.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: The intent of a Water Check is to produce water savings through a free, educational program in which participants learn to irrigate efficiently. The Water Check will provide the participant with an irrigation schedule for their landscape, an evaluation of their irrigation system, and educational handouts on related topics such as low water use landscaping, drip irrigation, and suitable plant lists.

Year(s) Data Collected: 1999-2005

Quantitative/Qualitative: A quantitative report with lots of charts showing the change of water use after a Water Check.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- The average annual cost of residential water checks from 1999-2005: $123/check
- The average annual cost of large water checks from 1999-2005: $472/check

Summary of Findings Related to Landscape Water Conservation BMPs:

- West Jordan: Overall, there has been a net savings of water by the Water Check participants. When using 2001 as a baseline year (253,000 gallons per household), in 2003 (first year after water check), there was a 15% decrease in use, and 20% decrease in use in 2004.
- Salt Lake City Public Utilities: Again, using 2001 as a baseline year (199,000 gallons per household), in 2003 (first year after Water Check) there was a 17% decrease and a 34% decrease in 2004.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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30. Western Resource Advocates. (2007). ***Front Range Water Meter: Water Conservation Ratings and Recommendations for 13 Colorado Communities.***

General Category: Xeriscape, Irrigation, Education, Soils

GreenCO BMP Category: Xeriscape, Irrigation Efficiency Audits, Soil Amendment

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: This Front Range Water Meter report, which provides an up-to-date snapshot of how Colorado Front Range cities compare across many water conservation categories, including rates of per capita use, breadth and depth of implementation of conservation programs, water loss, conservation funding, and many others. The Water Meter's scoring criteria provide a thoughtful and useful basis for comparison and a "score" for each utility. The Water Meter also provides a specific set of recommendations for how each utility can improve its conservation portfolio.

Year(s) Data Collected: 1999-2005

Quantitative/Qualitative: A detailed report with qualitative and quantitative information regarding each of the Front Range cities in Appendix A.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Each city has their own respective conservation budget and funding

Summary of Findings Related to Landscape Water Conservation BMPs:

- Four cities- Aurora, Boulder, Denver, and Colorado Springs- took top honors. Four more- Broomfield, Erie, Louisville, and Longmont- are making tremendous progress in achieving greater water efficiency. Five more cities- Berthoud, Evans, Fort Morgan, Fort Lupton, and Loveland- are relatively small but fast-growing cities that have substantial room for improvement, which is important because they will soon be home to many new Colorado residents.
- Denver, Aurora, and Colorado Springs are home to the three largest water utilities in Colorado. While not having the fourth largest utility in the state, Boulder has many conservation and efficiency measures in place that are comparable to those seen at bigger utilities. All four have demand-side management programs that are

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- Appendix A provides Detailed Individual Utility Summaries

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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31. Northern Colorado Water Conservancy District. (n.d.). *Turfgrass Irrigation Management.* Retrieved from http://www.ncwcd.org/ims/scheduler.asp

General Category: Maintenance: Turf, Water Budgeting

GreenCO BMP Category: Turf Management, Water Budgeting

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: The Turf Irrigation Management Program is used for audits, scheduling, ET calculation using high and low temperatures, and water budgeting. It provides an Excel spreadsheet that calculates ET and makes a water budget based on input parameters.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A quantitative Excel workbook that calculates ET.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- This spreadsheet can be used for any site where an irrigation audit has been performed, or can be performed.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☒ High ☐ Medium ☐ Low

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32. Keesen Water Management. (1998). *The Meadows.* Retrieved from http://www.keesen.com/successes.htm

General Category: Irrigation

GreenCO BMP Category: Irrigation System Design,

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: In 1994, Keesen Water Management performed an irrigation system evaluation for the Meadows Metropolitan District 37-acre streetscape. In 1996, they were contracted to develop Irrigation Design and Maintenance Requirements for The Meadows. These guidelines were filed with Douglas County and became a requirement for all future development.

Year(s) Data Collected: 1996-1997

Quantitative/Qualitative: A brief overview of the irrigation design and maintenance requirements. Report provides basin qualitative information with a table showing water savings.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- 1997 net water savings of $51,407

Summary of Findings Related to Landscape Water Conservation BMPs:

- 1997 net water savings: 25,449,000, or 28 inches

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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33. Sovocool, K. A. (2005). *Xeriscape Conversion Study, Final Report* . http://www.snwa.com/assets/pdf/xeri_study_final.pdf.

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: Recognizing the need for more exacting (and locally applicable) savings estimates, Southern Nevada Water Authority conducted a study that could yield quantitative savings estimates of what a xeriscape conversion facilitation program could yield under real world conditions. The experimental study involved recruiting hundreds of participants into treatment groups (a Xeric Study and a Turf Study Group and control groups), as well as the installation of submeters to collect per unit area application data. Data on both household consumption and consumption through the submeters was collected, as well as a wealth of other data.

Year(s) Data Collected: Began in 1995; multi-year study

Quantitative/Qualitative: A detailed, quantitative report comparing the water use for a Xeriscape Study Group, Turf Study Group, and a non-contacted Comparison Group.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:
See the report for detailed cost analysis, including payback periods.

- Tracking of the costs residents incurred when converting their landscapes from turf to xeric landscape revealed that at the time of the study, the average conversion cost was $1.55 per square foot across all of the conversion projects for which data was available. The average cost for those who did the work themselves was $1.37 per square foot, and for those employing a contractor, it was $1.93 per square foot. All of these costs are probably higher today due to inflation and a strong market for conversion projects.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Results show a 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.

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The major conclusions of this research are as follows:

1. Xeriscape conversion projects can save vast quantities of water at single-family residences. Homes in this study saved an average of 96,000 gallons annually following completion of an average-size conversion project. This is a savings of 30% in total annual consumption; a finding in line with those yielded by other research studies in this region.

2. Over the long timeframe of this study, total yearly savings have neither eroded nor improved across the years. On average, household consumption drops immediately and quickly stabilizes.

3. There is an enormous difference in application of water to locally used turfgrasses and xeric landscape by residents. On average, each year residents applied 73.0 gallons per square foot (117.2 inches) of water to grow turfgrass in this area and just 17.2 gallons per square foot (27.6 inches) to xeric landscape areas. The difference between these two figures, 55.8 gallons per square foot (89.6 inches) is the theoretical average savings yielded annually by having xeriscape in lieu of turf in this area. This is a *substantial* savings (76.4%) when considered in the context of the available residential water conservation measures. A sub-study of other commercial properties with xeriscape found the average application to xeric areas by these customers to be essentially equivalent to that observed for the residential customers.

4. Over the course of a year, the difference in application between turf and xeric areas varies in a predictable bell-shaped-curve manner, with the greatest difference occurring in summer. This is because turf irrigation peaks to a much greater extent in summer than xeric irrigation. The difference in irrigation between these two types of landscape varies from as little as 1.56 gallons per square foot for the month of December, on up to 9.62 gallons per square foot for the month of July.

5. In comparing irrigation application to the reference evapotranspirational rate (ET_o), it was found that on average application to turf exceeded ET_o in every month except March, exceeding it the most May through November. In contrast, xeric application remained well below ET_o year round.

6. The author experimented with using a locally invoked “rule-of-thumb” which holds that xeric plantings require about a third of the evapotranspirational rate as needed for turf. In comparing this developed reference, $0.33(ET_o)$, to application, it was found that these values were, in absolute terms, somewhat close month to month and very close over the entire year. In comparing this developed reference to application, it was found that xeric application was below $0.33(ET_o)$ half the year and above it the other half of the year (September-February).

Relative to questions about irrigation management and the potential for further efficiency gains, findings associated with conclusions 4 through 6 and subsequent analyses led the author to the suggest that (i.) the greatest absolute savings from assorted improvements in irrigation will be realized in the summer, but (ii.) the most

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readily obtained efficiency improvements (i.e., not requiring capital outlays) yielded from better controller management may be obtained September through January, as this is the period when a lot of residents fail to successfully decrease irrigation in response to lower irrigation requirements (for both types of landscape).

8. Multivariate regression modeling was used to help discover some of the factors associated with variability in water consumption at single-family residences. These are:

i. The amount of turf at the residence (positive correlation).

ii. The property value of the residence (as indicated by the local assessor's office; positive correlation).

iii. The age of the residence (positive correlation).

iv. The total income of the property's residents (positive correlation).

v. Whether or not the turfgrass present at the residence is Fescue (a locally popular cool-season grass; positive correlation). As a side-result from one of the multivariate analyses, Bermuda grass may be receiving approximately 59 gallons per square foot per year – certainly less than the application for the much more common cool-season grass in this study. Some variables which were significant in many other incarnations of the model (but not the final model) include parcel size, surface area of open water for pools and spas, the total number of occupants living at the residence, and total landscapeable area.

9. A similar approach was used to identify some of the factors associated with variability in irrigation application to monitored xeric areas. These are:

i. The total canopy coverage within the xeric area (positive correlation).

ii. The average per-station flow rate of the installed irrigation system serving the xeric area (positive correlation).

iii. The size of the xeric area (positive correlation).

iv. The property value of the residence (positive correlation).

v. Parcel size (inverse correlation).

vi. Whether or not the irrigation system was exclusively a drip irrigation system (i.e., not composed of microsprays, bubblers, other higher flow emitters, or combinations of emitters; inverse correlation). V

ii. Whether or not the resident responsible for managing irrigation at the home is knowledgeable about enforcement of local provisions prohibiting outdoor water waste (inverse correlation).

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Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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34. Western Resource Advocates, Colorado Environmental Coalition, and Western Colorado Congress. (2004). ***Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool.***

General Category: Water Budgeting

GreenCO BMP Category: Water Budgeting (Rate Structure)

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: In late June of 2004, we gathered water rate data from twelve municipal water utilities on the Front Range of Colorado and fourteen municipal water utilities on the Western Slope. This sampling provides a good cross-section of water providers along Colorado's Front Range, both in terms of geographic distribution and community size. Although the variation in rate structures used across Colorado can be seen as a rough indication of how each city prioritizes water conservation, each utility has a different water supply situation and different costs associated with these supplies. Therefore, rate structures can be expected to vary somewhat regardless of each city's commitment to conservation.

Year(s) Data Collected: 2004

Quantitative/Qualitative: A comprehensive report summarizing the rate structures used in throughout Colorado. It provides detailed quantitative information regarding type of rate structure and associated costs.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Table 1 lists the components of each rate structure that was implemented by these water providers as of June 22, 2004 in these water service areas.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Many cities with water rate structures that accurately reflect the value of water and the costs of obtaining new water supplies have lower per capita water use and can stretch existing water supplies further.
- The *increasing block rate structure* most effectively encourages efficient water use.
- Increasing block rate structures can maximize efficiency if the block volumes are individually customized to the specific water needs of each customer. This is called a *water budget rate structure*. Under this design, each customer is assigned a monthly allotment of water based on the

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customer's lot size, irrigable area, climate conditions, and household occupancy. In most cases, the monthly allotment, or budget, provides enough water for each customer to sustain normal indoor uses as well as basic landscape irrigation needs. If the customer exceeds the monthly water budget, the excess water use is charged at notably higher unit prices (as with the standard increasing block rate structure).

- The majority of the water providers in the analysis sample applied some form of an increasing block rate structure (Aurora, Boulder, Colorado Springs, Denver, Fort Collins, Highlands Ranch, Longmont, Thornton, and Westminster). This widespread use was not the case just a few years ago when uniform rate structures were more common. We can be encouraged by the fact that many Front Range cities are taking steps towards promoting efficient water use through their rate structures.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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35. Environmental Protection Agency. (2002). ***Cases in Water Conservation: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs.***

General Category: Water Budgeting, Education, Xeriscape, Irrigation

GreenCO BMP Category: Water Budgeting (Rate Structure), Public Education, Xeriscape, Irrigation Efficiency Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other 17 different cities in the U.S.

Study Description: These case studies feature the efforts and achievements of 17 water systems. These systems range in size from small to very large, and their efficiency programs incorporate a wide range of techniques for achieving various water management goals. In every case, the results are impressive.

Year(s) Data Collected:

Quantitative/Qualitative: A comprehensive report that goes into detail for 17 various cities throughout the U.S. regarding their approach to water conservation and their results.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- These case studies illustrate some of the tangible results achieved by water conservation programs implemented at the local level. Many of these accomplishments have broader relevance to other communities facing similar water resource management and infrastructure investment issues.
- Each city has seen impressive results in water conservation.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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36. Bureau of Economic and Business Research. (2005). Water Use and Residential Rate Structures in the Intermountain West. *Utah Economic and Business Review*, Volume 65, Numbers 3 & 4.

General Category: Water Budgeting

GreenCO BMP Category: Water Budgeting (Rate Structure)

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: This report examines water use in 25 Intermountain metropolitan areas with a focus on water delivered through public water supply systems. Water rate schedules for the utilities that serve half the population of the 25 areas are discussed and future water sources for metropolitan areas within Utah are noted.

Year(s) Data Collected: Published in March/April 2004

Quantitative/Qualitative: A concise report summarizing water use in 25 Intermountain metropolitan areas and quantifying the water rate schedule used.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- The highest marginal rate, or the rate for the last drip of water consumed during a billing period, ranges from less than $1 per 1,000 gallons to over $7 per 1,000 gallons.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Provides water rate schedules for largest utilities in selected metropolitan areas
- Most of the utilities have an increasing rate structure, with the per unit charge for water increasing as the amount of water used increases.
- Seasonal rates are imposed by five of the 38 utilities. Salt Lake City and Colorado Springs utilities have flat rates during the winter months and an increasing rate structure during the summer months.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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37. Kenney, D., Christopher, G., Klein, R., Lowrey, J., & Reidy, K. (2007). *Residential Water Demand Management: Lessons From Aurora, Colorado.*

General Category: Water Budgeting, Irrigation

GreenCO BMP Category: Water Budgeting (Rate Structure), Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: The investigation of residential water demand featured in this paper focuses on the City of Aurora, Colorado, a rapidly growing Denver suburb of approximately 309,000 residents served exclusively by a single municipal provider: Aurora Water.

Year(s) Data Collected: 1997-2005

Quantitative/Qualitative: A quantitative and statistically-based report that shows results for those items under utility control: price, restrictions, rate structures, and rebates.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- In summer 2002, Aurora transitioned from a flat rate to an increasing block rate (IBR) pricing structure, with all households subject to the same rates and block widths. Soon thereafter, Aurora began to refine their IBR structure by tailoring the size of each block width on a household by household basis.
- Rebates up to 50% of total cost for those for outdoor technologies, such as sprinkler system upgrades.
- Aurora Water customers wanting a Water Smart Reader (WSR), an in-home device that intercepts radio signals from an individual's water meter, displaying real-time information about levels of water consumption, area assessed a charge of $30 (roughly half the cost of providing the product.)

Summary of Findings Related to Landscape Water Conservation BMPs:

- Overall, our findings are consistent with the literature in demonstrating that residential water demand is largely a function of price, the impact of non-price demand management programs, weather and climate, and most likely, demographic characteristics of households and the homes they occupy.

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Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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38. U.S. Bureau of Reclamation. (2007). ***Reclamation Managing Water in the West: Weather and Soil Moisture Based Landscape Irrigation Scheduling Devices.*** **http://www.usbr.gov/waterconservation/docs/SmartController.pdf.**

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology and Scheduling

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other _____

Study Description: This report includes information on smart irrigation control products by 28 companies that were available as of June 2007. Three additional companies have been added and one companies' products are no longer available in the U.S. Previously reported product information (models, pricing, etc.) has been updated and minor revisions have been made throughout the document. It is Reclamation's intention to continue to update the report as often as needed in an attempt to keep all information current.

Year(s) Data Collected: Up to 2007

Quantitative/Qualitative: A detailed report that provides information regarding the different smart irrigation control products available including: description, operational features, prices and warranties, installation, and water savings.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- Provides cost of each smart irrigation control products.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Most of the product descriptions in this report discuss water savings. In some cases, water savings associated with various studies and demonstration projects are discussed. In most cases the water savings discussed are as reported by the manufacturer.
- Each product provides water savings data.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☒ High ☐ Medium ☐ Low

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39. Institute of Applied Research and Water Resource Institute. (2007). *Statewide Market Survey: Landscape Water Use Efficiency, Final Report.*

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology and Scheduling

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☒ Other (California)

Study Description: Researchers surveyed homeowners and landscape property managers, those who control the irrigation water applied to managed properties, about their irrigation behaviors and attitudes about water conservation measures. Over 1300 surveys were conducted in six regions of California.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative report based on survey findings that gives recommendations based on survey results.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Residential Survey Findings:
  - 89% with sprinkler systems have an automatic timer, 12% have weather based controllers
  - 41% said "appearance" was what matters most regarding their lawn and garden
  - 55% did not know how many gallons of water is used in the landscape
  - 76% said they would buy water efficient plants if they were to buy new plants
  - 81% said that offering cast for reducing lawn size and replacing it with more water efficient plants would work (35%) or might work (43%)
  - 87% said that offering rebates for weather-based controllers would work (59%) or might work (28%)
- Managed Property Findings:
  - 98% said that conserving water is important
  - 78% use water efficient plants

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- 49% expressed interest in finding a landscaper knowledgeable about water saving techniques and plants and would listen to their local water district regarding water conservation
- 52% would attend a free weekend workshop
- 71% would pay more for a water saving technology if it would save them time and money in the future.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low
Good resource to know what water conservation measures show interest by residents and managed properties

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40. American Water Works Association. (2006). *Water Conservation Programs- A Planning Manual, Manual of Water Supply Practices M52.*

General Category:

GreenCO BMP Category:

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other _____

Study Description: The manual provides 6 chapters of information regarding how to assess the need for conservation and describes the pros and cons of establishing a program in more detail; a process to set conservation program goals, qualitatively and quantitatively; methods to assess and reduce water losses; how to estimate water savings from conservation measures, benefits, and costs; and describes what is necessary to develop and carry out a water conservation program.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Provides detailed information regarding how to quantify water savings.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- Chapter 4 goes into great detail about how to calculate water savings by providing formulas and specific details on how to calculate water savings, which will result in cost savings from water conservation.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Appendix A provides case studies of successful programs

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low
Great information on how to implement a water conservation plan

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41. AquaCraft, Inc. (2009). *California Single Family Water Use Efficiency Study.*

General Category: Water Budgeting

GreenCO BMP Category: Water Budgeting

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: 10 participating agencies in the California Single Family Study were studied to obtain a detailed analysis on the indoor and outdoor water use patterns of a random sample of single family homes in each of the participating agencies.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative report comparing the actual application rate to the landscape in inches to the theoretical irrigation requirements.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- **San Diego County Water Authority:** The actual application should be around 81 of the ET based on the average landscape ration, but the actual applications averaged 219% of the theoretical requirements, while the median application ratio was only 87% of the theoretical requirements. 11% of the homes were applying more than 5 times the irrigation requirements. There was a total of 1976 kgal of excess water used during the study year. This averages approximately 36.6 kgal per home.
- **Redwood City:** The actual application should be around 89% of the ET based on the average landscape, and the actual applications averaged 120% of the theoretical requirement, while the median application ratio was 73% of the theoretical requirement. This shows that the water customers in Redwood City are generally doing a fairly good job of managing their irrigation uses, and most customers are irrigating below their requirements.
- **Sonoma County Water Agency:** The results of the outdoor analysis show that there was a total of 334 kgal of excess water use during the study year.

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- **Las Virgenes Water District:** The results of the outdoor study show that there was a total of 7855 kgal of excess water use during the study year. This averages approximately 135 kgal per home.
- **Los Angeles Department of Water and Power:** The results of the outdoor analysis show that there was a total of 2974 kgal of excess water use during the study year in the 97 homes. This averages approximately 30 kgal per home.
- **Irvine Ranch Water District:** On average the single family accounts in this study group were applying 285% of the amount of water that based on the best science should be necessary to maintain their landscapes.
- **City of San Francisco:** The results of the outdoor analysis show that there was a total of 141 kgal of excess water use during the study year by the 18 homes in the study group that were irrigating. This averaged approximately 2.8 kgal per study home.
- **City of San Diego:** The results of the outdoor analysis show that there was a total of 724 kgal of excess water use during the study year for outdoor purposes. This averages approximately 17 kgal per home.
- **City of Davis:** The results of the outdoor analysis show that there was a total of 1558 kgal of excess water use during the study year. This averages approximately 31 kgal per home.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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42. Dickinson, M. A. (2000). ***Water Conservation in the United States: A Decade of Progress.***

General Category: Water Budgeting, Education

GreenCO BMP Category: Water Budgeting, Public Education

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: This report summarizes the California experience of discussing the role that water use and efficiency and conservation could play. In 1989 the urban water community and the environmental community began to negotiate what the terms of 'water efficiency" might be and how it might best be done statewide. By September 1991, the document was ready for ratification by all parties concerned. To date, the "Memorandum of Understanding", has now been signed by 228 signatories. The Memorandum of Understanding includes a list of fourteen BMPs for water conservation and a schedule for their implementation.

Year(s) Data Collected: N/A

Quantitative/Qualitative: A qualitative report with information regarding BMPs to be implemented.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- The cost of each BMP varies widely, and these costs are in the process of being documented in a current Council study. On average, the collective implementation produces water for about $300 per acre-foot.

Summary of Findings Related to Landscape Water Conservation BMPs:

BMP completion requirements:

- Large Landscape Conservation Program and Incentives: prepare water budgets for 90% of all commercial and industrial accounts with dedicated meters; provide irrigation surveys to 15% of mixed-metered customers.
- Public Information Programs: provide active public information programs in water agencies to promote and educate customers about water conservation.
- School Education Programs: provide active school education programs to educate students about water conservation and efficient water uses

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- Conservation Pricing: eliminate non-conserving pricing policies and adopt pricing structures such as uniform rates or inclining block rates, incentives to customers to reduce average or peak use, and surcharges to encourage conservation.
- California's investment in conservation will yield approximately 1.4 million acre-feet.

Limitations:

- Does not quantify individual BMP water savings

Expected Transferability of Findings in Developing Quantitative Estimates:

☐ High ☐ Medium ☒ Low

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43. Kenney, D., Christopher, G., Klein, R., Lowrey, J., & Reidy, K. (2007). *Residential Water Demand Management: Lessons From Aurora, Colorado.*

General Category: Irrigation

GreenCO BMP Category: Irrigation Scheduling

Study Type: ☒ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: In this study the experiences of municipal water providers serving the following cities along Colorado's northern Front Range were tracked: Aurora, Boulder, Fort Collins, Lafayette, Louisville, Thornton, and Westminster. Denver Water was also tracked. This paper documents the various approaches they used and evaluates if voluntary and/or mandatory restrictions were effective in reducing water consumption and if so, to what extent.

Year(s) Data Collected: 2000, 2001, 2002

Quantitative/Qualitative: A quantitative report that summarizes the calculated effectiveness of water restrictions, both voluntary and mandatory, over the study period.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- In every city or provider region, conservation programs featuring mandatory restrictions were associated with significant savings in water use. Net savings ranged widely from 13 percent in Aurora to 53 percent in Lafayette.
- The performance of voluntary restrictions was, with a few exceptions, disappointing.
- This study indicates that outdoor watering restrictions, particularly mandatory programs, are an effective means of reducing water demand during drought periods among Colorado's Front Range municipalities.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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44. Smart Waer Application Technologies. (n.d.). *"Smart" Controller Efficiency Testing for Climate-based Controllers.* Retrieved from http://www.irrigation.org/SWAT/Industry/default.aspx?pg=tested_climate.asp

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☒ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description: The Irrigation Association has developed an independent third party testing protocol specific to "smart" climatologically-based controllers. Currently the protocol is administered through the Center for Irrigation Technology (CIT), an independent testing laboratory, applied research facility and educational resource center based at California State University, Fresno. The objective of this protocol is to evaluate how well current commercial technology has integrated the scientific data into a practical system that meets the agronomic needs of turf and landscape plants.

Year(s) Data Collected: Varies: 2006-2009

Quantitative/Qualitative: Several "smart" controllers have completed IA-SWAT protocol testing and results have been released by the manufacturer. The SWAT Performance Reports provide detailed quantitative results.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Out of 18 smart controllers that were tested, the following controllers had 0% irrigation excess (how much irrigation water was applied beyond the needs of the plant material):
  - Calsense ET2000e-24-GR-RB with RB-1 Tipping Rain Bucket
  - Irritrol Smart Dial
  - Rain Bird ET Manager with ESP-TM Controller
  - Rain Master RME Eagle (RMEGEG)
  - SMG Superior Controls Sterling 8 Controller w/ Water2Save
  - Toro Intelli-Sense

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- Water Optimizer
- WeatherTRAK

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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45. Sharvelle, S., Azar, M. N., Stromberger, M., & Roesner, L. (2009). ***Graywater Irrigation as a Means to Meet Water Demands in Arid Regions.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Using Nonpotable Sources

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
Provides information for households in California, Colorado, and Texas

Study Description: Graywater irrigation systems offer many benefits, however the use of such systems has not become widespread due to concerns about safety issues. While some states have begun to legalize and regulate the practice of graywater reuse for residential landscape, little guidance based on scientific data has been provided for the safe operation of graywater irrigation systems. We selected three households where graywater has been applied for irrigation for more than five years to include in this study located in California, Colorado, and Texas.

Year(s) Data Collected: Soil samples have been collected and analyzed at households where graywater has been applied for irrigation for at least five years.

Quantitative/Qualitative: Provides detailed qualitative soil sample results for the various study locations.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- If graywater is used for irrigation of a typical residential landscape, it could supply about 30% of the demand, and with increasing emphasis on xeriscape in the semi-arid West, it has the potential to supply 100% of the irrigation demand in some areas.
- Pathogen indicator organisms were measured in soil samples to assess their fate after graywater application. No clear trend of an effect of graywater irrigation was observed. However, it is notable that pathogen indicators were generally not found to be higher in soils irrigated with graywater than control soils irrigated with freshwater.

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Limitations:

- Only some states, including California, Arizona, and New Mexico have legalized the graywater practice.
- The use of graywater systems is not viable for most homeowners in Colorado. Currently, the treatment, disposal, and potential use of graywater is regulated by the State of Colorado Guidelines On Individual Sewage Disposal Systems and applicable county Individual Sewage Disposal System (ISDS) regulations. The Colorado Department of Public Health and Environment (CDPHE) does not currently separate graywater from blackwater in its regulations. Consequently, surface applications require permitting and monitoring. Application of graywater from systems discharging 2,000 gallons or more per day requires a permit from the CDPHE; smaller systems require permits from your local health department.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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46. Grabow, G. L., Dukes, M., & Thapa, B. (2009). ***The use of Soil-water Sensors in Turf Irrigation Control- How Effective are they?***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☒ Regional ☐ Summary ☐ Other _____
Florida and North Carolina

Study Description: Several studies involving soil-moisture sensors have been done in Florida and one study in North Carolina is near completion, These studies have looked at soil-water sensor based systems of various manufacturers in similar settings; have compared results between different moisture setting thresholds; have contrasted water usage with ET based controller systems; and have monitored root zone soil-water status in plots irrigated by soil-water based systems.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Provides both qualitative and quantitative information comparing soil-water based controller systems with ET controller systems.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Soil-water sensor controller systems have conceptual advantages in irrigation control since they integrate all elements of a soil-water budget into the soil. Studies have shown that these systems consistently reduce water use when compared to standard controller systems set to irrigation of historical ET or historical gross irrigation requirement.
- In a study conducted in Utah, the use of a simple automated device for overriding a standard electronic irrigation clock by monitoring soil-water can result in an average of 10% savings in water use and can still maintain healthy green lawns compared to a system without a rain sensor.
- In Florida, most SMS systems saved significant amounts of water when compared to time-based irrigation schedules typically used

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by homeowners. They recorded "wet weather" savings of 69% to 92% for three of the four systems tested and "dry weather" savings of 28% to 83% while maintaining turfgrass quality at acceptable levels.

- In a study that evaluated three commercially available ET controllers, found water savings as much as 40% compare to the theoretical gross irrigation requirement, and water wastage by as much as 63% depending upon the season.

Limitations:

- One argument against the soil-water based systems has been the perceived problems with representativeness of sensor location and repeatability of the sensor systems.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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47. Cardenas-Lailhacar, B., Dukes, M. D., & Meaks, L. (2009). ***Irrigation Rain Sensors Accuracy.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
University of Florida Agricultural and Biological Engineering Department turfgrass research facility in Gainesville.

Study Description: The objectives of this research were to evaluate two expanding disk rain sensor types, Mini-Click (MC) and Wireless Rain-Click (WL), with respect to: a) the accuracy of their set point with respect to rainfall depth, b) the number of times in irrigation bypass mode, and c) the duration in irrigation bypass mode. Four treatments with four replications each were established. For the MCs, three set points were established: 3, 6, and 13 mm thresholds. The dry-out ventilation windows of the MCs and WLs were kept completely open.

Year(s) Data Collected: January 1, 2006 – July 31, 2007

Quantitative/Qualitative: Provides quantitative information evaluating the two expanding disk rain sensor types

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Accuracy tests results suggested that the 3-MC responded close to its set point (73%), but 6-MC and 13-MC resulted in lower accuracies (30 and 58%).
- Replicates at a particular set point were variable, sometimes responding properly according to their settings, sometimes not detecting rainfall events five or more times their set points, and sometimes even shutting off several hours after the rain had stopped.
- Most of the time, treatments remained in bypass mode for less than 24 hours, and almost all treatments dried out in less than 48 hours during this testing period.

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Limitations:

- After more than two years of continuous operation these devices still have the ability to bypass irrigation cycles during rainy weather; however, their accuracy appears to be degrading with time.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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48. Davis, S. L., & Dukes, M. D. (2009). ***Preliminary Results for Bench Testing of Evapotranspiration-based Irrigation Controllers in Florida.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
University of Florida Agricultural and Biological Engineering Department turfgrass research facility in Gainesville.

Study Description: The objectives of this study are to duplicate the soil water balance calculations specified by the smart water application technologies (SWAT) test and recreate the SWAT bench test in a humid region using ET controllers previously tested under the SWAT protocol in an arid climate. Three brands of ET controllers previously tested under the SWAT protocol by CIT were installed. The controllers are as follows: Weathermatic SL1600 with SLW20 weather monitor, Toro Intelli-sense duplicates utilizing the WeatherTRAK ET Everywhere Service, and ETwater Smart Controller 100 duplicates.

Year(s) Data Collected: The ET water controllers began the SWAT test on September 14, 2008 with manufacturer permission and testing ended on January 11, 2009. The Weathermatic controller began the SWAT test on September 23, 2008. The Toro WORS and Toro WRS controllers began testing on October 23, 2008.

Quantitative/Qualitative: Provides detailed qualitative information on the materials and methods of how the daily moisture balance to simulate the water dynamics of a landscape plant system is calculated. Quantitative information is provided for whether the controllers have accurate irrigation scheduling capabilities.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Cumulative totals for rainfall and ET over the study period were lower than the historical average, averaging 56% and 40%, respectively. The combination of low ET and rainfall suggests that

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irrigation wouldn't generally be required and plan material would be dormant during most of the time period.

- The results found during the 2008 SWAT test showed that the ET controllers generally scored well in SWAT performance scores of scheduling efficiency and irrigation adequacy.
- The controllers resulted in slightly lower scores, mainly concerning scheduling efficiency, than what was published from the original SWAT test. Scheduling efficiency results were lower than the original published results by 2.5% for the ETwater controllers, 14% by the Toro controllers, and 5.6% by the Weathermatic.

Limitations:

- Since controller programming is extremely important to obtaining good SWAT results, manufacturers program the controllers based on how to get a good score rather than using the landscapes described in the protocol.
- It is likely that manufacturers would have opted not to publish these results as a SWAT score and restarted the test with minor adjustments.
- The SWAT testing protocol should be clearly outlined and detailed enough for results to be reproducible if it will continue to be used as an industry standard. However, the testing procedures are not reproducible based on the current form of the protocol document.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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49. McCready, M., & Dukes, M. D. (2009). ***Evaluation of Irrigation Scheduling Efficiency and Adequacy by Various Control Technologies Compared to the Theoretical Irrigation Requirements.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
Plant and Science Research and Education Unit in Citra, Florida

Study Description: A variety of commercially available technologies for reducing residential irrigation water use are available to homeowners. These technologies include soil moisture sensors, rain sensors and evapotranspiration (ET) based controllers. The purpose of this research was to evaluate the adequacy and efficiency of the irrigation schedules for each control device with an irrigation schedule developed using a theoretical soil water balance.

Year(s) Data Collected: There were four treatment periods during April 22, 2006 to June 20, 2006 (SP06); September 23, 2006 to December 15, 2006 (F06) and May 1, 2007 to August 31, 2007 (S07).

Quantitative/Qualitative: Provides detailed qualitative information on the materials and methods of how the daily moisture balance to simulate the water dynamics of a landscape plant system is calculated. Quantitative information is provided for comparing the adequacy and efficiency of the irrigation schedules for each control device.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- In general, adequacy of irrigation for all treatments improved in the fall months compared to the spring months of testing.
- Simply using adequacy alone or efficiency alone was not a good indicator of the accuracy of an irrigation schedule.
- Some treatments received high efficiency scores but very low adequacy scores because irrigation was not sufficient for plant needs.
- Tables in back of report provide detailed quantitative results.

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Limitations:

- There were some limitations for the experimental treatments compared to the SWB. The SWB was allowed to irrigate whenever soil moisture dropped to RAW and it only irrigated to FC. The experimental treatments were scheduled for irrigation on specific days of the week (1, 2 or 7 d/wk) and irrigation depth was programmed into the time, with the exception of TORO.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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50. McCready, M., & Dukes, M. D. (2009). ***Evaluation of Irrigation Scheduling Efficiency and Adequacy by Various Control Technologies Compared to the Theoretical Irrigation Requirements.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
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Year(s) Data Collected: There were four treatment periods during April 22, 2006 to June 20, 2006 (SP06); September 23, 2006 to December 15, 2006 (F06) and May 1, 2007 to August 31, 2007 (S07).

Quantitative/Qualitative: Provides detailed qualitative information on the materials and methods of how the daily moisture balance to simulate the water dynamics of a landscape plant system is calculated. Quantitative information is provided for comparing the adequacy and efficiency of the irrigation schedules for each control device.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- In general, adequacy of irrigation for all treatments improved in the fall months compared to the spring months of testing.
- Simply using adequacy alone or efficiency alone was not a good indicator of the accuracy of an irrigation schedule.
- Some treatments received high efficiency scores but very low adequacy scores because irrigation was not sufficient for plant needs.
- Tables in back of report provide detailed quantitative results.

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Limitations:

- There were some limitations for the experimental treatments compared to the SWB. The SWB was allowed to irrigate whenever soil moisture dropped to RAW and it only irrigated to FC. The experimental treatments were scheduled for irrigation on specific days of the week (1, 2 or 7 d/wk) and irrigation depth was programmed into the time, with the exception of TORO.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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51. O'Brien, B. (July/August 2008). SOIL: Not Just a Four-Letter Word. *Colorado Green* , Volume 24, No 4.

General Category: Soils

GreenCO BMP Category: Soil Amendment/Ground Preparation

Study Type: ☒ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A journal article explaining how good soil preparation is the foundation for healthy, sustainable landscapes.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Qualitative information regarding the necessity of using soil amendments

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- "Proper soil amendment with deep tillage will improve the soil's water-holding properties and is the first step in my list of things to do to improve irrigation efficiency and management in the landscape." –Brent Mecham
- More and more Colorado cities are requiring or strongly recommending soil amendment.
- Denver Water announced its new soil amendment rule (effective August 2008) for all new residential and commercial construction within the city and county. Proof of soil amendments must be submitted prior to meter sets. For the most part, the rules include testing, addition 4 to 6 inches or organic matter and tilling to a minimum depth of 4 to 6 inches.
- "Since Aurora's lawn permit ordinance was enacted in the mid '80s, he has witnessed healthier lawns that use less water."- Kevin Reidy, water conservation supervisor with the City of Aurora
- "I have witnessed improvements in the overall health and quality of landscapes since the rule was implemented in 2002." – Natalie Stevens, marketing technician with the City of Greeley

Limitations:

- Not all sites will require amendment, specifically those designed to preserve natural habitats and those designed with the use of native plants.

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Depending on the existing soil conditions, soil amendment could have adverse effects and actually do more harm than good.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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52. Shedd, M., Dukes, M. D., & Miller, G. L. (2007). ***Evaluation of Evapotranspiration and Soil Moisture-based Irrigation Control on Turfgrass.***

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
Plant Science Research and Education Unit in Citra, Florida

Study Description: A variety of commercially available technologies for reducing residential irrigation water use are available to homeowners. These technologies include soil moisture sensors, rain sensors and evapotranspiration (ET) based controllers. The purpose of this research was to evaluate the effectiveness of these various technologies based on irrigation applied and turfgrass quality measurements.

Year(s) Data Collected: Treatments were implemented in the spring and fall seasons of 2006. The spring treatments started on April 22, 2006 and ended June 30, 2006 (71 days), and the fall treatments began on September 23, 2006 and ended December 15, 2006 (84 days).

Quantitative/Qualitative: Provides detailed qualitative information on the materials and methods of how the daily moisture balance to simulate the water dynamics of a landscape plant system is calculated. Quantitative information is provided for evaluating the effectiveness of the various technologies.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Even though both seasons were relatively dry, all of the technologies tested managed to reduce water application compared to the 2-WORS (without rain sensor) treatment, with some treatments also maintaining acceptable turf quality.
- The highest overall water saving with high quality turf were seen in the ET-based treatments and the 2-DWRS (a deficit replacement schedule that was 60% of the 2-WRS)
- ET-based treatments managed to use between 36% and 59% less water than the control treatment 2-WORS.

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- Time-based treatments in the spring showed that the frequency may have an impact on quality of turf, with more frequent irrigation to a shallow depth providing higher quality but not necessarily higher water savings.

Limitations:

- These experiments were performed during two relatively dry seasons when the treatments were expected to produce little water savings.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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53. Diamond, R. A. (2003). ***Project Review of the Irvine ET Controller Residential Runoff Reduction Study.*** *****how does this compare against IRWD 2004 Study******

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____
Five similar neighborhoods in Irvine, California

Study Description: The Residential Runoff Reduction Study (R3) had four primary purposes. The initial purpose was to develop and expand the application and use of pager-signal technology to manage irrigation water for residential homes and larger dedicated landscape areas. Secondly, the study was intended to evaluate the effectiveness of an education program consisting of landscape maintenance information and a suggested irrigation schedule on both water use and runoff. The third study goal was to determine the connection between proper water uses in the landscape and the quantity and quality of dry weather runoff that enters the urban storm drain system. Finally, the study was intended to gauge the acceptance of water management via the ET controllers and whether this style of water management affected the overall appearance of landscape.

Year(s) Data Collected: 18-month study period

Quantitative/Qualitative: Provides quantitative results for water savings.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- The ET controller retrofit group homes received a site evaluation and installation of an ET controller to manage the irrigation system. Also, the residents of these homes received information regarding environmentally sensitive landscape practices.
    - Water conservations savings from the ET controller group was 41 gallons per day.
    - There was a 49% direct reduction in water runoff (pre and post) in the ET controller area during the dry-season periods.

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    - 72% of participants indicated that they liked the controllers. This group also found that the controller irrigation either maintained or improved the appearance of the landscape.
- The second group was referred to as the educational group. This group received the same environmental landscape practice information as the ET controller group, plus a suggested water schedule each month.
    - The educational group residential customers saved 26 gallons per day.
    - Direct pre and post runoff from the educational group increased 36% while runoff increased 72% in comparison to the control group.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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54. Olmstead, S. M., & Stavins, R. N. (2007). ***Managing Water Demand: Price vs. Non-Price Conservation Programs.***

General Category: N/A

GreenCO BMP Category: N/A

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: This paper offers an analysis of the relative merits of price and non-price approaches to water conservation. As economists, we emphasize the strong empirical evidence that using prices to manage water demand is more cost-effective than implementing non-price conservation programs. Price-based approaches also have advantages in terms of monitoring and enforcement. In terms of predictability and equity, neither policy instrument has an inherent advantage over the other. As in any policy context, political considerations are also important.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Provides qualitative information comparing price vs. non-price conservation programs to manage water demand

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- On average, in the United States, a 10% increase in marginal price of water can be expected to diminish demand in the urban residential sector by about 3 to 4 percent.
- Estimates of the water savings attributable to non-price demand management policies such as watering restrictions and low-flow fixture subsidies vary from zero to significant savings.
- More stringent mandatory policies (when well-enforced) tend to have stronger effects than voluntary policies and education programs.
- Where water savings have been estimated from non-price approaches, they are usually smaller than expected, due to behavioral responses.
- Price-based approaches to water conservation are more cost-effective tan non-price approaches.
- The gains from using prices as an incentive for conservation come from allowing households to respond to increased water prices in the manner of

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their choice, rather than by installing a particular technology or reducing particular uses, as prescribed in non-price approaches.
- Non-price demand management policies require monitoring and enforcement, since they are easy to violate.
- Raising water prices can be politically very difficult; perhaps as a result, water demand management through non-price techniques is the overwhelmingly dominant paradigm in the United States.

Summary of Findings Related to Landscape Water Conservation BMPs: N/A

Limitations:
- In specific cases, non-price water conservation programs can only be compared with price increases if water suppliers have a measure of the benefits of non-price conservation programs. In compiling this report, we were unable to find any estimates of the impacts of these types of water conservation policies in New England, and few such estimates exist, even for very expensive programs, across the United States.
- Water conservation in this reference is generic and not landscape BMP specific

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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55. Environmental Protection Agency. *Water-Efficient Landscaping: Preventing Pollution and Using Resources Wisely.* http://www.epa.gov/WaterSense/docs/water-efficient_landscaping_508.pdf.

General Category: Irrigation

GreenCO BMP Category:

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: This booklet describes the benefits of water-efficient landscaping. It includes several examples of successful projects and programs, as well as contact, references, and a short bibliography.

Year(s) Data Collected: N/S

Quantitative/Qualitative: Provides qualitative water-efficient landscaping information with generic quantitative information.

Cost Data: ☐ N/A ☒ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

- Residents of Glendale, Arizona, can receive a $100 cash rebate for installing or converting more than half of their landscapable area to non-grass vegetation.
- In Las Vegas, Nevada, homeowners can receive up to $1,000 for converting their lawn to Xeriscape, while commercial landowners can receive up to a $50,000 credit on their water bill.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Las Vegas, Nevada: Preliminary results of a five-year study show that residents who converted a portion of their lawns to Xeriscape reduced total water consumption by an average of 33 percent.

Limitations: N/A

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☐ Medium ☒ Low

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56. Clary, J., O'Brien, B., & Calomino, K. (2006). ***Working Together to Promote Landscape Water Conservation.***

General Category: Irrigation, Water Budgeting, Education

GreenCO BMP Category: Xeriscape, Irrigation Design, Irrigation Technology, Water Budgeting, Public Education

Study Type: ☒ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: To assess how builders are going about promoting and/or implementing water conservation and water-quality protection, several homebuilders were contacted to participate as case studies. The three builders selected included Engle Homes, McStain Neighborhoods, and Village Homes. The goals of the studies were:

1. Assess what water conservation practices builders are implementing.
2. Share these approaches with the broader builder community to demonstrate how water conservation and water-quality protection can be integrated effectively into builder practices.

Year(s) Data Collected: N/S

Quantitative/Qualitative: Provides qualitative information for each case study with general quantitative information.

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- **Engle Homes**: There are five alternative backyard Xeriscape designs that buyers can request to have Engle's subcontractors install, hire their own subcontractor, or use the designs for their own landscaping.
- Table 2 provides summary costs for alternative backyard xeriscape designs.

Summary of Findings Related to Landscape Water Conservation BMPs:

- **Engle Homes:** As part of Engle's Water-Wise Program, it created a water-wise booklet with Valerian LLV to provide buyers with information regarding Xeriscape, soil preparation, hydrozoning, efficient irrigation, mulching, appropriate maintenance, and drought-tolerant plants.
- Engle Homes completes front yard landscaping in most of its projects. The water-wise standards for these installations include the following:
    - Soil amendments added (3 cubic yards per 1,000 square feet)

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    - Irrigated turf limited to 50% to 60% of the total landscape area
    - Balance of yard planted in drought-tolerant bedding areas and rock or wood mulches
    - Use of drought-tolerant trees and shrubs
    - Drip irrigation zones installed for shrub beds
    - Rain sensors installed as standard to curtail irrigation during natural precipitation
- **McStain Neighborhoods:** In 2003, McStain Neighborhoods developed a guidance document called the "McStain Neighborhoods Water Conservation Standards for Common Area and Open Space Landscapes."
- In order to promote long-term landscape water conservation, McStain has developed both landscape maintenance and irrigation system maintenance specifications so that expectations are clearly defined for contractors.
- **Village Homes:** When Village installs individual lot landscaping, it strives to provide water conservation-oriented specifications for irrigation systems, soil amendment, and/or landscape design.
- Village has recognized the importance of homeowner education with regard to the critical role that landscaping practices play in a development, both in terms of community enjoyment and protection of water quality.

Limitations:

- **McStain Neighborhoods:** Because McStain's projects following these standards are still in the early phases of development, performance data and potential water cost savings were not available for inclusion in this report. (As of September/October 2006)

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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57. Vickers, A. (2001). *Handbook of Water Use and Conservation*. Amhurst: Water Plow Press.

General Category: Irrigation, Water Budgeting, Education

GreenCO BMP Category: Xeriscape, Irrigation Design, Irrigation Technology, Water Budgeting, Public Education

Study Type ☐ Journal ☐ Private Study ☒ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: Comprehensive handbook on water conservation, with substantial information on landscape water conservation.

Year(s) Data Collected: Prior to 2001

Quantitative/Qualitative: Both

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Summary of Findings Related to Landscape Water Conservation BMPs: **Good general reference for background**. Several specific case studies provided.

Limitations: General reference book

Expected Transferability of Findings in Developing Quantitative Estimates: ☐ High ☒ Medium ☐ Low

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58. Mecham, B. (March 2003). ***Conservation Strategies for Lawn Watering During Drought or Water Shortages.***

General Category: Xeriscape

GreenCO BMP Category: Xeriscape,

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A brief study with conservation strategies with accompanying options that could be used to reduce irrigation demand that are based on the typical growing season of April 1 to October 31 and assume near normal rainfall.

Year(s) Data Collected: N/S

Quantitative/Qualitative: A quantitative report that shows the amount of water reduced based on different conservation strategies.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- **Conservation Strategy #1 at 10% landscape irrigation reduction**:
  - A 10% reduction in irrigation run times- **Reduction: 10%**
  - Irrigation May 1 to September 30- **Reduction: 15%**
- **Conservation Strategy #2 at 20% landscape irrigation reduction:**
  - A 20% reduction in irrigation run times- **Reduction: 20%**
  - Irrigation April 23 to October 7 at 1" per week- **Reduction: 24%**
- **Conservation Strategy #3 at 30% landscape irrigation reduction:**
  - Irrigation May 1 to September 30 at 1" per week- **Reduction: 28%**
  - Irrigation May 1 to June 30 at irrigation requirement, NO irrigation July 1 to July 30, Irrigation August 1 to October 15 at irrigation requirement- **Reduction: 32%**
- **Conservation Strategy #4 at 40% landscape irrigation reduction**:
  - Irrigation May 1 to October 15 at 0.75" per week- **Reduction: 35%**

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- Irrigation May 1 to June 30 at 1" per week, NO irrigation July 1 to July 31, Irrigation August 1 to October 15 at 1" per week- **Reduction: 43%**
- Irrigation April 15 to June 15 at irrigation requirement, NO irrigation June 15 to August 15, Irrigation August 16 to October 31 at irrigation requirement- **Reduction: 44%**
- Water budget or water diet- **Reduction: 40%**

Limitations:

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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59. Keesen, L. (2009). Next Steps After an Audit are Implementing Changes For Less Water Use and Long Term Sustainability.

General Category: Irrigation

GreenCO BMP Category: Irrigation Efficiency Audits

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A PowerPoint presentation with brief information on an East Cherry Creek Valley Water District sponsored Irrigation System Evaluations and Pilot Program of Greenfield/Liverpool.

Year(s) Data Collected: 2000

Quantitative/Qualitative: Quantitative information regarding the water savings of the Greenfield/Liverpool streetscape system evaluation

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

- **Greenfield:** Renovation cost: $11,100; payback 4.7 years; Total water savings: $7,155 (3-year)
- **Liverpool:** Renovation cost: $7,492; payback: 2.9 years; Total water savings: $11,379 (4-year)

Summary of Findings Related to Landscape Water Conservation BMPs:

- New spray heads were installed with 4-inch pop-up height, check valves and pressure control
- New nozzles were installed to better control the spray
- Check valves were installed in rotors
- Rain and freeze sensors were installed on controllers
- Goal was to beat 30-inches annually or lower
- Greenfield:
  - 2001 usage went down from 61.7 to 50.1 inches
  - Three year savings of 2.7 million gallons or 8 acre-feet.
- Liverpool:
  - 2000 usage went down from 63.0 to 30.0 inches
  - Down 53% first year
  - Four year savings of 4.5 million gallons or 14 acre-feet

Limitations: N/A

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Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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60. Medina, Jonnie G., and Julia Gumper, 2004: YARDX: Yield And Reliability Demonstrated in Xeriscape: Final Report. Metro Water Conservation, Incorporated, Littleton, CO, 140 p. www.coloradowaterwise.org

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description: The YARDX project is one of five field projects of Reclamation's National Xeriscape Demonstration Program (NXDP) established to study the benefits of installing Xeriscape under differing climatic and other potentially impacting conditions.

Year(s) Data Collected: 1997-2002

Quantitative/Qualitative: Quantitative

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Summary of Findings Related to Landscape Water Conservation BMPs:

Abstract Extracted from Report:

Metro Water Conservation, Inc. (MWCI) of Denver, Colorado, in partnership with the Bureau of Reclamation, conducted a water conservation study known as the Yield And Reliability Demonstrated in Xeriscape (YARDX) project to estimate the benefits of water-conserving landscaping known as Xeriscape. Benefits to be assessed were seasonal water savings, landscape installation, and annual maintenance costs. Seven municipalities from Fort Collins, Colorado, to Colorado Springs, Colorado, participated in the study. The YARDX project is one of five field projects of Reclamation's National Xeriscape Demonstration Program (NXDP) established to study the benefits of installing Xeriscape under differing climatic and other potentially impacting conditions.

YARDX was conducted from 1997 through 2002. The project included seven field demonstrations, each with some differing attributes, including Xeriscape application type (retrofits or new starts), application level (high or moderate water savings designs), yard size, irrigation method, socio-economic level, and soil

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type. In seven demonstrations, control groups of traditional high water use turf were established with similar characteristics to Xeriscapes, except for landscape type. Participants had to install Xeriscapes, except at one demonstration. All participants had to maintain them with no major revision during the study period. Xeriscape participants were provided a small rebate to join the study, and were given education on installing and maintaining Xeriscapes. One demonstration involved comparison of older, established Xeriscapes, with comparable control landscapes.

Data analysis of historical water use established the need for sample sizes of approximately 30 properties studied over 4 growing seasons, to have at least a 90-percent chance of detecting a 30-percent change in water use at the 5-percent significance level. The demonstrations yielded high-quality data that generally enabled the estimation of water savings and annual maintenance costs.

Xeriscape installation costs ran a modest $0.90 to $1.45 per square foot, with homeowners in the project contributing a substantial amount of labor. Demonstrations obtained water savings from 18 to more than 50 percent over control samples. Results indicated that relatively consistently, water savings in the 30-percentile range could be obtained for properly designed and maintained Xeriscapes. Annual maintenance costs ranged from $0.34 to $1.33 per square foot. For cost estimation, homeowner labor was computed at $18 per hour. Generally, the maintenance cost of the Xeriscapes sampled, compared to the non-Xeriscaped properties, was found to be less than controls during the plant establishment years, but somewhat more during the plant maturation years. This suggests that as Xeriscapes age, they gradually require more maintenance, compared to traditional landscapes.

Xeriscape participants overwhelmingly expressed satisfaction with their landscapes and would freely recommend this type of landscaping to others. The information gained in the YARDX project should provide an additional alternative in dealing with water conservation needs in the Colorado Front Range.

Limitations: The final year of data collection 2002 was influenced by drought.

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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61. Colorado Springs Utilities. (n.d.). Residential Irrigation Equipment Rebates. Retrieved June 15, 2009, from Colorado Springs Utilities: http://www.csu.org/residential/greenback/rebates/irrigation/item1117.html

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other

Study Description: Rebate program information, including estimates of savings associated with various irrigation technology rebates. Source of data not specified on website.

Year(s) Data Collected: N/A (Information retrieved from website in June 2009.

Quantitative/Qualitative: Semi-quantitative

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Water Savings to Customers:
Weather-based irrigation controllers: $50/yr estimated savings
Matched precipitation nozzles: save the average customer nearly $25 each year
Sprinkler heads with check valves: a savings of at least $30 each year.

Rebate Program allows up to $200/customer

Summary of Findings Related to Landscape Water Conservation BMPs:

Weather-based irrigation controllers: …can reduce irrigation water usage by an average of 16%" Elsewhere, "Studies suggest irrigation savings of about 20 percent or more can be expected. Actual savings is dependent of previous watering habits and weather, but a reasonable range is 10 to 30 percent. It can also reduce runoff by more than 50 percent."

Rain Shutoff Device: Savings is dependent on the frequency and volume of rainfall and watering, but a reasonable range in Colorado Springs is 5 to 10 percent of irrigation use.

Sprinkler heads with check valves: Savings is dependent on a number of factors including the number of cycles run, but 5 to 10 percent of irrigation use is conservative.

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Matched precipitation nozzles: Savings is dependent on a number of factors, but research suggests that 10 to 20 percent is possible.

Other CSU fact sheets state that prior to mandatory water restrictions in 2002, SF residential use was 122 gpcd. In 2006, usage had decreased to 96 gpcd, attributable to watering restrictions, regional drought awareness, favorable weather conditions and water conservation programs.

Limitations: Source of estimates assumed to be other literature or vendors.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low (estimates general and basis is unknown at this time)

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62. Broustis, D. (2008). Moving Toward Water Use Metrics (and Benchmarks), Seattle Parks and Recreation. *WaterSmart Innovations '08. Las Vegas, NM, October*. http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008

General Category: Irrigation, General

GreenCO BMP Category: Irrigation, Landscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ **Government/Agency** ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☐ **Other**

Study Description: Presents suggested approach to development of water use metrics/benchmarks. May provide a template for consideration in Colorado

Year(s) Data Collected: N/A

Quantitative/Qualitative: Designed to facilitate quantitative evaluation of data

Cost Data: ☐ **N/A** ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: ***none***

Summary of Findings Related to Landscape Water Conservation BMPs:

Selected notes clipped directly from Powerpoint Presentation:

Residential: Outdoor benchmarks limited, data not as good
Multifamily: Submetering results in lower use
Irrigation: Weather-based control reduces use
GPCD vs. g/sq ft
Recommendations:

- Develop relevant metrics based on end use
  - Housing: People are more important than square footage
  - Commercial: Square footage may be appropriate
  - Irrigation: Consider weather, area and landscape type
- Agree upon standardized metrics
  - Residential
    - Gallons per capita per day
- Commercial
  - Set assumptions and methods for addressing each sector
  - Address odd uses
- Establish a clearinghouse for information

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- Encourage end users (and possibly utilities) to populate databases
    - Poor or inaccurate utility records may confound data from utilities
- Proposed Water Use Indices (WUI)
    - WUIirr: inches/irrigated sq. ft. or CCF/1,000 irrigated sq. ft.
- Current irrigation "benchmarking"
    - Weather-based control to reduce use
        - Doesn't necessarily optimize opportunities
- Water budgets(calculation methodology should be standardized)
- But how to compare actual use from year to year?
    - Annual variability of +/-15%...or more
- Irrigation use tells only part of the story if it isn't weather normalized
    - ET isn't the be all/end all of efficiency
    - ET alone doesn't correct actual consumption for annual variability
        - Rain and actual water use vs. presumed ET need
- Weather-corrected irrigation benchmarking proposed using Irrigation Utilization Index (IUI)
    - WUIIrr = inches/irrigated square foot (non-weather adjusted)
    - IUI = Average WUIIrr * (Current need/Average need)
    - Using IUI, ET and rain in a given year can be compared to an average or baseline use
        - Tells if current water use is higher or lower than anticipated
- Stumbling Blocks:
- Databases are not as sexy as HETsand rain barrels
- Residential year-round irrigation data hard to separate from indoor use
    - Outdoor use could confound data
    - Seasonal irrigation: could be segregated
    - Inconsistent/inaccurate fixture consumption "in the field" could skew results
    - Useful to know to address concerns and minimize use
- Commercial odd uses skew comparisons
    - Accurately and consistently handling odd uses
- Commercial irrigation could be difficult to categorize
    - Difficult to categorize the wide range of landscape options
    - But could drive end users to efficient choices
- Recommendations to standardize metrics, utilize existing knowledge, seek simplicity/consistency, designate one or more information warehouses, populate database/share information

Limitations:

Expected Transferability of Findings in Developing Quantitative Estimates:

☐ **High** ☐ Medium ☐ Low

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63. Isaman, V. (2008). Topsoil, Compost and Water Quality Guidelines for Landscaping Help Reduce Irrigation Demands. *WaterSmart Innovations '08. Las Vegas, NM, October*. http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008

General Category: Soil Amendment

GreenCO BMP Category: Soil Amendment

Study Type: ☐ Journal ☒ Private Study ☐ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other

Study Description: Presentation on benefits of composting.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Qualitative

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- Premise: The most state of the art irrigation controllers, Eto based weather systems, devices and sensors will not compensate for inherent landscape deficiencies…
- Benefits of Compost:
  - Improve soil structure resulting in increased water infiltration rates
  - Increase water-holding capacity
  - Increase nutrient holding capacity
  - Improve the micro-organism environment
  - Improve root growth through reducing compaction
  - Improve tilth (the 'workability' of the soil; clays don't stick, sands don't fall apart)
  - Reducing erosion (by increasing soil infiltration and water holding)

Limitations: Quantitative water conservation estimates not provided

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☐ **Low**

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64. Martien, L. (2008). Conservation Audits of Denver Public Libraries. *WaterSmart Innovations '08. Las Vegas, NM, October*. http://www.watersmartinnovations.com/2009/sessions-all.php?year=2008

General Category:

GreenCO BMP Category: Irrigation Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other benchmarking

Study Description: Results of Denver Public Libraries Conservation Audits

Year(s) Data Collected: 2006

Quantitative/Qualitative: Quantitative water use information with projected savings; actual implementation results not yet available.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:
Irrigation Savings:
• 3,397– kgal annually
• $11,623– annual savings
• $81,635– present worth of savings
• $6,552-– cost of recommended measures
• 12.5– benefit/cost ratio

Summary of Findings Related to Landscape Water Conservation BMPs:
- Study Scope:
  - 22 library branches – 18 irrigation audits
  - Serve 3,800,000 customers annually
  - 5,441 customer days per year
  - 227,787 ft2 irrigated area
  - Total water use– 11,580 kgal in 2006
  - Irrigation– 6,392 kgal in 2006 (58%)
- Shows approach to defining irrigation use
- Practical Problems: limited staff, inadequate irrigation scheduling, vandalism
- Recommendations:
  - Utilize controller percent adjust feature
  - Improve staff training
  - Track billing data
  - Make irrigation upgrades w/landscape upgrade

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- Schedule routine maintenance

Limitations: Don't know outcome of project/whether recommendations were implemented and whether they were successful.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ **Medium** ☐ Low

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65. Pennsylvania State University. (1996). *Using Composts to Improve Turf Performance*. University Park: College of Agricultural Sciences Cooperative Extension. http://turfgrassmanagement.psu.edu/composts.cfm

General Category: Soils

GreenCO BMP Category: Soil Amendment

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other

Study Description: Guidelines on improving turf performance using compost

Year(s) Data Collected: N/A

Quantitative/Qualitative: Guidance oriented; quantitative savings not provided.

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

- In clay soils, good quality compost will improve structure, reduce surface crusting and compaction, promote drainage, and provide nutrients.
- In sandy soils, compost increases water and nutrient retention, supplies nutrients, and increases microbial activity.
- These improvements promote faster turf establishment, improved turf density and color, increased rooting, and less need for fertilizer and irrigation.

Limitations: Quantitative approach to estimating reduced irrigation requirements not provided.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☐ Medium ☒ Low

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66. Denver Parks and Recreation. (2009). Martin Luther King Jr. Boulevard Post-Construction Analysis. Fact Sheet provided by Jill Wuertz. June. Denver, CO.

General Category: Irrigation, Landscape, Xeriscape

GreenCO BMP Category: Irrigation Efficiency, Xeriscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other

Study Description: Based on the MLK Boulevard Master Plan completed in 2001, the project goals included the beautification of the boulevard's medians, commemoration of Dr. King's legacy, and improvement of maintenance operations and safety conditions. Highlights from the project include: (1) Construction of stone entry monuments at Colorado Boulevard and Quebec Street to identify the Park Hill neighborhood and commemoration of Dr. King's legacy by exhibiting public art along the corridor. (2) Enhancement of the existing flower beds at Monaco Parkway, and new raised planting beds at the ends of every median. (3) Median tree infill with new deciduous and evergreen trees to provide a continuous canopy. (4) Improved water conservation through complete renovation of the existing irrigation system and plant selection. Construction of the project occurred from January 2005 – February 2006 for the approximately 2.1 mile stretch.
Year(s) Data Collected: 2001-2007

Quantitative/Qualitative: Quantitative

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data: Irrigation portion of costs for the project: approx.$300,000.

Summary of Findings Related to Landscape Water Conservation BMPs:
From notes prepared by Jill Wuertz:

DPR Water Conservation reviewed aerial photographs and analyzed 7 of the 15 individual medians within the project boundary. The pre-construction condition of MLK Blvd was a predominantly turf median with tree plantings. The project converted these original turf medians into combinations of turf, planting areas, hardscape and irrigated mulched tree beds. See Fact Sheet for detailed breakdown.

Replacement of the irrigation system in its entirety was recommended for this project based on three reasons: 1) the forty to fifty year life of the existing systems has exceeded the expected life span (typically 15 years) for piping and most irrigation equipment, 2)

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irrigation inefficiencies have grown due to lack of availability of original irrigation equipment, advancements in irrigation technology and years of grit build-up at curbside locations hampering efficient management and operation of the irrigation system, 3) the addition of the proposed splash guard at back-of-curb locations required extensive modifications to the existing irrigation system. Seventeen water meters serving the project site and were determined to be too numerous for a project of this size. Estimates revealed that only eight to ten meters of the existing seventeen meters were required to properly irrigate the project site. Through a process of linking a single water meter to multiple medians via a common irrigation main with street crossings, a means to reduce some costs and upgrade the irrigation control system to current technology was provided. Cost savings were realized through the requirement for fewer radio-controlled irrigation field controllers, fewer backflow prevention devices needing to be replaced or installed, and fewer irrigation management components such as master valves and flow sensors being installed.

Water Consumption Analysis:

Water consumption was analyzed during pre-construction and post-construction periods. Precipitation and evapotranspiration requirements do affect water consumption within a given year, however patterns within consumption can still be assessed. Prior to construction improvements, the irrigation system constructed during the 1950's-60's prevented efficient watering from taking place. In 2001 and 2002, the system consumption shows a 30-35% overwatering based on a 30" per acre water budget for bluegrass turf that is typically used within Denver Parks and Recreation. Overwatering during 2006 possibly takes into consideration a dry year as well as plant establishment watering from the newly constructed medians. Water consumption in 2007, an above normal precipitation year (17" versus 15.81"), and 2008, a below normal precipitation year (10.83" versus 15.81") clearly shows that the irrigation and landscape upgrades allows operation of the system in a way that meets a water budget based on plant requirements for turf, planting areas and mulched tree beds. The current water consumption also shows a savings of 48% from an average of 2001 and 2002 versus an average of 2007 and 2008.

Limitations: Will be valuable to track performance long-term and see similar data from other sites. Results could be adjusted to reflect precipitation and ET variations in the years assessed.

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low

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67. U.S. Environmental Protection Agency. (1998). Water Conservation Plan Guidelines. Washington, DC: Office of Water. http://www.epa.gov/WaterSense/pubs/guide.htm.

General Category: General

GreenCO BMP Category:

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other benchmarking

Study Description: Appendix B from EPA's Water Conservation Plan Guidelines provide reductions in end use estimates "compiled from various sources."

" Actual water savings can vary substantially according to a number of factors. These data are provided for illustrative purposes only and may not be current or applicable. To the extent practical, planners should regionally appropriate or system-specific assumptions and estimates."

Appendix D also lists useful information resources that may have additional information.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Quantitative, but not specific to Colorado

Cost Data: ☐ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

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Excerpts from Table B-4: Benchmarks for Savings from Selected Conservation Measures

Category and Level (1-3)	Measure	Estimated Reduction in End Use
Universal metering (1)	Connection metering	20 percent
	Submetering	20 to 40 percent
Water accounting and loss control (1)	System audits and leak detection	Based on system
Costing and pricing (1)	10% increase in residential prices	2 to 4 percent
	10% increase in nonresidential prices	5 to 8 percent
Information and education (1)	Public education and behavior changes	2 to 5 percent
End-use audits (2)	Outdoor residential use	5 to 10 percent
	Large landscape water audits	10 to 20 percent
Pressure management (2)	Pressure reduction, system	3 to 6 percent of total production
	Pressure-reducing valves, residential	5 to 30 percent
Outdoor water-use efficiency (2)	Low water-use plants	7.5 percent
	Lawn watering guides	15 to 20 percent
	Large landscape management	10 to 25 percent
	Irrigation timer	10 gpcd
Water-use regulation (3)	Landscape requirements for new developments	10 to 20 percent in sector
	Graywater reuse, residential	20 to 30 gpcd

Notes:

- With regard to low-water use plants, EPA discusses cooperating with local nurseries to ensure availability of low water plants.
- EPA encourage selective irrigation submetering to improve irrigation management

Limitations: Data are general ranges, not specific to Colorado or site-specific conditions

Expected Transferability of Findings in Developing Quantitative Estimates:
☒High ☒ Medium ☐ Low (*useful for basic "reality checks"*)

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68. Mayer, P., Hayden, M., Davis, R., Caldwell, E., Miller, T., & Bickel, P. (2009). *Evaluation of California Weather-based "Smart" Irrigation Controller Programs*. Presented to the California Department of Water Resources by the Metropolitan Water District of South California and the East Bay Municipal District. California Urban Water Conservation Council. http://www.aquacraft.com/Download_Reports/Evaluation_of_California_Smart_Controller_Programs_-_Final_Report.pdf

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer (*consultant & local governments*)

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other

Study Description: *(selected excerpts quoted from Executive Summary; fairly lengthy notes are provided for this study due to its complexity and magnitude)*

This report presents an evaluation of the California Weather-Based Irrigation Controller (WBIC) programs. This project presents empirical data on the performance of smart controller products distributed and installed through different methodologies in a wide variety of settings. This report is intended to fulfill a key requirement of the DWR grants and provide information and guidance for future smart controller and landscape conservation programs.

This report reflects the results of an effort that began over four years ago in cooperation with the California Department of Water Resources, the California Urban Water Conservation Council, the Metropolitan Water District of Southern California and their 26 member agencies, and a consortium of six water agencies in northern California led by the East Bay Municipal Utility District.

Improving irrigation efficiency is perhaps the single most important goal for water conservation professionals in the coming years. In support of this goal, the California Department of Water Resources (DWR) funded two large-scale regional efforts to affect urban irrigation efficiency and reduce runoff through the installation of smart controllers.

The fundamental unit of analysis for this smart controller evaluation study was on the site level. A site is a property where one or more smart controllers were installed. A single-family residential property with a single smart controller is a site as is a multi-family housing complex with 20 smart controllers installed. Only sites for which sufficient data were provided could be included in the analysis portion of this study. Utility partners

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were able to provide the necessary data for 2,294 sites encompassing 3,112 smart controllers to be included.

The southern California smart controller programs were made up of a large number of distribution programs developed and implemented by more than 20 water agencies. MWD's member agencies invested significant time and resources to implement and market their smart controller programs, tried various approaches, and made mid-stream adjustments because of lack of participation.

Three fundamental smart controller distribution program methodologies were implemented in southern California: rebate and voucher programs, exchange programs, and direct installation. While some agencies tried to target the smart controllers to historically high irrigators, by and large, the southern California program effort was a general distribution program that provided smart control technology to interested and motivated customers.

The northern California Smart Controller programs were made up of rebate, voucher and direct installation programs at five participating agencies under the leadership of the East Bay Municipal Utility District. In an effort to maximize potential water savings, agencies in northern California targeted customers with historically high outdoor water use demands through an analysis of historic billing data.

Fourteen different brands of controller were included in the analysis portion of this study.

Participants were responsible for installing about 60% of the smart controllers in this study. They could have hired someone to perform the installation for them, but that level of detailed information is not known. At about 40% of the sites the controller was installed and/or programmed by an irrigation professional, utility representative, or other party besides the customer.

Other Notes:

"Irrigation demand is the single largest end use of water in the urban sector in California. Irrigation demands typically account for 50% or more of the total water used in many California homes and businesses."

"Research studies over the past 8 years have measured statistically significant water savings and runoff reduction achieved through the implementation of smart irrigation control technology [Citing various references--(Bamezai 2004), (DeOreo, et. al. 2003), (IA, 2006, 2007, 2008), (Jakubowski 2008), (Kennedy/Jenks 2008), (Mayer, et. al. 2008), (MWDOC, IRWD 2004), (SCWA 2005), (US DOI 2007, 2008)]. Over that time nearly

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20 smart control product developers and manufacturers have emerged and weather-based irrigation control has become a strategic focus of the irrigation industry."

Year(s) Data Collected: 2002-2006 (data weather-normalized)

Quantitative/Qualitative: Highly quantitative with statistically based study design and analysis. Quantitative study approach may be useful to implement in Colorado.

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data: Installing smart controllers may or may not be cost-effective for a utility or their customers. The determination of cost-effectiveness depends upon the water savings, the avoided cost for water, local retail water rates, the discount rate factor used, and the expected useful life of the product.

The cost-effectiveness analysis was conducted from two perspectives: (1) the water utility; and (2) the end user or customer. See the report for results.

Summary of Findings Related to Landscape Water Conservation BMPs: *(selected excerpts quoted from Executive Summary)*

The evaluation of research described in this report provides strong evidence for the following findings and conclusions:

- On average smart controllers are a moderately effective measure for reducing the amount of water applied by automatic irrigation systems, while maintaining the health, and appearance of landscapes.
- When seeking irrigation water savings, the pre-existing level of excess irrigation at the site is the most important factor to consider.
- The water savings achieved through installation of smart controllers can be maximized by targeting the technology to irrigators with historically high irrigation application rates, not simply customers with high irrigation use.
- The many irrigators who historically apply less than the theoretical irrigation requirement for their landscape are likely to increase their irrigation application rate after installing a smart controller.
- Survey results indicate that smart controllers are likely to achieve a high degree of customer acceptance once they more broadly penetrate the consciousness of irrigation contractors and the general public.
- The utility programs implemented through the DWR grant have succeed in raising public awareness of this technology, but survey results suggest most consumers have no knowledge of smart irrigation control.
- Smart controllers can achieve cost effective water savings for utilities and irrigators under some cost and pricing scenarios, however this technology will not be cost effective for all utilities and customers.

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- Most of the smart control brands and technologies evaluated in this study reduced irrigation demands on average, but not all of these reductions were statistically significant.

The average weather-normalized change in water use per smart controller site is presented in Table ES.3 of the report. Overall, outdoor water use was reduced by an average of 47.3 kgal per site (-6.1% of average outdoor use) across the 2,294 sites examined in this study as part of the California Weather-Based Irrigation Controller Programs. This reduction was found to be statistically significant at the 95% confidence level.

At smart controller sites in northern California the average change in outdoor use was a reduction of 122.2 kgal per site (-6.8% of average outdoor use). This change was not statistically significant at the 95% confidence level, but was significant at the 90% confidence level.

At smart controller sites in southern California the average change in outdoor use was a reduction of 30.9 kgal per site (-5.6% of average outdoor use) and this was statistically significant at the 95% confidence level.

The overall impact of smart controllers installed in this study was to reduce irrigation demands, but the results suggest that those who historically apply less than the theoretical irrigation requirement for their landscape are likely to increase water use after installing a smart controller. The Application Ratio is a measure of how closely irrigation applications at a site matched the theoretical irrigation requirement determined from proximal ET weather stations. The level of excess or under irrigation (pre-AR) prior to the installation of the smart controller was the most important factor in determining if a site increased or reduced water use with the smart controller. In this study, a total of 1,300 (56.7%) of the 2,294 study sites had a statistically significant reduction in weather-normalized irrigation application ratio while 959 (41.8%) sites had a statistically significant increase in application ratio. For 35 (1.5%) of sites, there was not a statistically significant change in application.

Sites that increased application after installation of a smart controller had a mean pre-application ratio of 131% and a median of 95%. The median indicates that more than half of these customers were applying less than the theoretical irrigation requirement prior to the installation of the smart controller. Since smart controllers are designed to adapt irrigation to match the theoretical requirement, it would be expected that installing a smart controller at a site with a history of applying less than the theoretical irrigation requirement will result in increased demand.

Factors that Influenced Water Savings:
Multiple regression analysis was used to determine the factors that did and did not influence changes in application ratio. This analysis methodology allowed the researchers to examine the relationship between key site characteristics (such as controller technology) and application ratio after adjusting for factors known to influence savings such as the application ratio prior to installation of the smart controller. The following

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factors were examined and determined to have a statistically significant impact on the change in application ratio:

- Pre-smart controller Application Ratio – the application rate relative to the calculated theoretical irrigation requirement
- Installation method (self vs. professional)
- Participating agency (sometimes significant)

Factors that Did Not Influence Water Savings:
The following factors were examined and determined not to have a statistically significant impact on the change in application ratio:

- Site classification (residential vs. non-residential)
- Region (northern vs. southern California)
- Climate zone (coastal, intermediate, inland)
- Smart irrigation control methodology (historical ET, on-site readings, remote readings, soil moisture sensor)

See the report for differences in performance among brands of controllers, as well as discussion of long-term performance considerations.

Other Note: "The irrigation controller is important, but only one piece of the puzzle. Even the best, most water efficient controller cannot make up for poor system design, installation, and maintenance. The focus of this report is on irrigation controllers, but a holistic approach to irrigation systems and landscape design and maintenance is required to achieve the full potential of water savings in the urban irrigation sector."

Study provides a detailed breakdown by climate, controller type, installation type, etc. Study design may be a useful model to follow for application in Colorado.

Limitations: Conducted in California

Expected Transferability of Findings in Developing Quantitative Estimates:

☒ High ☐ Medium ☐ Low

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69. GDS Associates. (2002). Quantifying the Effectiveness of Various Water Conservation Techniques in Texas. Texas Water Development Board. http://www.twdb.state.tx.us/assistance/conservation/gdsstudy.asp.

General Category: Irrigation

GreenCO BMP Category: Irrigation Audits

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☒ Other benchmarking

Study Description: In May 2001, the Texas Water Development Board (TWDB) contracted GDS Associates, Inc. (GDS) to perform a research study quantifying the effectiveness of various water conservation techniques (Study). The main purpose of the Study is to provide information regarding the effectiveness and costs of water conservation strategies on a regional level. The study also provides the sixteen water-planning regions (Regions) with comprehensive water conservation planning alternatives, as well as providing the TWDB with information to assist in the development of more accurate water demand scenarios. Landscape practices included in the study focused on:

- SF Irrigation Audit for High Users
- SF Rainwater Harvesting
- SF Rain Barrels
- MF Irrigation Audit
- MF Rainwater Harvesting
- Commercial Irrigation Audit
- Commercial Rainwater Harvesting

Where water efficiency measures are not affected by household size the savings per measure (gpd) is used to calculate the savings per person (gpcd). Generally, these measures affect residential outdoor water use.

Maximum Participation Rate Estimates: The maximum participation rates are based upon the maximum percentage of eligible customers who could reasonably be expected to participate in an implemented water efficiency measure. Assumptions were made for each measure regarding the percentage of customers that have already implemented a measure due to regulation, natural replacement, or other factors. The maximum participation rates are also based on the assumption that an effective and aggressive marketing and outreach approach effort is implemented. For the purposes of this Study, maximum participation rates do not vary between Regions.

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Projected Lifetime Considerations: irrigation audits are extremely dependent on customer education. Once an irrigation audit is complete, the savings depend on how well customers implement the recommendations to adhere to a watering schedule, repair broken sprinkler heads, etc. In order to maintain the savings of an irrigation audit over time, frequent follow-ups with the customer is necessary.

Year(s) Data Collected: N/A

Quantitative/Qualitative: Quantitative estimates based on literature and assumptions

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data: Costs estimated using direct and indirect costs.

Summary of Findings Related to Landscape Water Conservation BMPs:

SF Irrigation Audits – High Users
Maximum Participation Rate: The assumption is that 10 percent of residential customers are high users (consume more than 20,000 gallons per month for outdoor usage during the summer months) who would qualify for this measure and that half of these customers would participate in the program. Therefore, 5 percent of eligible customers could be expected to participate.
· Estimated Costs: $70/audit
· Water Savings: 50 gallons per measure (gpd). The savings calculation assumes an average outdoor water use of 500 gpd and an average audit savings of 10 percent. Therefore, a SF irrigation audit would result in a reduction of 50 gpd.

MF Irrigation Audit

Maximum Participation Rate
With multi-family customers, participation rates are higher than with SF customers due to the cost savings of more efficient large-scale irrigation systems to property managers and owners and the larger number of irrigation audits made by one decision maker. Therefore, it is assumed that 50 percent of eligible customers will participate in a MF irrigation audit.
· Estimated Costs: $150
· Water Savings 125 gallons per day. The savings were calculated based upon the following assumptions:
- 50,000 gallons per month average outdoor water use;
- the audit results in 15 percent reduction of outdoor water use; and
- the estimated savings computes to 250 gallons per day during the summer months and are then annualized.

Commercial Irrigation Audit
Maximum Participation Rate-- With multi-family customers, participation rates are higher than with SF customers due to the cost savings of more efficient large-scale irrigation systems to property managers and owners and the larger number of irrigation audits made by one decision maker. Therefore, it is assumed that overall commercial water use can be reduced by one percent.

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· Estimated Costs Direct Costs: $150
· Water Savings 125 gallons per day. The savings were calculated based upon the following assumptions:

- 50,000 gallons per month average outdoor water use;
- the audit results in 15 percent reduction of outdoor water use; and
- the estimated savings computes to 250 gallons per day during the summer months and are then annualized.

Rainwater Harvesting estimates were also provided, but not included in the review since they are not currently viable under Colorado water law for most urban areas.

Analysis of estimated savings divided among urban, suburban and rural areas, with estimates for base use, seasonal use and dry year provided.

Limitations: Developed for Texas.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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70. Texas Water Conservation Advisory Council. (2008). A Report on Progress of Water Conservation in Texas. http://www.savetexaswater.org/documents/WCAC_report.pdf.

General Category:

GreenCO BMP Category:

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☒ Other benchmarking

Study Description: Annual report on water conservation submitted to legislature with recommendations to maximize water conservation benefits.

Year(s) Data Collected: Annual report for year ending 2008

Quantitative/Qualitative: Qualitative, with a strategy defined for a more quantitative approach to assessing conservation

Cost Data: ☐ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data:

Summary of Findings Related to Landscape Water Conservation BMPs:

According to the 2007 State Water Plan, conservation accounts for nearly 23 percent of the projected additional water supply needed in 2060—a total of about two million acre-feet per year, which is enough to supply half of the current annual municipal use in Texas. To accomplish this, 11 Recommendations are central focus of report:

- Recommendation 1: Develop methodology, metrics, and standards for water conservation implementation measurement and reporting
- Recommendation 2: Develop specific guidelines for how gallons per capita per day should be determined and how it should be applied to population-dependent water use only
- Recommendation 3: Develop reporting guidelines for improved data collection
- Recommendation 4: Expand data collection efforts to include all water providers and water use categories
- Recommendation 5: Develop a pilot project for water use data reporting
- Recommendation 6: Develop a pilot project for determining population figures appropriate for certain water use metrics

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- Recommendation 7: Provide the Council with the necessary resources to sufficiently develop and implement tools to monitor implementation of water conservation strategies recommended in the regional water plans
- Recommendation 8: Expand public awareness of water conservation statewide and coordinate campaigns at the state, regional, and local levels
- Recommendation 9: Establish a statewide water conservation recognition program
- Recommendation 10: Collaborate with national efforts to develop a clearinghouse of resources, tools, and best management practices
- Recommendation 11: Direct the Texas Water Development Board to develop a certification process for conservation training programs and provide preference for technical and financial assistance to these certified programs.

Limitations: Specific to Texas

Expected Transferability of Findings in Developing Quantitative Estimates:
☒ High ☐ Medium ☐ Low
(general recommendations and strategy may be helpful to Colorado)

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71. Zoldoske, D. F. (2003). *Improving Golf Course Irrigation Uniformity: A California Case Study*. Center for Irrigation Technology, California State University, Fresno. California Agricultural Technology Institute. http://cati.csufresno.edu/cit/Golf%20Course%20Irrigation%20Nozzle%20Study.pdf

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other

Study Description:
Five golf courses in California participated in this study, including a total of 606 irrigated acres representing 108 holes of golf (six-18 hole courses). The time span of data collection was one year prior to the nozzle change and one year of operation post nozzle change.

Year(s) Data Collected: N/A

Quantitative/Qualitative:

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data: Since all of the water on the participating golf courses is pumped, there is significant energy savings in addition to water savings. The average estimated gross water savings per golf course in this study (for 18 holes) is 16.6 acre feet per year. For the purpose of illustration, the study assumes a one-time cost of nozzle replacement is $12,000. The cost of water and energy would need to be $361 an acre-foot to achieve an estimated two-year payback period to recover the cost of re-nozzling based on the assumptions listed above. Water and energy costs higher than $361 would provide a shorter payback period, while lower water and energy costs would require a longer payback period to recoup the investment. Also higher or lower initial re-nozzling costs would effect this estimate, either positively or negatively.

Additionally, the golf course superintendent will likely put a dollar value on any perceived improvement in turf quality, reduction in hand-watering, and/or playability of the course. This would favorably impact or shorten the payback period. Finally, each golf course that participated in this study had water savings either higher or lower than the average used in the example used, so individual savings varied. The ultimate determination of whether re-nozzling is a viable option will be based on local economics, and must include all relevant conditions.

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Summary of Findings Related to Landscape Water Conservation BMPs:

The estimated total gross water savings for all the participants was 99.8 acre feet of water (32,519,304 gallons) or 6.5% of the applied water. Individual golf course gross water savings ranged from positive 21.4% to a negative <11.3%>. Adjusting for useful rainfall, the estimated savings falls to 82.9 acre feet (27,012,799 gallons) or 5.7% of the applied water. Individual golf course-adjusted water savings ranged from a positive 14.7% to negative <3.1%>. Assuming the actual savings is somewhere in between, the total savings experienced may be nearer 91.4 acre feet (29,782,507 gallons) and an average savings of 6.1% per golf course of the applied water.

Limitations: Located in California.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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72. **Haley, M., & Dukes, M. (2007). Evaluation of Sensor Based Residential Irrigation Water Application.** ***2007 ASABE Annual International Meeting*** **(Paper No. 072251). Minneapolis: American Society of Agricultural and Biological Engineers.** **http://asae.frymulti.com/abstract.asp?aid=23040&t=2**

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☒ Site-specific ☒ Regional ☐ Summary ☐ Other _____

Study Description:

An irrigation study to determine the effects of sensor based irrigation controllers on residential irrigation water use is described in this paper. This project included 59 homes in Pinellas County, Florida, with automatic in-ground residential irrigation systems.

Experimental treatments evaluated include: T1) an automatic time based irrigation controller, set and operated by the cooperator, with the integration of a soil moisture sensor, T2) a rain sensor with a timer-based irrigation schedule, T3) an automatic time based controller only, and T4) similar to T2 with educational material detailing seasonal irrigation recommendations based on historical climate data.

Related Study Cited: Haley et al. (2007) conducted study in St. Johns River Water Management District, where 64% of water went to irrigation, increasing to 88% in the summer. Setting irrigation controllers to historical resulted in a 30% reduction in irrigation use, with a 50% reduction when this was combined with microirrigation of planting beds.

Year(s) Data Collected: 2006-2007

Quantitative/Qualitative: Quantitative

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:
Preliminary results show that sensors are successful for irrigation water use savings at the single family home level. Data reported here is from June 2006, through March 2007. In homes with the installation of the soil moisture sensors (T1), water savings of 51% have

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been recorded compared to homes with an irrigation time clock only (T3). With the installation of a rain sensor (T2) the water used was 19% lower than T3. A further decrease in the amount of water use occurred after the distribution of the educational materials, with a difference of 58% between the two rain sensor treatments (T2 and T4).

Limitations: Conducted in Florida

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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73. Dukes, M. D., Cardenas-Lailhacar, B. and Miller, G. (2008). *Evaluation of Soil Moisture-Based on-demand Irrigation Controllers Final Report,* August 8. Prepared for and funded by Southwest Florida Water Management District. **http://www.acclima.com/08images/research/Dukes,_M._et_al_(2008)_Evaluation_of_Soil_Moisture-based_on-demand_Irrigation_Controllers.pdf**

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: A four-year research project, funded by the Southwest Florida Water Management District (SWFWMD), to evaluate a SMS-based irrigation system was recently completed. Four different SMS models/brands were initially tested and, later on, two more brands were included.

The initial objectives of this experiment were to quantify irrigation water use and to evaluate turf quality differences between: 1) a time-based irrigation schedule system with and without a rain sensor, 2) a time-based schedule compared to a soil moisture sensor-based irrigation system, and 3) different commercially available irrigation soil moisture sensor (SMS) systems. Later on, the consistency of the different SMS units within a brand to control irrigation was evaluated, as well as their potential to completely automate the irrigation systems without the need for seasonal time clock adjustment by personnel ("set and forget").

The research was conducted at the Agricultural and Biological Engineering Department research facilities at the University of Florida, in Gainesville, Florida. The experimental area consisted of common bermudagrass [*Cynodon dactylon* (L.) Pers.] plots (3.7 x 3.7 m).

All agencies involved in addition to SWFWMD staff included: Pinellas County, Pinellas County Florida Yards & Neighborhoods, Institute of Food and Agricultural Sciences, Florida Nursery Growers and Landscape Association, Florida Irrigation Society, Tampa Bay Water, Florida Department of Agriculture and Consumer Services, and the City of St. Petersburg. In addition, the Florida Department of Agriculture and Consumer Services contributed funds toward the project.

Other background notes: "A recent study carried out by Haley et al. (2007) in Central Florida found that homeowners tended to irrigate by as much as 2-3 times the turfgrass requirements. It has been reported that over irrigation promotes the establishment and survival of some turfgrass weeds (Busey and Johnston, 2006), increases the severity of some

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pathogens (Davis and Dernoeden, 1991), and increases evapotranspiration (Biran et al., 1981). Control of irrigation by soil moisture or soil tension has been shown to reduce both over-irrigation (Augustin and Snyder, 1984) and nitrogen leaching below the root zone (Snyder et al., 1984)."

Year(s) Data Collected: 2004-2007

Quantitative/Qualitative: Quantitative

Cost Data: ☒N/A ☐ Savings from BMPs ☐Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

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 turfgrass quality below acceptable levels. Therefore, SMSs represent a promising technology for water conservation. Moreover, one SMS brand enabled a flexible watering schedule for turf, without the need for seasonal adjustments by personnel.

Limitations: Conducted in Florida and on field plots, as opposed installations operated by homeowners.

Expected Transferability of Findings in Developing Quantitative Estimates:
☐ High ☒ Medium ☐ Low

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74. Seattle Public Utilities. (2009). *Seattle Water Supply System Regional 1% Water Conservation Program, Saving Water Partnership 2008 Annual Report*. http://www.savingwater.org/docs/2008%20Annual%20Report.pdf.
General Category:

GreenCO BMP Category:

Study Type ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description: The regional 1% Water Conservation Program (1% Program) is sponsored by the Saving Water Partnership (SWP). This Partnership includes the City of Seattle retail service area (population 628,000) and a group of 17 utilities (population 416,000) purchasing water wholesale from the City of Seattle.

Residential Landscape Program Components

- Reduce peak water use
- Irrigation system performance
- Landscape watering behaviors
- Practices that affect watering (e.g. mulch, soil prep and plant selection)
- Irrigation system efficiency rebates
- Right Plant/Right Place promotion via retailer partnerships (nurseries, home & garden centers)
- Savvy Gardener e-newsletter and classes
- The Garden Hotline
- Natural Lawn & Garden Guides (how-to materials)
- Trainings for irrigation professionals
- Development of standards for irrigation component performance through Irrigation Association Smart Water Application Technologies Initiative
- On-line weather data, watering index and irrigation scheduling tools

Commercial Landscape Program Components

- Improve watering efficiency
- Upgrade irrigation equipment (controllers, rain sensors, drip)
- Improve scheduling & maintenance
- Targeted outreach to large commercial customers
- Provide site-specific recommendations and technical assistance
- Financial incentives (custom projects and set rebates)
- Targeted recruiting and promotion to large commercial customers

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- Market transformation by establishing and building vendor and contractor relationships
- On-line weather data, watering index and irrigation scheduling tools
- Trainings for irrigation professionals

A variety of supportive measures for the program include youth education, overall messaging and program evaluation.

The Saving Water Partnership (SWP), with the support of residential, commercial and institutional customers, completed the eighth year of the 1% Program (2000- 2010). Regional per capita use is continuing to decline when normalized for variation in weather conditions. In 2008 the 1% Program achieved 0.75 million gallons per day (mgd) of savings, for a cumulative total of 8.4 mgd.

In the landscape sector, the Savvy Gardener lecture series added a new winter class to keep the message going year-round, and built on the "Right Plant, Right Place" campaign to promote a 'climate-smart' message in partnership with participating garden centers. The irrigation rebate program conducted mailings in July and September, and co-sponsored the largest Washington Irrigation Contractors Association biannual professional training yet. In the commercial sector, two successful customer events were held. An Integrated Conservation Workshop included topics ranging from new technologies to customer motivation, and attracted more than 100 attendees. A Green Properties Forum attracted more than 40 property managers to learn about regional incentive programs. In addition a research study of a large customer, the University of Washington (U of W), showed that their cumulative efforts since 2000 have reduced their water use by 30 to 40%, saving nearly $20 million.

Since 1990, water consumption has steadily declined due to the combined effects of conservation programs, increases in water and sewer rates, the state plumbing code, and improved system operations, despite continued population growth. Annual consumption is now about 123 mgd. The last time the Seattle regional system used that little water was about 50 years ago.

Year(s) Data Collected: 2008 (with reference to past 8 years)

Quantitative/Qualitative:

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: Cost was not the primary purpose of this report. Cost data are assumed to be available. **"**One of the motivating factors behind the aggressive conservation program is that **c**ost-effective extension of existing supplies. The measures identified in the 1% Program are less costly on a per unit basis than developing most traditional new sources of water supply. This benefits customers by keeping rates lower than they would be if a new source of supply

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were added to the system to meet demand in lieu of reducing it through conservation."

Summary of Findings Related to Landscape Water Conservation BMPs:

During 2008, the new annual savings associated with landscape water usage were: 0.08 annual average mgd at a cost of $ 269,000.

Price and Behavioral Savings include permanent conservation achieved from changes in customer water-using behaviors. Estimated to be 0.26 mgd annual average in 2008, behavior savings are difficult to separate from price savings since price has a strong influence in stimulating customers to change water using behaviors. The price savings estimate of 0.08 mgd is derived from the price elasticity and overlap parameters from SPU's water demand forecast model and actual changes in water and sewer prices. ET controllers are a key component of the program and have been shown to reduce water use by up to 30%. From review of a bar chart, it appears that the conservation component of the savings has grown ten-fold from 2000 to about 10 mgd (average annual) savings. Educational component involvement is detailed according to participation in the report. Landscape-related savings include:

2008 Landscape Rebates

	Number of Customers	**Savings (gallons/day)**
Single Family Homes	108	9,600
Single Family Non-Rebate	NA	21,055
Commercial (Including Multifamily)	44	16,506
Commercial Non-Rebate	NA	28,243
Total Savings		75,404

The rebates focused on ET and soil moisture sensor controllers.

"Soils amended with compost hold more moisture, decreasing the amount of water needed in gardens and the demands on water supply."

Savvy Gardener E-newsletter: By mid-2008, the newsletter had nearly 2000 subscribers and it was time to assess the newsletter's effectiveness and identify areas for improvement. SWP sent an electronic survey to subscribers and received 188 responses. We found that as a result of reading the newsletter, 40-48% of the respondents had applied mulch (40%), added compost to their soil (41%) and selected plants based on the sun, shade and soil in their garden (48%).

Commercial Outreach: staff conducted intensive outreach to commercial customers and to irrigation and landscape contractors who specialize in commercial properties. Forty-four commercial projects took place, saving nearly 17,000 gallons per day.

Contractor Training: In December, the SWP co-sponsored a weeklong irrigation training series with the Washington Irrigation Contractors Association (WICA) and, for the first time, with Cascade Water Alliance. Approximately 160 individuals attended one or more

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classes. The training included the only Spanish-language irrigation classes offered in western Washington. These Spanish language classes have been some of the most popular classes since the SWP began offering them in 2007. In 2009, staff will work to expand training opportunities for landscape professionals in the region by collaborating with other organizations and local irrigation distributors.

Evaluation Planning for Landscape Programs: Over the life of the 1% Water Conservation programs, staff have used many forms of evaluation to assess customer awareness, knowledge and behavior change in residential landscapes. An effort to summarize this work in a report has begun. The report is expected to be especially helpful to wholesale partners in understanding the complex nature of affecting change in customers' water use habits. Development of the report has been helpful to staff in identifying evaluation gaps as well as important continuing methods of evaluation. As a follow up to these recommendations, staff began development of a short set of key indicators to monitor behavior change on an annual basis. Prior to this, SWP has executed large and costly surveys that are several years apart. While these surveys are more comprehensive, they have not allowed staff to assess the impacts of the landscape programs on a more immediate basis.

Limitations: Data/savings are specific to Seattle, but overall approach has application in Colorado

Expected Transferability of Findings in Developing Quantitative Estimates:

☒High ☐ Medium ☐ Low

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75. Seattle Public Utilities. (2009). Water Smart Technology, Irrigation Case Study, Shoreline School District. Retrieved June 2009 from the Saving Water Partnership: www.savingwater.org

General Category: Irrigation

GreenCO BMP Category: Irrigation Technology

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description:
The Shoreline School District irrigates 16 sites scattered over approximately 15 square miles just north of Seattle. The suburban setting of the district's schools features extensive irrigated landscapes in addition to irrigated turf athletic and playfields.

Working with Seattle Public Utilities, the school district developed a comprehensive program to reduce the amount of water used in irrigation. Conservation strategies centered around installation of a weather-based control system. As a result, the school district's cost for irrigation water has dropped by up to 50 percent.

Year(s) Data Collected: Not specified in fact sheet; problem identified in 1992

Quantitative/Qualitative:

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Project Cost: $175,358
Rebate: $59,031
Water/Wastewater Savings: 20 million gallons/year = $50,600 per year
Payback time under 2 years.

Summary of Findings Related to Landscape Water Conservation BMPs:

- Moved toward 'scientific scheduling' of irrigation, based on actual irrigation system performance, soil characteristics, plant water needs and climatic data. Site audits showed that this alone decreased water use by 30 percent with no adverse effects.

- Installed rain sensors and widespread use of sprinklers with in-head check valves.

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- The school district's landscape architects also joined in the effort, modifying accepted design standards and incorporating new products and technologies into specifications. The synergy that developed as a result of collaboration with SPU, designers, vendors and Shoreline's management allows for vastly improved, value-added projects to be developed.

Limitations: Located in Seattle

Expected Transferability of Findings in Developing Quantitative Estimates:

☐ High ☒ Medium ☐ Low

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76. Johnson, G. A., Davis J.G., Qian Y.L., Doesken K.C. (2006). Topdressing turf with composted manure improves soil quality and protects water quality. *Soil Science Society of America Journal,* 70, 2114-21.
General Category: Soil Amendment

GreenCO BMP Category: Soil Amendment, Turf Management

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☐ Summary ☒ Other field tests

Study Description: (from study abstract)

Compost can improve soil properties when incorporated into soil; however, little information is available regarding impacts of compost topdressing. Objectives of this study were to evaluate the effects that topdressing composted dairy manure onto Kentucky bluegrass (Poa pratensis L.) has on: (i) soil physical properties, (ii) soil chemical properties, (iii) soil nitrate (NO3–N) and P concentrations below the rootzone, (iv) total runoff and sediment losses, and (v) N and P concentrations in runoff.

Plots were topdressed with compost at 0, 33, 66, and 99 m3 ha–1. Saturated hydraulic conductivity, bulk density, water retention, and soil nutrient levels were measured. A rainfall simulation was conducted, and runoff was collected and analyzed for total nitrogen (TN), nitrate nitrogen (NO3–N), ammonium nitrogen (NH4–N), total phosphorus (TP), total dissolved P (TDP), and ortho-phosphate (OP).

Year(s) Data Collected:

Quantitative/Qualitative:

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Summary of Findings Related to Landscape Water Conservation BMPs:

Compost application of 99 m3 ha–1 reduced bulk density, and increased water retention and P, K, Fe, and Mn concentrations in the surface soil.

Compost applications of 66 m3 ha–1 or greater raised soil electrical conductivity (EC); however, this increase in soil EC did not negatively impact turf quality.

Other benefits also reported.

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Topdressing composted manure onto established turf improved soil physical properties and nutrient concentrations without increasing nutrient runoff, with the exception of increased NH4–N levels in runoff.

See a related unpublished(?) 2006 manuscript by Johnson, Quian, and Davis (2006) titled "Topdressing Kentucky Bluegrass with Compost Increases Soil Water Content and Improves Turf Quality during Drought.".

Limitations:

Expected Transferability of Findings in Developing Quantitative Estimates:

☐ High ☒ Medium ☐ Low

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77. Johnson, G. A., Qian Y.L., Davis J.G. (2006). Topdressing Kentucky Bluegrass with Compost Increases Soil Water Content and Improves Turf Quality during Drought. Obtained from original manuscript. Fort Collins: Colorado State University. (*final publication location unknown*).
General Category: Soil Amendment, Turf Management

GreenCO BMP Category: Soil Amendment, Turf Management

Study Type: ☐ Journal ☐ Private Study ☐ Book ☐ Government/Agency ☒ University ☐ Manufacturer

Data Type: ☒ Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description:

Study conducted because little information has been available concerning the effects of compost topdressing after core cultivation on turfgrass drought response. The objectives of this study were to evaluate the effects that core cultivation and topdressing compost onto established Kentucky bluegrass has on: i) soil water content; ii) turf canopy temperatures; and iii) turfgrass quality during periods of drought. Following core cultivations in May and September 2003 and May 2004, compost treatments [0 (control), 33, 66, and 99 m3 ha-1] were topdressed onto established 'Nuglade' and 'Livingston' Kentucky bluegrass in the field (Experiment I). In Experiment II, 'Kenblue' Kentucky bluegrass was topdressed with 0 (control), 66, and 99 m3 ha-1 compost after core-cultivation. In addition, a non-core-cultivated and no-compost-topdressed treatment was included. Three 10-d dry down periods were imposed during the summers.

Year(s) Data Collected: 2006(?)

Quantitative/Qualitative: Quantitative

Cost Data: ☒ N/A ☐ Savings from BMPs ☐ Cost to Implement

Summary of Cost Data: N/A

Summary of Findings Related to Landscape Water Conservation BMPs:

During the dry down periods, compost treatment increased SWC in the 15-30 cm soil depth during the first four days of dry down and in the 0-15 cm depth 7-10 into the dry down period. Compared to the control, compost treatments at 66 and 99 m^3 ha^{-1} reduced turf canopy temperature by 1.2-3.3°C during 4-10 days of dry down, indicating less drought stress. While turf quality in the control of 'Nuglade' and 'Livingston' varieties declined to an unacceptable level on day 8 of dry down, plots with 66 and 99 m^3 ha^{-1} compost treatments maintained acceptable turf quality during the entire dry down

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periods. In Experiment II, turf quality of Kenblue dropped to below 6 on day 4 for the non-cultivated and no-compost-topdressed treatment, on day 7 for the core-cultivated but no-compost-topdressed control and on day 9 for 66 and 99 $m^3 ha^{-1}$ compost treatments. Results suggested that compost topdressing after core cultivation is a management practice that could reduce turfgrass irrigation requirements.

Other notes extracted from the report:

In typical agricultural settings, researchers have found that organic material amendments have beneficial effects on soil physical properties, such as increased water-holding capacity, soil aggregation, soil aeration and permeability, and decreased soil crusting and bulk density (USDA, 1957; USDA 1978; Hornick and Parr, 1987). [*obtain these references in the future*] These improvements to soil physical properties could improve root growth and increase the proportion of water that is available to plants, which could reduce irrigation requirements.

The experiment indicated that core cultivation could help Kenblue Kentucky bluegrass maintain its turf quality 3 days longer during the 10-day-period without irrigation or precipitation. Compost topdressing (at 66 and 99 $m^3 ha^{-1}$) after core cultivation could help Kentucky bluegrass maintain acceptable turf quality 2-3 days longer compared to the core cultivated but no-compost-topdressed control. This will translate into reduced irrigation frequency, thereby reducing turfgrass irrigation demands. Core cultivation is considered one of the routine management practices to control thatch and enhance water infiltration. We have documented with this work that compost topdressing after core cultivation will provide additional benefits of increased water infiltration rate, enhanced water movement into deeper soil depths, and therefore, improve water conservation.

In summary, this experiment suggested that compost topdressing following core cultivation could provide a means of water conservation in managing aesthetically appealing turfgrass systems. Compost topdressing following core cultivation can increase water infiltration and penetration into deep soil depths, which increases root zone water availability. The mulching effect of compost also reduces evaporation loss of water in the soil. To reduce urban water use, it is necessary to combine various means in such a way as to attain the maximum conservation at the lowest cost with the least inconvenience. Compost topdressing can be considered as an important water conservation method in turfgrass management.

Limitations: none

Expected Transferability of Findings in Developing Quantitative Estimates:

☒ High ☐ Medium ☐ Low

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78. Medina, J., & Lee, A. (2006). *FX Project, Fargo Xeriscape Project, Final Report*. Bureau of Reclamation and City of Fargo. http://www.cityoffargo.com/attachments/085a3837-2779-406d-8f30-4298f66e43ea/Fargo%20Xeriscape%20Project%20Final%20Report.pdf

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☐ Private Study ☐ Book ☒ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☒Site-specific ☐ Regional ☐ Summary ☐ Other _____

Study Description:
As part of the NXDP, Fargo was selected as one of the five cities involved with the Bureau of Reclamation's landscape water use study. Fargo has relatively low rainfall and its rising population. The Fargo Xeriscape Project's intent was to provide information to the about installation costs, maintenance costs, and water savings when installing Xeriscape style landscaping versus a traditional style landscape.

Year(s) Data Collected:

Quantitative/Qualitative: Quantitative

Cost Data: ☐ N/A ☒ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:
For a house to retrofit itself into a Xeriscape, it would average $0.71 per square foot and for a new start construction it would average $1.11 per square foot.

Summary of Findings Related to Landscape Water Conservation BMPs: (notes extracted from Executive Summary)

Signing up initial participants was the most challenging aspect of the project; new start participant numbers were the most difficult demonstration to fill. The initial cost of a house with the burden of having enough discretionary money left over to install plant material and an automatic irrigation system was daunting for many homeowners.

June of 2000 brought about a large rainfall event of nearly 8 inches over 2 hours. This left many home basements flooded and planting beds left in disarray. Maintenance of planting beds was not a priority for most participants, due to the heavy amount of clean up left to do inside the house. The results of the FX project demonstrated that maintenance costs were higher for both Xeriscape retrofits and new starts, when compared to their respective controls. Retrofits required 32% more maintenance and new starts required close to 10% increased maintenance than the control landscapes.

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Water savings on Xeriscape new starts averaged 29% water savings, while retrofit Xeriscapes used more water on average. This was partly due to the slightly higher rainfall amounts over the study period leaving retrofit control properties with little or no need to water. Consequently, retrofit Xeriscape properties were in the initial plant establishment period where water usage is quite high. Additionally, many of the retrofit control properties watered very little outdoors, which is a good thing, but when taken in the context of this study it has shown that retrofit properties can use more water in the establishment period. Homeowner demographics likely play a large part in the retrofit demonstration with older residents rarely using water for outside plants.

Fargo demonstrated that water savings can easily range from 10% up to 50% when properly designed, installed and maintained. Reducing the amount of turf area has the highest impact on water usage per property, and when turf is limited to one-third to one-half of the landscape area, maximum results can be achieved.

Limitations:

Expected Transferability of Findings in Developing Quantitative Estimates:

☒ High ☐ Medium ☐ Low

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79. Gregg, T., Strub, D., & Gross, D. (2007). Water Efficiency in Austin, Texas, 1983-2005, An Historical Perspective. *Journal AWWA*, 99 (2), pp. 76-86. ***not the actual reference; this is a summary from another NXDP project; need to go to original***

General Category: Xeriscape

GreenCO BMP Category: Xeriscape

Study Type: ☐ Journal ☐ Private Study ☒ Book ☐ Government/Agency ☐ University ☐ Manufacturer

Data Type: ☐ Site-specific ☐ Regional ☒ Summary ☐ Other _____

Study Description:

Year(s) Data Collected:

Quantitative/Qualitative:

Cost Data: ☐ N/A ☐ Savings from BMPs ☒ Cost to Implement

Summary of Cost Data:

Summary of Findings Related to Landscape Water Conservation BMPs:

- Buffalo grass (considered water conserving) saved about 30 percent water over St. Augustine (high use turf).
- Irrigation systems were associated with about 38 percent more water use (than without).
- Highest income areas were associated with 57 percent more water use than middle incomes.
- Lowest incomes were associated with a 28 percent decrease in water use from middle income water use.
-

Additional study by Gregg (1999) yielded these additional findings:

- Xeriscapes used approximately 211 gallons per day (gpd) less water in summer than non-Xeriscapes
- In-ground irrigation systems raised water consumption by 83 percent regardless of grass type.
- A Xeriscape rebate program reduced summer water use by about 133 gpd. It was estimated that the benefit/cost becomes positive at 13 years.
- An irrigation audit program was successful in altering watering by 69 percent of participants

Limitations:

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Above average rainfall in 3 of the 5 study years accounted for some unexpected abnormalities.

Expected Transferability of Findings in Developing Quantitative Estimates:

☒ High ☐ Medium ☐ Low

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Note: See bibliography and Attachment 2, Tabulation of Water Conservation Measures for additional information. Several references identified near closure of the scope of work were not included in these notes sheets.

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Attachment 4.

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