CENTER FOR
ReSource
CONSERVATION

COLORADO WATER CONSERVATION BOARD
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WATER CONSERVATION IMPACT ASSESSMENT

2013 Final Report

Water Conservation Impact Assessment 2013 Final Report

Grant Number OE PDA 13000000102

Prepared for
The Colorado Water Conservation Board

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With Support from
The Colorado Water Conservation Board
City of Broomfield
City of Boulder
Town of Castle Rock
Centennial Water & Sanitation District
Town of Erie
City of Lafayette
City of Loveland
Parker Water & Sanitation District
City of Thornton
City and County of Westminster
Willows Water

January 20, 2014

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Executive Summary

Overview

In April 2013 the Center for ReSource Conservation (CRC) was awarded a grant from the CWCB to conduct a research project with the goal of measuring the water savings and other impacts of our water conservation programs that operate in over 25 water service areas around the state. Most of the study focused on an assessment of Slow the Flow (STF); a 10 year old outdoor irrigation inspection program that is offered to hundreds of thousands Colorado homeowners every year.

In the original application the CRC committed to an in-depth analysis of the STF program as well as of several other water conservation programs, and to share the findings of the analysis with all water utilities in the state. We conducted the analysis following these main tasks:

- Task 1: Additional Data Collection and Literature Review
- Task 2: Expand and Enhance STF Data Analysis
- Task 3: Methodology Adaption to Other Programs
- Task 4: Reporting and Dissemination of Results

As of January 20, 2014, all of these tasks have been completed and the CRC is pleased to submit this final project report. The report includes a narrative description of the work done to complete each task, methods and results from the analyses, and conclusions drawn from the analyses. In addition, the report summarizes the challenges encountered as well as possible future next steps that could be taken for further related work.

The challenges encountered for this project centered on the availability of data; our dependence on outside sources for water usage data was a limiting factor for how broad our analysis was able to be. Beyond this challenge, we were successful at completing each of the tasks listed above. **The main finding from the analysis is that the average STF participant saved 4.8 kgal of water in the first year following the audit, and then continued to save water for up to five years beyond the audit**. The other key findings from the analysis of 2,054 participants are summarized below.

Key Findings

- Average outdoor water use, a non-weather controlled variable, was reduced from 125 kgal pre-audit to 120 kgal post-audit.
- During the time period of interest, 2005-2013, 2012 had the highest growing season ET demand of 25.4 in., and 2009 had the lowest ET demand of 18.1 in.
- Average Rate of Water Application, a measure of outdoor watering efficiency that takes into account weather, landscape size, and landscape type, dropped from 92% above ET demand pre-audit to 81% above ET demand post-audit.
- Despite a slow return to inefficient watering rates over time post-audit, average savings actually increased over time. This surprising finding can be explained by high-users receiving the most benefit from the program, and in general, maintaining their improved watering practices for several years post-audit.
- The Slow the Flow program offered a competitive water supply option in the Front Range, costing utilities approximately $6,789 per acre foot of savings.
- Despite lack of targeted advertising, the Slow the Flow program was generally reaching utilities' highest water users.

- Raw outdoor usage is positively related to ET demand and landscape area, with higher outdoor use when ET demand is higher and when landscape areas are larger. Surprisingly, outdoor use was significantly lower post-audit at homes with “Some” xeriscape than at homes without xeriscape. This finding suggests that the audit’s impact is focused on turf landscapes.
- The Rate of Water Application, a measure of watering efficiency, was not significantly affected by most standard measurements of sprinkler system health. This indicates that weather and human behavior were major factors in participant over- or under-watering. Therefore, direct education of each participant on sprinkler system use and appropriate watering levels and schedule for their landscape must have been the main factor contributing to the success of the program at generating water savings.
- Water savings are positively related to raw outdoor water use and the Rate of Water Application (RWA), indicating that those who benefit most are those with the highest outdoor use and highest RWA.
- Preliminary results from the 2012 STF participants who received updated recommendations during their audits with the goal of increasing the program’s conservation benefits indicates that the average change in the RWA may be larger than in previous years. Average water savings were nearly equivalent to previous years.
- Slow the Flow Indoors has saved Front Range residents 15 AF of water since the first season in 2010-2011, and potential savings from this same time period were 47 AF.
- Garden-In-A-Box has converted approximately 562,000 sq. ft. of landscape to xeriscape. The potential savings from these conversions are 18 AF of water.

Along with these findings, we also discovered more questions. Our analysis of factors that control and contribute to outdoor usage, watering efficiency (measured as RWA), and water savings just skimmed the surface of what we could do with the dataset that we have. The answers we got showed us that there was more complexity than a simple linear regression could explain. We discovered that more data is needed to quantify actual savings from some of our smaller programs, such as the rotor nozzle retrofit program. We also discovered that our experiment with Northern Colorado Water Conservancy District, to measure the water use in three of our Garden-In-A-Box xeric gardens, is going to be a major addition to the nation-wide literature available on xeric garden water demands relative to turf grass.

Future research and analysis work by the CRC will draw upon this analysis to measure the impact of our water conservation programs, allowing enhanced program development, and improved information for our utility partners and the broader conservation community on the impact of our programs.

Project Narrative

In this section we summarize the work done to complete each task. Specifically we review the goals of the tasks and then list the subtasks and deliverables that we used to focus our work.

Task 1: Additional Data Retrieval and Literature Review

This task focused on retrieving data, expanding and updating our current analysis to make it more comprehensive, and performing a review of the current state of analysis work of water conservation programs in order to ensure that our own analysis would meet the currently accepted standards for this kind of work. In order to complete this task the CRC performed the following subtasks:

- Extract program identification information (e.g. Water Account Number, Water Provider Name) from CRCs master customer database and prepare for request to water providers.

- Draft and send letters to partner water providers to request water usage data for participants as well as for overall water district water usage data. The letters will specify to our partners the description of our project and goals of the project in order to educate them of the broader impact of their support.
- Receive data from partner water providers and compile the water usage data with the CRC data to create comprehensive spreadsheets that contain all pertinent customer information to water usage.
- Conduct a literature review of past and current assessments of water conservation, using academic publications (e.g. AWWA Journal), online resources, and contact with various local, regional and national water entities (e.g. Northern Water, Alliance for Water Efficiency).
- Obtain additional and more accurate climate data.

From this task the CRC produced the following deliverables:

- Letters to partner water providers requesting more data
- Updated climate data
- Literature review, format of sources and pertinent findings

This task was completed on time and successfully produced the promised deliverables. After sending out the letters to explain the project and request participation from our partner water providers, we received interest from 11 of our partners. The 11 municipalities that provided us with water usage data are listed below.

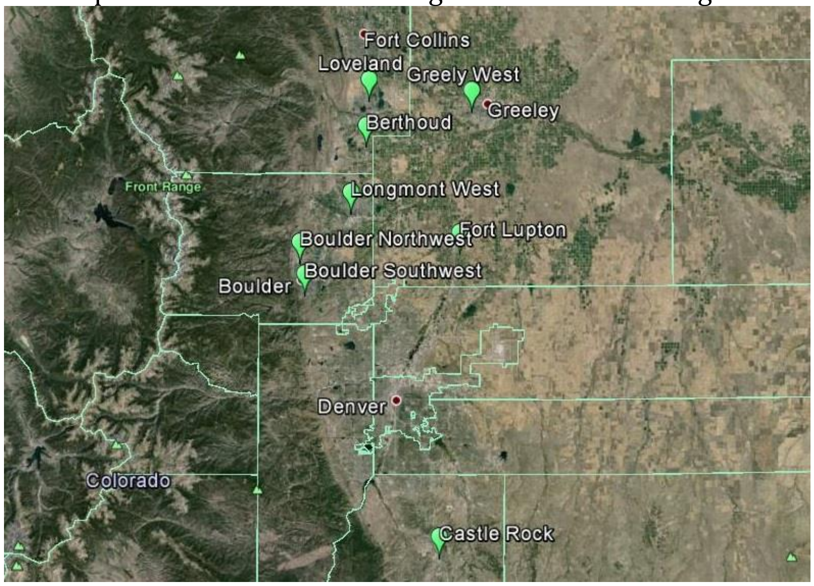
Partner water providers that contributed data to the 2013 Impact Analysis.

City of Boulder
City of Broomfield
Town of Castle Rock
Centennial W&SD
Town of Erie
City of Lafayette
City of Loveland
Parker W&SD
City of Thornton
City of Westminster
Willows W&SD

The literature review was successful in expanding the breadth and scope of background knowledge on water conservation theory, local programs, and the state of the science. The list of new bibliographic sources is included at the end, in **Appendix A** of this report.

While an extensive investigation was undertaken in order to expand and improve the climate dataset, very few additional sources with adequate climatologic data were found. The greatest expansion of the dataset was made with the contribution of ET and P data from the Town of Castle Rock. The Town of Castle Rock owns and has operated four climate stations within their service area since 2008. The Castle Rock weather data added a key southern data point into the overall climate dataset. See Figure 1 for a map of the weather stations used for the analysis. Another update to the dataset was made by changing our consideration of the watering months from only including May-September, as was used in the pilot impact analysis, to now including April-October. This change aligns our methods with the standard methods that are used across the Front Range and improves the dataset by more accurately representing the time frame during which Front Range Colorado residents use their sprinkler systems. Details of the ET values used for each year are included in the results section.

Figure 1. Map of weather station locations used in the impact analysis. The single point in Castle Rock represents four stations. Image obtained from Google Earth.



Task 2: Expand and Enhance the Slow the Flow Data Analysis

This task focused on updating and expanding our analysis of water savings and other impacts of the Slow the Flow (STF) sprinkler inspection program. The main goals of this task were to add a control group analysis and to analyze water savings over a longer time period than had previously been evaluated. We also worked to incorporate the updated climate data set into the calculations. The subtasks performed for this task were:

- Review of existing CRC methodology, comparing and contrasting to other methodologies discovered in the literature review (Task 1).
- Make any and all necessary updates to the climate dataset being used in the analysis. Recalculate water savings as necessary.
- Using statistical methodologies, use (a) control group(s) (i.e. water usage data from customers in the same district as STF participants of STF, who did not participate in STF) to calculate and clarify the amount of influence outside factors may be influencing the water savings calculations.
- Longitudinal impact assessment of STF. Evaluate the number of years water savings exist and rate of change in measurable water savings after the program has been administered.
- Run a variety of statistical analyses on the water savings results (e.g. simple linear regression to identify correlations that exist between various data parameters and water savings, Analysis of Variance to evaluate if the calculated water savings are significant).
- Create charts and graphs capturing the results of the analyses in clear and transparent formats.
- 50% Progress Report to the CWCB.

The deliverables for this task were:

- Updated results of the STF impact analysis using new climate data
- Results of control group(s) study of STF impact analysis
- Results of longitudinal study of STF impact analysis
- 50% Progress Report to CWCB

Task 2 was completed on time. All goals were met, however certain details of some of the individual tasks did not come through as planned. For example, the original plan was to use the updated weather data to re-calculate water savings from the pilot study dataset as well as with new data received for this larger and more thorough impact analysis. However, about half of the pilot study data was not able to be updated, but we were able to obtain complete consumption records for approximately 2,000 participants. This sample size was sufficient for statistical requirements of the planned analysis.

Time spent on this task was comprised mostly of data-managing, cleaning, and analyzing. A statistical evaluation of the sample size requirements for a statistically valid sample was performed. Summary statistics, graphs and charts were created in order to describe and display findings. Water savings and change in water usage was tested for statistical significance. The longitudinal impact assessment of the STF program was performed for up to five years post-audit. A correlation analysis was run using variables collected by the CRC during the audits in order to evaluate the most important factors for predicting water use and water savings. These results and others are presented in the Results section later on in the report.

We successfully compared our methodology to existing methodologies for calculating water savings of other conservation programs. There were not many other methodologies to compare to, but what we discovered was that most other water savings methods calculate the expected difference in water use for once fixtures have been replaced, rather than looking at actual water use change. For outdoor programs, some have also compared percentage changes in weather/ET to percentage changes in GPCD or outdoor use, or have simply compared total outdoor use pre- and post-program, without controlling for weather. Our methodology goes further by quantifying water savings in gallons, using measured landscape size and annual net ET demand of the landscape. These methods follow the approach recommended in the Colorado WaterWise Guidebook of BMPs for Municipal Water Conservation in Colorado (2010).

Task 3. Methodology Adaption to Other Programs

For this task we made the necessary adaptations of our impact analysis methodology to calculate water savings for STF Indoors, Garden-In-A-Box and other programs. The subtasks completed for this step included:

- Develop a methodology for calculating water savings of STF Indoors
- Develop a methodology for calculation water savings of Garden-In-A-Box
- Produce results using these methodologies
- 75% Progress Report to the CWCB

The deliverables created for this task were:

- Development of methodology for assessing additional programs
- Preliminary results from the assessment of additional programs
- 75% Progress Report

For calculating water savings from STF Indoors, we have developed a similar methodology to calculating water savings for STF Outdoors. Briefly, monthly water consumption records for each participant can be broken down by year between outdoor and indoor usage. Then, indoor usage between the pre-audit years can be directly compared to indoor usage in post-audit years. Unfortunately, due to extremely small sample sizes and our inability to get consumption data from our partners in time for this analysis, we do not have results using this method. Instead, we have expanded our established water savings calculations (these calculations involve comparing manufacturer specified flow rates for newly installed fixtures to measured or manufacturer specified flow rates for old fixtures) by examining the impact of the program as a whole and over time. Overall, we feel that both of these measurement techniques are valid and important for different reasons. Calculating the water savings is important for evaluating the effectiveness of the program, while calculating the deemed savings is valuable for participant and utility education. The information detailing what our participants could save helps us to continue to make sure that the program is relevant.

Developing a methodology for measuring water savings from the Garden-In-A-Box (GIAB) program was more difficult than for the indoor audit program. Measuring water savings from GIAB poses similar challenges to measuring water savings from a rebate program – the unknown factors are numerous, including knowledge of whether or not the garden has been planted, whether it was planted in the property that it was specified for, or what kind of landscape it was used to replace (turf, already xeriscaped area, cement, etc.). Because of the inherent number of unknown factors associated with measuring water use change related to this program we felt that making a theoretical estimation based on information from a literature review would be the most appropriate way to measure water savings from the program at this point. The literature review revealed that there have been only a few studies on xeriscape water use. Our list of findings is included in **Appendix B**. For our calculation of water savings we decided to use the recommendations for xeric garden care from Northern Water, which are to use an "average landscape coefficient (K_L) [of] 0.3 (30% of tall canopy (alfalfa) reference evapotranspiration, ET_{rs}, equivalent to 0.35-0.38 ET_{os})." This suggests that a xeric garden has 35%-38% of the ET demand as a turf landscape of the same size. Estimations of savings from 2013 GIAB are included later in the report. These savings estimations assume that all GIAB gardens replaced turf landscape, were watered at appropriate levels and are cared for at this level from the year they are planted until the present. Therefore, the water savings predicted by GIAB are most likely over-estimated. Further work will be needed in order to measure the amount of error in this calculation.

Another project geared at measuring the water use from Garden-In-A-Box has recently started. Through the support of the CRC, Northern Colorado Water Conservancy District has developed an experiment to test how much water three different GIAB gardens need relative to turf grass. For this experiment, the CRC donated staff time and gardens for planting. Northern Water is managing the experiment, has provided the space and is collecting the majority of the data. The experiment began this spring, with designing and preparing 27 garden plots at the Northern Water headquarters in Berthoud. The 27 plots are composed of 3 different gardens, each planted 9 times (the gardens are the Morning Sunrise, Paradise, and Western Horizon). Within each garden type, 3 different watering levels will be applied to the plants, creating a fully testable experimental design to get at the question: how much water does a xeric garden need? Also, in close proximity to these gardens are several plots of turf grass. All water applied to the gardens and grass plots are metered. This will allow us to ask the question: how much water does a xeric garden require relative to a turf plot of the same size? Together, the CRC and Northern Water developed a plan for managing and monitoring the gardens into the future. We expect to continue the experiment for 2-3 years. By the end of the experiment we will be able to tell how much water each of the three gardens require to stay adequately healthy and attractive, as well as how much water these gardens require relative to turf grass under the same conditions.

Task 4. Reporting and Dissemination of Results

The main objectives of this task were directed toward education and outreach and the dissemination of our results. The subtasks included:

- Create reports and provide partners with clear summary of the impact of STF on their customers
- Develop and present reports at various water conservation organizations including the Water Conservation Technical Advisory Group, Colorado WaterWise, and the Inter-Basin Compact Commission
- Create abstracts for conferences that have opportunities to present on water conservation, such as AWWA[1]
- Make presentations at in-state conferences for the water conservation community (e.g. Upper Colorado River Basin Water Conference (Grand Junction, November, 2012), Rocky Mountain Land-Use Institute Annual Conference (Denver, March, 2013), American Water Works Association Annual Conference (Denver, June, 2013), and WaterSmart Innovations Conference (Las Vegas, October, 2013))[2]
- Final Report to the CWCB

The deliverables included with this task are:

- Final reports to all partner water providers
- Final report to the CWCB
- Presentations at one conference
- Abstract submission to a journal

With the completion of this report we have finished all of the work associated with this task. By January 20th, 2014, all 11 partner water providers, as listed in Table 1, had received their final reports. An example of a report is included in **Appendix C**.

We have presented the impact analysis methodology and results at several conferences including at the Upper Colorado River Basin Water Conference in 2012 and 2013, at the Rocky Mountain Land-Use Institute Annual Conference in March, 2013, at the American Water Works Association Annual Conference in June, 2013 and at WaterSmart Innovations in October, 2013. A complete list of each conference and presentation title are included in **Appendix D**. We have also given presentations for the Rocky Mountain Conservation Group at AWWA (January 13, 2014, Castle Rock) and for the board of Colorado WaterWise (December 19, 2013, Fort Collins). We have also submitted three WaterSmart Innovations 2014 conference abstracts on related topics.

We have published one article in the Summer 2013 issue of the Colorado WaterWise newsletter and are working to submit another article for the Winter 2014 issue.

We had listed an abstract submission to a journal, but learned recently that the journal requires the entire article prior to submission. We have submitted 7 abstracts to various conferences and are in progress of writing up an article for a journal submission. For the purposes of this project and goals associated with this task we feel that we have sufficiently completed all stated deliverables.

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[1] Staff time and travel costs, not conference registration or abstract submission fees will be charged to this project.

[2] See 1.

Challenges

This project has gone very smoothly and there have thankfully been very few and only minor challenges encountered. The challenges that we did encounter were mostly related to acquisition of sufficient and accurate data; we were challenged to get more than 2,000 usable participant records for the STF analysis, and we were challenged to find an adequate dataset for evaluating the water savings from other programs beyond STF. While neither of these challenges prohibited us from completing the deliverables, they both have various, but minor, consequences to the outcomes of the analysis.

The sample size used for the main STF analysis of 2,054 participant records was large enough to measure statistically significant changes in water use and other parameters. However this sample size was not available for all years, particularly not for looking at changes beyond three years post-audit. For four and five years post-audit, results are presented, but do not carry the same level of certainty as results from one, two, and three years post audit. For a more in-depth explanation of determination of sample size, please see the methods section. The main reason that we did not have a larger sample size was because we were unable to obtain more water records from our utility partners. Of those records we did receive, we did have to remove a portion of the data due to inaccuracies and incomplete water records. Again, the methods section below provides a comprehensive explanation about what data was removed and what criteria were used to remove it.

We had the greatest challenge with obtaining sufficient data to evaluate the programs beyond Slow the Flow, such as Slow the Flow Indoors, Garden-In-A-Box, and our sprinkler-head retrofit program. Slow the Flow Indoors and Garden-In-A-Box water saving calculations, therefore, were done following standard methodology which uses the estimated reductions multiplied by the number of changes made from the programs (i.e. faucet aerators replaced or square feet of xeric garden planted) to calculate savings. This method is useful for participants and water utilities alike, providing them with the potential water conservation resultant from their action. Measuring the actual savings from these programs as we have done for STF will require more usable participant water records and possibly follow-up surveys to evaluate to the extent that each participant followed the specified water conservation practices (i.e. faucet aerator replacement or garden design) provided to them from the service. For the rotor nozzle sprinkler retrofit program, we were not able to obtain a statistically significant sample size. The results of the analysis below are only preliminary, but show that there is little consistency in outdoor water usage change between pre- and post-retrofit. Overall, these findings do not provide adequate information to assess the impact of the program. However these findings are consistent with findings from other researchers that show no savings and inconsistent impact from MP Rotor retrofits[3].

Analysis

Introduction

The over-arching goal of the impact analysis is to verify and quantify the impact of a major water conservation program in Colorado, and to share this information with the water conservation

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[3] Petersen & Eugene Water & Electric Board. 2013. *Reducing Peak Hour Demand With Nozzle Retrofits: Three Year Evaluation*. Presentation at WaterSmart Innovations, Las Vegas. Oct. 3, 2013. AND Sovocool, Morgan, and Drinkwine, SNWA. 2013. *Observed Long-Term Results of Multi-Stream Rotational Spray Heads and Associated Product Retrofits*. Presentation at WaterSmart Innovations, Las Vegas. Oct. 3, 2013.

community. Toward this goal we set out to develop and implement a data analysis methodology that accurately characterizes the impact of the program on outdoor water use. Furthermore, we worked to develop a methodology to calculate water savings that could be applied to other water conservation programs and to analyze the water savings from other programs.

The specific goals of the impact analysis were to evaluate water usage trends pre- and post-audit, assess longitudinal savings, perform a cost-benefit analysis, supply a comparison/control group study, and measure what factors contribute to outdoor usage, watering efficiency, and water savings. Below, we present in detail the methods used to perform these analyses as well as the findings from the analyses. From our work with over 30 water utilities across the state of Colorado we feel that this analysis will provide extremely useful and relevant information to our partners and the broader water conservation community.

Methods

The methodology presented here was designed to quantify the impact of the STF program on the water usage of the homeowner participants in the program, particularly between one and five years after the audit was performed. Other aspects that are evaluated with this methodology include the water savings of each participant, water use (in GPCD) of the participants in the program relative to the rest of the single-family homes in several water utility districts, and statistical tests to assess the importance of various factors (e.g. landscape size, presence of a drip system, etc.) on outdoor water use, watering efficiency, and water savings. All calculations of water saved by the STF program were done at the individual participant level, using information collected by the CRC during the audit as well as water usage data from our partner water providers, and weather data from local weather stations.

Participant information collected by the CRC included water account number, address, and turf and shrub landscape sizes (in sq. ft.) per household. The CRC requested monthly water usage data (in gal or kgal) for at least two years prior and two years following the audit for each participant[4]. Using water account number and address information, the CRC matched the water usage data to the landscape size data.

Following acquisition of the data, it was cleaned and prepared for analysis. Cleaning is the process of making any necessary conversions and removing incomplete records. Incomplete records included those who did not have the same homeowner and associated water account number for at least three full years, the year (Jan-Dec) prior to the audit through a full year (Jan-Dec) after the audit. This eliminated the possibility of measuring water use of a homeowner who had not participated in the audit, but had simply moved into the home where an audit had been performed. All water usage data provided in gallons was converted to thousands of gallons (kgal). Each participant record was also required to have an area value for turf and/or shrub and/or total landscape size. For any record missing any of these required criteria, it was removed from the data set.

Once clean, several variables were calculated. Annual outdoor water usage (U_o) (gal) was calculated as:

$$U - U_i = U_o \qquad \text{Eq. 1}$$

[4] For example, if the audit was performed at a household in 2007, then water usage data for 2005 and 2006 were used for the pre-audit data and water usage data from 2008 and 2009 were used for the post-audit data.

where U is total annual usage (gal), the sum of water use between January through December for the calendar year, and U_i is total annual indoor usage (gal), calculated following Equation 2:

$$((U_{Jan.}+U_{Feb} + U_{Dec})/3)*12 = U_i \quad \text{Eq. 2}$$

where U_{Jan}, U_{Feb}, and U_{Dec} were the total water usage (gal) for each of the three months, January, February, and December. These three months were assumed, following standard practice in Colorado, to be the months when homeowners in the Front Range do not use significant amounts of water outdoors. This gives us an average monthly indoor use value, from which we can calculate annual outdoor use with Equation 1.

There is one main exception to this method for calculating indoor water usage. Certain utilities have water meters read every other month rather than monthly and for these cases a slightly altered methodology had to be created. For indoor use, a single winter month, January or February, was considered to be twice the annual indoor use, and therefore it was multiplied by 6 to get total annual indoor use (U_i). Total use and outdoor use were still calculated as described above for records from these utilities.

After calculating total, indoor, and outdoor water use, the calculated values were reviewed for erroneous results, including total annual, annual indoor, or annual outdoor usage of <1 kgal and/or outdoor use calculations equal to zero. When these values were found, that year's data was considered to be incomplete and was removed from the analysis. In cases where that year of incomplete data was preceded or followed by another year of data, those years further from the audit year were also removed. Finally, if, by removing these erroneous years of data the original rule of having a minimum of at least one year pre- and one year post-audit was violated, then the entire participant record was removed.

Weather data, including daily reference evapotranspiration (ET_o) (in.) for bluegrass and daily measured precipitation (P) (in.) was obtained from Northern Colorado Water Conservancy District (Northern Water) and The City of Castle Rock weather stations[5]. All stations from Northern Water that measured ET_o from bluegrass were selected to include in the study, leaving up to 7 stations with available data, depending on the year. The City of Castle Rock has operated and maintained 4 weather stations with full ET_o and P records back to 2008. ET_o and P data from 2009 forward from these stations was included in this study. Only a few dates between January 1, 2005 and October 31, 2013 had missing ET_o and P data. To fill missing spaces we used the average value for that day of year from all non-missing years for that station.

The annual ET demand for turf (ET_r) is a value estimated from ET_o and P following Equation 3:

$$(ET_o \times k_c) - P_{eff} = ET_r \text{ (in.)} \quad \text{Eq. 3}$$

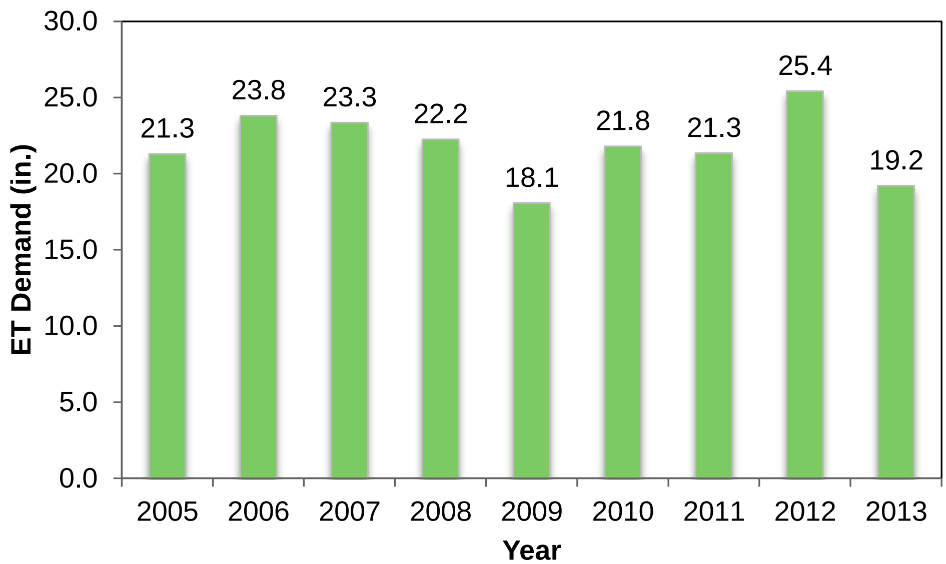
where ET_o is the sum of the growing season (April-October) ET_o, P_{eff}, effective P[6], is calculated as the sum of growing season P multiplied by 0.5 to account for runoff, and k_c is the landscape coefficient, equal to

[5] See http://www.northernwater.org/WaterConservation/WeatherandETData.aspx for Northern Water ET and P data. For ET and P data from The City of Castle Rock, inquire through the Water Utilities Department at Water@CRgov.com.

[6] Effective P is defined as the precipitation that is actually available for plant uptake, rather than total or measured P which includes P that evaporates before being available to plant uptake.

0.8 for urban turf + shrub mixed landscapes in the Front Range of Colorado[7]. ET_r, also called ET demand, is the estimated depth of water, in inches, that a landscape needs, per square foot, in order to remain healthy on an annual basis within the study area. We use a single ET_r value for each year for all locations. We choose to do this both because it followed our practice of providing a single recommended ET demand value to all STF participants during the audit, and because weather stations that measure ET_o and P are not well distributed within the study region, making it impossible to have accurate ET_o for each water provider district. Figure 1 displays annual ET demand from 2005-2013.

Figure 1. Annual ET demand (inches).



Impact Analysis Calculations

The calculations used to quantify the amount of water saved (or not), per STF participant per year, began with calculating how much water each participant needed, for their landscape size, and for the amount of water required by the ET demand of the plant, turf and/or shrub. This value was called the Need (*N*), and was in thousands of gallons:

$$(((ET_r/12)*T*7.48) + ((ET_r/12)*S*7.48*0.7))/1000 = N \quad \text{Eq. 4}$$

where 12 is a conversion factor to change ET_r from inches to feet, *T* and *S* are Turf and Shrub landscape size in square feet, respectively, 7.48 is a conversion factor to convert from cubic feet to gallons, 0.7 is the shrub ET-adjustment factor to convert ET_r for bluegrass to a shrub landscape, and the division by 1000 is to convert from gallons to thousands of gallons. Equation 4 was only modified if either measured *T* or *S* did not exist, and in those cases, that half of the equation was removed.

[7] Mayer, P. W., & Deoreo, W. B. (2010). Improving urban irrigation efficiency by capitalizing on the conservation potential of weather-based "smart" controllers. *Journal American Water Works Association*, *102*(2), 86–97.

Next, the difference between *N* and the amount of annual outdoor water used (U_o) (both in kgal) was calculated to quantify the amount that the participant over- or under-watered for that year (U_D):

$$U_o – N = U_D \quad \text{Eq. 5}$$

Furthermore, you can also compare U_o to N directly to get a measure of watering efficiency based on the amount of water applied to the landscape (in kgal) relative to the amount of water that the landscape needed (in kgal). We call this the participant's Rate of Water Application (RWA):

$$(U_o/N) - 1 = RWA \quad \text{Eq. 6}$$

The ratio of U_o:N is a value that represents the rate at which each participant over- or under-waters[8] on an annual basis. A ratio of 1.0 indicates perfect watering. By subtracting 1 from this ratio and converting the new value into a percent, the RWA can be established. The RWA is essentially a measure of watering efficiency. Negative RWAs indicate watering below N, positive values indicate watering above N, and 0% indicates perfect watering.

The average pre-audit RWA was used to calculate the projected water use (U_p) (kgal) of each participant for all years following the audit:

$$(RWA_{pre}+ 1) * N = U_p \quad \text{Eq. 7}$$

A final calculation to quantify the amount of water saved (*WS*) (kgal) was done by finding the difference between U_p and U_o for all years following the audit:

$$U_p – U_o = WS \quad \text{Eq. 8}$$

If a participant watered at a rate below their pre-audit RWA, then *WS* was positive, and water was considered to have been saved. If a participant watered at a rate above their pre-audit RWA, then WS was negative, and water was not considered to have been saved. While in some cases this methodology produces results that show that not all participants saved water from the STF program, it is important to note that the original goals of the program were to help participants better understand how to use and maintain their sprinkler system and how to maintain a healthy landscape. In 2012 the CRC made some key changes to the program to address the desire of our partner water providers to enhance the water efficiency and water saving potential of the program. A brief analysis of the impact of the STF program in 2012, after these changes had been instated, is included in this report to provide a preliminary assessment of the effect of these changes.

For the longitudinal (i.e. long term) water savings estimation, we looked for sustained patterns of watering efficiency change. If a participant improved their watering efficiency in the first year post-audit, but then had a decrease (relative to their initial watering efficiency) in two years post-audit, we removed that record for all future years. The rationale is that even if this person increases their watering efficiency again, three years post-audit, that increase is no longer attributable to the audit. We did this by using a set of criteria to apply to the RWA for each year post-audit, as this value best represents each participant's watering habits. First, we recorded whether during the first year post-

[8] Over- and under-watering are defined relative to the Need determined for their landscape on an annual basis (Eq. 4).

audit each participant had an increase or decrease in their RWA relative to their average pre-audit RWA. This binary designation (increase or decrease) was then used to evaluate all of the following RWA values for each participant. For those who *decreased* in their first year post-audit, their savings were kept in the analysis so long as their RWA did not go *above* their average pre-audit RWA. For those who *increased* in their first year post-audit, their savings were kept so long as their annual RWA did not go *below* their average pre-audit RWA. For example, if a participant had an average pre-audit RWA of 50%, and in their first year post-audit their RWA was lower than 50% (i.e. decreased), then in all following years they had to have an RWA less than 50% in order for their calculated savings to be kept in the analysis. The same applies to someone who increased use; for example, if a participant had an average pre-audit RWA of 10% and in the first year post-audit their RWA was greater than 10%, then in all following years they had to have a RWA greater than 10% to be kept in the analysis. Once a participant's savings were removed based on these criteria, their data was no longer used in the analysis in future years. This process eliminates the chance of counting water savings (positive or negative) when someone's watering habits changed oppositely to how their watering habits changed in the year after the audit. The example below is provided for clarification.

ID	Avg Pre-Audit RWA	1 Yr Post-Audit RWA	Increase (I) or Decrease (D)	2 Yrs Post-Audit RWA	Keep Calculated Savings or Remove?	3 Yrs Post-Audit RWA	Keep Calculated Savings or Remove?
Participant1	150%	140%	D	144%	Keep Savings	152%	Remove
Participant2	110%	130%	I	145%	Keep Savings	115%	Keep Savings

Statistical Methods

Statistical tests of the data were used to quantify the probability that the conclusions reached from the analyses were true. In all cases the probability/significance level (α) for acceptance of the null hypothesis was set at 0.05. Standard statistical tests including descriptive statistics, basic linear regression, and one-way analysis of variance were used. If the data was not normally distributed non-parametric tests equivalent to those listed above were also run.

Determining Sample Size

We calculated the sample size necessary for detecting a statistically significant change in water use and in the RWA. In order to do this calculation we followed Equation 9[9]

$$n = \frac{\left(z_{1-\alpha} + z_{1-\beta}\right)^2 \sigma_\Delta^2}{\sigma^2} \qquad \text{Eq. 9}$$

where *n* is the samples size, *z* is the z-score of the desired confidence interval and the z-score of the statistical power of the inference, $z_{1-\alpha}$ is the z-score where α quantifies the chance of incorrectly designating a statistically significant difference when no difference truly exists (i.e. Type I error), $z_{1-\beta}$ is the z-score where β quantifies the chance of NOT noting a statistically significant difference when one does truly exist (i.e. Type II error), σ_Δ is the standard deviation of the observed differences, and Δ is the

[9] This equation was used following steps taken in Aquacraft, Inc., 2009, which is a report to the State of California, entitled Evaluation of California Weather Based Smart Irrigation Controller Programs.

size of the change that you desire to detect. In order to have a 95% confidence level, the α and β levels were set to 0.05 and z was set to 1.64.

We derived *n* using the data set from the Pilot Impact Analysis, which included 1,775 participant records. Using this data we found that in order to detect a statistically significant change in RWA at the 95% confidence level we would need a minimum of 809 samples. For detecting a statistically significant change in outdoor use at the 95% confidence level we would need a minimum of 78 samples. Our sample size of 2,054 was therefore acceptable for this analysis. However, as mentioned above, due to lack of participant records in the fourth and fifth years post-audit, the results from these years do not have the same level of accuracy as results from the other years.

Comparison to GPCD

Many water providers track water use on a per capita basis within their service region (as gallons per capita per day (GPCD)). This value helps to reveal annual trends in changes to water usage at the individual citizen level. Eight of the eleven water providers that collaborated with the CRC on this impact analysis provided some form of GPCD data from their total populations to use as a comparison to the GPCD of STF participants.

To calculate GPCD for STF participants we followed the methods used by the utility when known (e.g. assumptions of 2.6 persons per household or similar methods). When they were not known, we summed the total annual water use of all participants, divided by the total number of participants, and then divided by the total number of days in the year. 366 was used for leap years, in 2008 and 2012.

The number of participants was the summation of the average number of individuals living in each participatory household (average of the number of summer residents and number of winter residents, as recorded during the audit). During years when houses did not have adequate data to be included in the analysis, their consumption data was not included and their household members were removed from the population count.

Sources of Error

While we have done all that we can to ensure the accuracy and statistical validity of the results presented in this report, there are several sources of error that we are not able to control for and cannot directly quantify. Sources of error include error from datasets received from outside parties (due to misread water meters or from challenges of accurately measuring ET and P), error within our own data set (due to poor measurements in the field or errors introduced during transfer from field notes into the computer database), and error introduced by our calculation methods. In order to ensure the highest accuracy of the data, we have used thorough data cleaning techniques and have removed all data that we know to be incorrect. In order to remain unbiased however, we did not remove data simply because it seemed unreasonable or unlikely, except by very strict criteria. This criterion was based off of the calculated RWA values and was that any participant with an RWA below the 1st quartile plus 1.5 times the inter-quartile range (IQR), or above the 3rd quartile plus 1.5 times the IQR for all RWA values in <u>all years</u> for which there was data, was considered an outlier and was removed. This decision to remove the most extreme outliers was also made with the knowledge that some of the highest RWA values were caused by inaccurate landscape area measurements, which were discovered with checks of properties using Google Earth software. Following this criterion 27 records were removed.

Calculated values should be viewed as best approximations. This is mainly because the technique used to determine outdoor water use cannot provide exact outdoor use, but rather a best-estimate of outdoor water use. Also, while we are attributing the calculated savings (or lack thereof) to the STF program, many other factors likely impacted participant outdoor water usage in the years following the audit. For example, watering restrictions, both mandatory and recommended, have been imposed in many of our partnering municipalities in the past 5 years, possibly impacting participant outdoor water use. Other sources of error in our calculations include our assumption that no outdoor water use occurs between November and March, that no changes are made to the landscape after the audit, and that the evaporative needs of turf and shrub areas, respectively, are uniform within and between each participant household.

Error from the weather data from Northern Water and the City of Castle Rock is possible from missing data or inaccuracy of the machines measuring the data or from techniques for calculating the ET_o. For further details on the specifications of these machines, the techniques, and the accuracy of each, please see the sources listed in the Cited Sources section for Northern Water and the City of Castle Rock.

Results

The results from this analysis are grouped in seven different focus areas. First are the results from assessing the water use trends, particularly relative to pre- and post-audit time periods to see if any changes can be detected. Next we present water savings, followed by the longitudinal analysis. We then describe the cost-benefit results which show the value of the STF program in terms of dollars and acre feet. Next we provide the results from a control-group study which compares the average STF participant in various water districts to those individual water district's reported annual GPCD for single-family households. The findings from the analyses of factors that contribute to outdoor usage, watering efficiency, and water savings are detailed and provide insight into which households might expect to see the most savings from the STF program. Finally, we present results from a small analysis of 114 participants from the 2012 season to highlight a group of participants that have received the program as it is currently offered. A brief summary of conclusions are provided at the end of the section.

The final data set included 2,054 participants from five audit years (2007-2011). The 114 participants from the 2012 audit season are in addition to these. Table 1 contains a list of the water providers as well as the number of participant records used for the analysis from that provider. Table 2 contains a list of the number of participants by audit year. The 2012 participant information is included below in a separate section.

Table 1. Participant number (N) by water provider.

Water Provider	N
City of Boulder	155
Town of Castle Rock	56
Centennial W&SD	539
Town of Erie	199
City of Lafayette	183
City of Loveland	52
Parker W&SD	68
City of Thornton	400
City of Westminster	402
Total	**2054**

Table 2. Participant number (N) by audit year.

Audit Year	N
2007	219
2008	443
2009	567
2010	624
2011	201
Total	**2054**

Water Use Trends

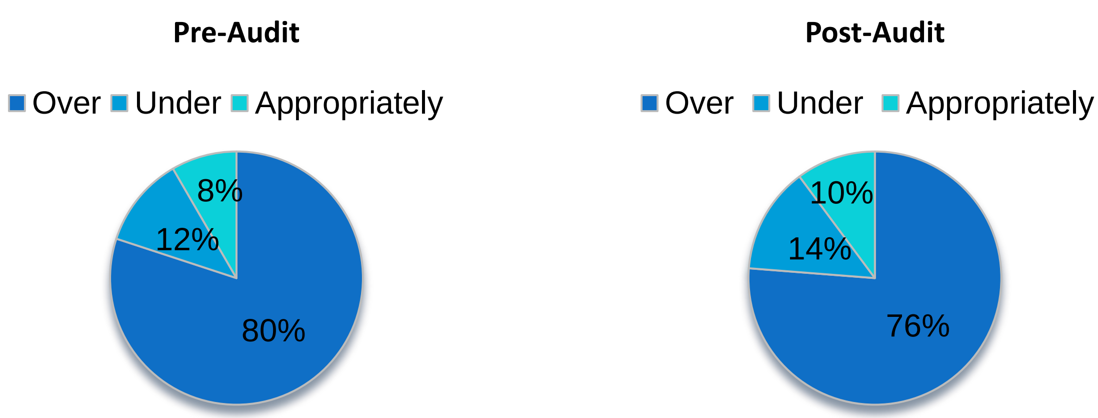
Total, indoor, and outdoor annual water use were calculated for each participant. The average total water use showed a significant decrease between 1 year pre- and 1 year post-audit from 125 kgal to 120 kgal. Average indoor use was significantly higher in the 1st year post-audit at 44 kgal, relative to the year prior to the audit at 40 kgal. Average outdoor water use is summarized in Table 3. While outdoor water use is not a weather controlled calculation, the mean outdoor use of the STF participants from 2007-2011 in the first year post-audit was significantly lower than the mean outdoor use in the year prior to the audits, suggesting a positive impact by the program. By the second year post-audit there was no statistically significant difference between the pre- and post-audit outdoor use.

Table 3. Outdoor water use (kgal)

	Years Pre/Post	Mean	St. Dev.	Median	Min	Max
Pre-Audit	2 Years	85	57	74	1	676
	1 Year	83	56	72	1	569
Post-Audit	1 Year	76	49	67	1	567
	2 Years	80	52	69	1	656
	3 Years	84	56	75	1	617
	4 Years	89	64	76	2	636
	5 Years	95	54	89	6	436

When weather (ET demand) and landscape size and type were taken into account, 80% of STF participants were over-watering prior to their audit, 12% were under-watering, and 8% were watering appropriately (within ± 10% of ET demand)(Figure 2). After the audit, the percentage of those who were over-watering decreased slightly, while the percentage of those who were under-watering and appropriately-watering both increased.

Figure 2. Precent watering over, under or at (within ± 10%) of ET demand.



A Rate of Water Application of 0% indicates that the participant is neither over- nor under-watering their landscape, based on their landscape type (turf and non-turf), size, and the ET demand. This value is essentially a measurement of outdoor watering efficiency. While some participants water efficiently, at or near 0%, the average participant in pre-audit years was over-watering with an RWA of 92% (Table 4). Post-audit, the average RWA dropped to 81%, indicating that the audit improved the mean watering efficiency by 12%. The large standard deviation on these mean values indicates that there is a large amount of variability in the RWA between all participants. The minimum and maximum values reveal the variability in RWA as well. Median percentages indicate that 50% of the participants were actually over-watering by 71% (or less), and that post-audit, half of all participants were over-watering at 58% (or less). This reflects a drop of 18% in the median RWA.

Table 4. Rate of Water Application (RWA)

	Mean	St. Dev.	Median	Min	Max
Pre-Audit	92%	106%	71%	-98%	1218%
Post-Audit	81%	113%	58%	-97%	2131%

Water Savings & Longitudinal Analysis

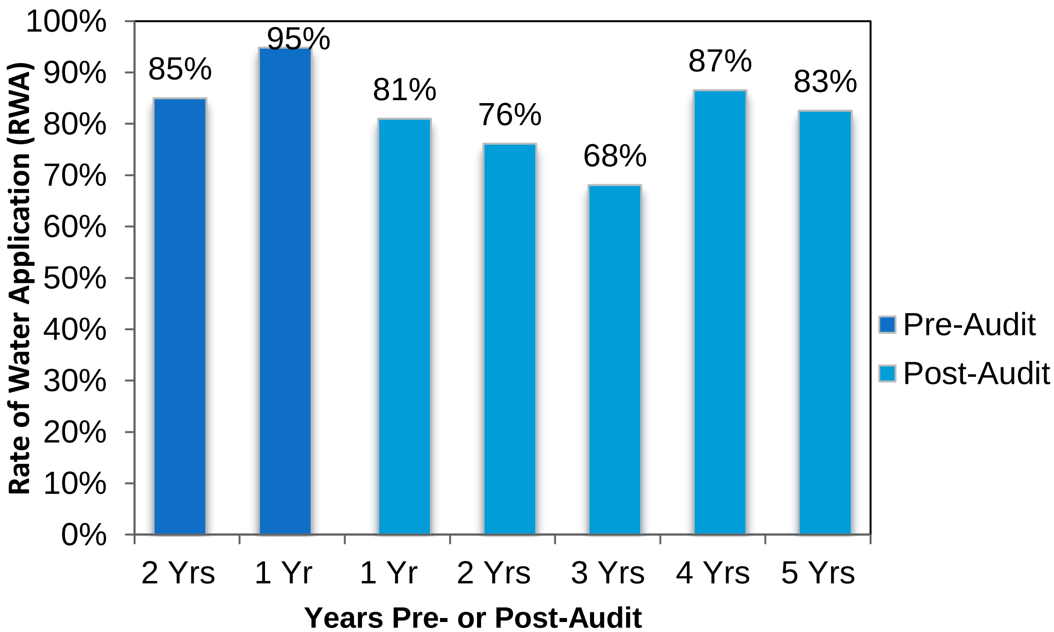
Longitudinal water savings are those water savings that appear to last over time, beyond the first year after the audit was performed. For the average STF participant, water savings appeared to last at least five years post-audit (Table 5). Surprisingly, water savings increased over time, with the highest average savings five years post-audit. This occurred despite the fact that RWA eventually returned to pre-auditing levels by 4 to 5 years post audit (Figure 3). This phenomenon is a result of two factors. First, those who benefited from the audit by becoming more efficient and saving water, tended to be participants that were over-watering by the largest amounts before the audit (see results in Table 10 for evidence). Therefore the water savings from these individuals were relatively large. These participants also tended to maintain their improvements over time, whereas those who did not seem to benefit from the audit were more volatile over time. Due to our effort to reduce the inclusion of savings that were not attributable to the program, these volatile participant records were often removed, following the criteria explained in the methods section. Also, those who had little to no improvement in RWA (a measurement of the amount of water applied relative to the amount of water needed), and saw little to no water savings, tended to be those who were over-watering by small amounts pre-audit (again, see results in Table 10 for evidence). Therefore their return to, or lack of inefficient water use had a weaker overall impact on average water savings.

Table 5. Water savings (kgal)

Years Post Audit	Mean	St. Dev.	Median	Min	Max	N
1	4.8	32	2	-223	221	2054
2	8.5	34	7	-114	205	1317
3	14.6	43	14	-206	232	696
4	14.9	53	17	-198	238	313
5	21.2	57	19	-157	187	80

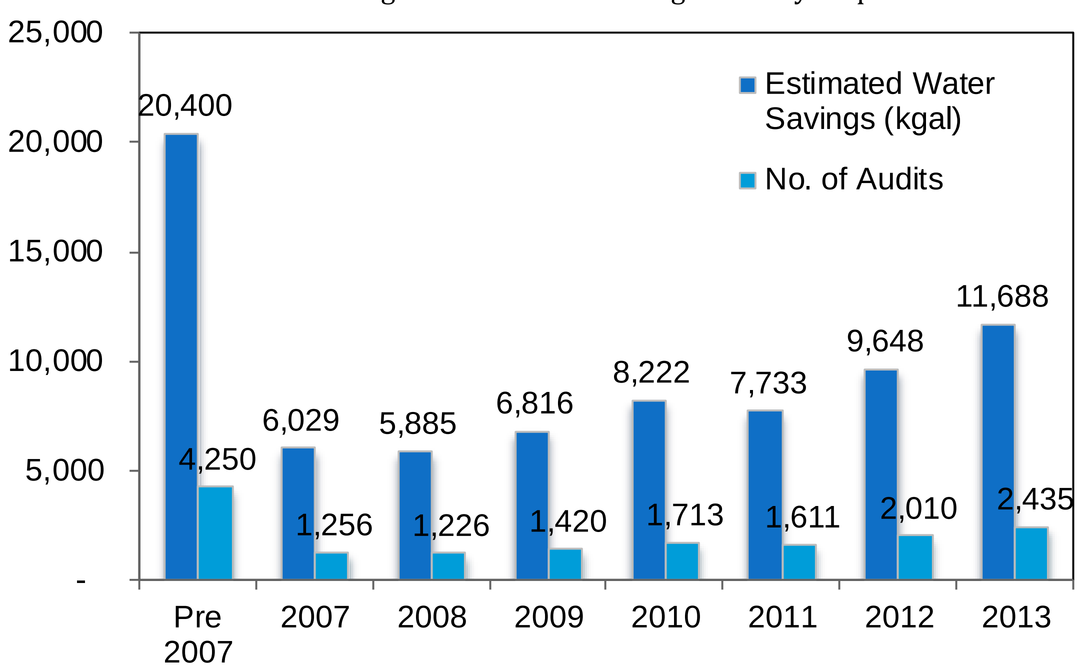
The large increase in RWA in the 4th year post-audit is most likely due to a combination of hot and dry weather (the 4th year post-audit data is mostly from 2012) and the inability of most participants to retain the education gained from the audit for that length of time.

Figure 3. The average RWA from two years pre- to five years post-audit.



We estimated the water savings of all STF audits that had been performed since the programs start in 2003 (Figure 4). Since 2003 the CRC has performed 15,921 audits. If the average savings from our audits is 4.8 kgal, then the total savings since 2003 from the program have been 76,421 kgal, or 234.5 AF, not counting any savings from beyond one year-post audit. If the trends found from this sample are accurate, then the savings from the audits are in fact, much, much higher.

Figure 4. Bar plot of water savings and number of audits by year since the start of the STF program. These estimates are calculated using the mean water savings from 1 year post-audit from Table 5.



Cost-Benefit Analysis

The cost-benefit analysis is provided to help water conservation professionals translate the water savings from the program into a monetary value that can be directly compared to estimations of alternative options to conservation for increasing water supply. For calculating the cost of savings of one acre foot (AF) of water from the STF program we used an assumption of 100 total participants and 4.8 kgal of savings per participant (Table 6). This savings value comes from the average savings from 1 year post-audit of all 2,054 participant records provided to the CRC by 9 different water providers for the impact analysis. The cost per audit is representative of the actual cost paid by our partner water providers in 2007-2011 for each audit. Table 7 contains the estimated cost of on AF of savings.

Table 6. Water savings assuming 100 participants and average water savings from the entire impact analysis sample of 2,054 participant records in the first year post-audit.

Number of Participants	Avg Savings (kgal)	Annual Savings (kgal)	Annual Savings (AF)
100	4.8	480	1.47

Table 7. Cost of audits and of saving 1.47 AF of water using this hypothetical example.

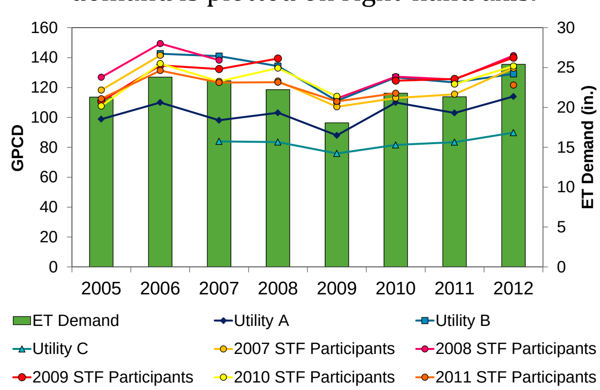
Cost per Audit	Cost All Audits	Cost per AF of Water Saved
$ 100	$ 10,000	$ 6,789

These numbers indicate that with 100 participants, the program would be worth 1.47 AF of water savings, at the cost of $6,789 per acre foot. This estimation only counts a single year of water savings, however, as mentioned above with regards to cumulative water savings, we believe that there is evidence that the savings from the program actually last for several years beyond the audit for the average participant, and therefore the cost per audit may actually be lower.

Comparison to the Average Resident

From three Front Range utilities (Utility A, B, and C) we used single family residential gallons per capita per day (GPCD) data to compare to GPCD of the STF participants (Figure 5). We learned two lessons from this comparison. First, those participating in STF were using more water, on average, than the general population. This indicates that the program is being delivered to the correct population. Second, the juxtaposition of GPCD data with annual ET demand shows how closely the general population and STF participants follow the weather with their outdoor watering habits. During years with high ET demand, GPCD is also high, and during 2009 when ET demand was low, GPCD numbers reach their lowest point.

Figure 5. Average GPCD of single-family residential accounts for Utility A, B, and C and STF participants by audit year (left-hand axis). Gaps occur for the year participants were audited. ET demand is plotted on right-hand axis.



Factors that contribute to outdoor usage, watering efficiency, and water savings

We conducted an analysis of some of the factors that may contribute to outdoor water usage, water use efficiency, and water savings from the STF program. The analysis included a sample of 2,054 participants and incorporated descriptive and parametric statistical tests[10] for significant[11] differences in water use, watering efficiency (i.e. Rate of Water Application), and water savings based on a variety of landscape and irrigation system factors. Factors included in the analysis were sprinkler system age, presence of drip systems, amount of xeriscape landscape, severity of irrigation system problems (e.g. broken/tilted heads/overspray/poor spacing), distribution uniformity, precipitation rate, and other factors that may contribute to inefficient water use. The three main questions that we have tried to answer with this analysis are:

1. What factors contribute to outdoor water usage?
2. What factors are related to outdoor watering efficiency/RWA?
3. What factors help to predict water savings from the Slow the Flow program?

In order to answer these questions we used single-factor analysis of variance (ANOVA) and linear regression. Both of these tests are used to evaluate the significance of a single factor (the independent variable, X) on the outcome of another factor (the dependent variable, Y). With the ANOVA test, the conclusion that can be drawn is whether or not there is a significant difference in the dependent variable's mean based on the categories designated by the independent variable. Linear regression provides both the proportion of total variability explained by the model (Adjusted R^2), as well as the intercept and slope of the model, with associated significance levels.

A summary of the results are presented below. These findings include the data from 2,054 participants from 5 audit years, 2007-2011. This sample size allows for statistically significant conclusions to be drawn from the tests applied to the data. Preliminary results show that variation in trends can occur between different water providers. Future work is needed in order to evaluate geographic differences in outdoor water use, watering efficiency, and savings from the STF program.

To answer the first question we evaluated the participant outdoor water use with landscape type and size, the weather (represented by ET demand), the number of days that the irrigation system runs per week, and number of cycles that the irrigation system runs. Table 8 presents the detailed results of each test. From the tests it was found that outdoor use pre-audit was not significantly different based upon the presence of xeriscape in the yard (none vs. some), however post-audit, outdoor use was significantly different based upon the presence of xeriscape. Participants without xeriscape had a significantly lower mean outdoor water use of 77.3 kgal per year than participants with xeriscape, who had a mean of 83.7 kgal per year. This difference may be caused by the greater reductions in outdoor use experienced by participants with larger proportions of turf, as the audit and recommendations are focused on applying appropriate water to turf landscapes. The amount of turf, shrub, and total landscape area (in square feet) were all significantly and positively related to outdoor water use. Furthermore, turf and total landscape area seemed to have a stronger effect on outdoor water use, both having adjusted R^2 values around 0.25, relative to shrub area, which had an adjusted R^2 value less than 0.1. The weather,

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[10] Descriptive statistics are used to assess the range, central tendency (i.e. mean, median), and other general attributes of the data. Parametric tests are used for data that come from a normal probability distribution.

[11] Significance is reported as a P-value. The P-value is the probability that the outcome being tested has occurred is by random chance. A P-value of 0.05 or less was required for the outcome to be considered significant; this assures a 95% or greater probability that the outcome did not occur by chance.

represented by ET demand (in inches), was highly positively related to outdoor use (Figure 6). This finding is not surprising, but highlights the importance that the weather has on influencing outdoor watering habits of Front Range residents. Neither the number of cycles nor the number of watering days per week were found to significantly affect outdoor water use.

Figure 6. ET demand (in.) vs. outdoor use (kgal) from pre-audit. Each point is labeled with the year that it represents.

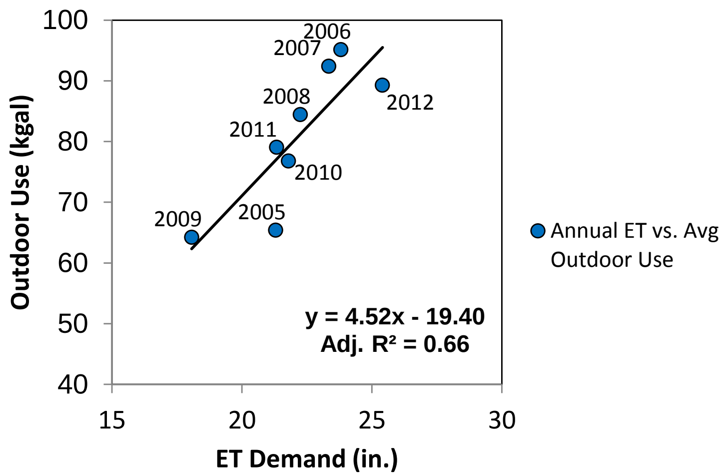


Table 8. Results of statistical tests to evaluate what variables (X) contribute to outdoor water usage(Y). Significant results are in **bold**. NA = Not Applicable.

Independent (X) Variable	Test Used	Regression Statistic	Significance (p-value)	Regression Coefficients	Conclusion
Xeriscape (None, Some)	ANOVA	NA	0.276	NA	Outdoor water use **pre-audit** is not significantly different based on presence of xeriscape (some or none).
Xeriscape (None, Some)	ANOVA	NA	**0.007**	NA	Outdoor use **post-audit** is significantly different based on presence of xeriscape (none or some). When there is no xeriscape, participants had significantly less outdoor water use post-audit than those who had some xeriscape. This may be because the audit is mostly focused on turf irrigation rather than on xeriscape.
Turf area (sq. ft)	Regression	Adj. R2 = 0.25	**4.22E-01**	**Intercept = 113**	Outdoor use pre-audit is significantly and positively related to Turf area. As turf area increases, outdoor usage increases.
			<0.0001	**Slope = 35**	
Shrub area (sq. ft)	Regression	Adj. R2 = 0.09	**1.11E-04**	**Intercept = 294**	Outdoor use pre-audit is significantly and positively related to shrub area. As shrub area increases, outdoor usage increases.
			<0.0001	**Slope = 10**	
Total Landscape area (sq. ft)	Regression	Adj. R2 = 0.28	**3.81E-04**	**Intercept = 536**	Outdoor use pre-audit is significantly and positively related to total landscape area. As total landscape area increases, outdoor usage increases.
			<0.0001	**Slope = 43**	
ET Demand	Regression	Adj. R2 = 0.66	**0.03**	**Intercept = -19.4**	Outdoor use is significantly and positively related to ET Demand. As ET demand increases, outdoor use increases.
			0.01	**Slope = 4.5**	
Number of Cycles	ANOVA	NA	0.75	NA	Outdoor use is not significantly different based on the number of cycles.
Watering Days per Week	ANOVA	NA	0.98	NA	Outdoor use is not significantly different based on the number of watering days per week.

The Rate of Water Application, a pseudonym for watering efficiency, is calculated as the amount of water applied to the landscape relative to the amount of water that the landscape needs, based on its size, type (turf vs shrub), and the weather (ET demand), and it is a percentage that describes the proportion of over- or under-watering that occurred. For this analysis we used each participant's average pre-audit RWA. We choose to evaluate pre-audit RWA as we have no information as to whether homeowners made changes to the various sprinkler system parameters after their audit or not. Table 9 contains the results of comparing RWA pre-audit to 20 different factors that are often assumed to be directly related to irrigation system efficiency and health. Surprisingly, of these 20 factors, only one, presence of a drip system (yes/no), was found have a significant relationship to RWA. Furthermore, the results from this test indicate that those participants with drip systems had lower (worse) RWA pre-audit than those who did not. It is not understood what may have caused this. One possibility, with rather significant implications, is that watering efficiency (i.e. RWA) is NOT determined by sprinkler system health or technology, but rather, by human behavior. If this is true, it would suggest that the educational component of the audit, rather than any improvements made to the sprinkler system, are what caused the savings from the audit and are the most important factor contributing to outdoor water use. Another possibility as to why there were few of the factors significantly related to RWA is because it is dependent upon multiple factors, and therefore the ANOVA and linear regression tests that only evaluate the influence of a single factor at a time do not provide accurate results. Future work needs to incorporate a multiple regression analysis that takes into account multiple factors at once. Another job for future investigation is to address the datasets with unequal variances, which made them unsuitable for the Single-Factor ANOVA test. Below, in Figures 7 and 8, RWA is plotted as a function of sprinkler system age and PSI. The predicted Y values show that there is little relationship between the independent variables (X) and the dependent variable (RWA (Y)).

Figure 7. Sprinkler system age (years) vs. RWA with actual (Y) and predicted values.

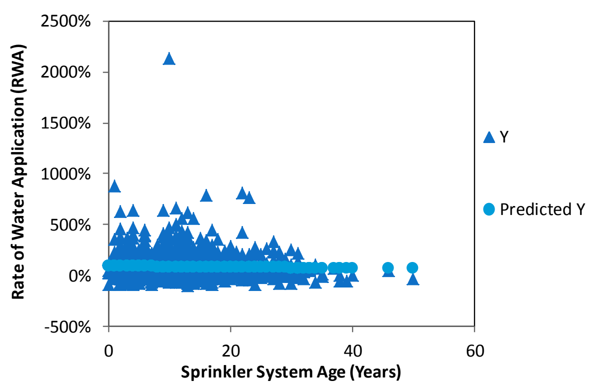


Figure 8. PSI vs. RWA with actual (Y) and predicted values.

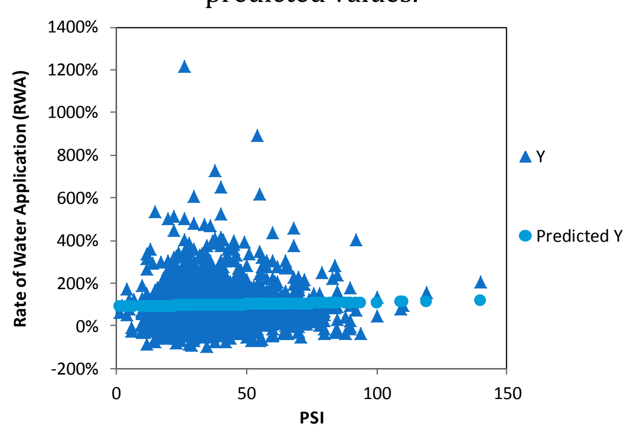


Table 9. Results of statistical tests to evaluate what factors contribute to RWA pre-audit. Significant results are in **bold**. NA = Not Applicable.

Independent (X) Variable	Test Used	Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Sprinkler System Age	Regression	Adj R2 = 0.0	NA	NA	RWA is not significantly related to sprinkler system age.
Backflow preventer	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
Drip system presence (yes/no)	ANOVA	NA	**0.01**	NA	RWA is significantly lower (i.e. worse) pre-audit for those participants who have a drip system in at least part of their yard.
MP Rotators	ANOVA	NA	0.39	NA	No detectable significant difference exists in RWA based on presence of MP Rotators (Some vs. None).
Check Valves	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
ET/Soil moisture sensor	ANOVA	NA	0.45	NA	No detectable significant difference exists in RWA based on presence of ET or soil moisture sensors.
Rain Sensor	ANOVA	NA	0.88	NA	No detectable significant difference exists for RWA based on presence of a rain sensor.
PSI Zone A	Regression	Adj R2 = 0.0	1.02E-39	Intercept = 0.88	**RWA is not significantly related to PSI in Zone A or Zone B.**
			0.19	Slope = 0.0	
PSI Zone B	Regression	Adj R2 = 0.0	0.99	Intercept =0.0	
			0.00	Slope = 0.14	
DU Zone A (Poor, Acceptable, Good, Excellent)	ANOVA	NA	0.14	NA	No detectable significant difference exists in RWA based on the DU in Zone A.
DU Zone B (Poor, Acceptable, Good, Excellent)	ANOVA	NA	0.98	NA	No detectable significant difference exists in RWA based on the DU in Zone B.

Table 9. Continued

Independent (X) Variable	Test Used	Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Broken heads	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
Low heads	ANOVA	NA	0.44	NA	RWA is not significantly different pre-audit for those participants with some, few or no low sprinkler heads.
Clogged heads	ANOVA	NA	0.17	NA	RWA is not significantly different pre-audit for those participants with none, few or some clogged sprinkler heads.
Overspray	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with parametric tests.
Unmatched Precipitation Rates	ANOVA	NA	0.12	NA	RWA is not significantly different pre-audit for those participants with none vs few unmatched precipitation rates.
Poor head spacing	ANOVA	NA	0.45	NA	RWA is not significantly different pre-audit for those participants with few vs some vs many poorly spaced sprinkler heads.
Broken/leaking valve	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
Inefficient Watering Schedule	ANOVA	NA	0.28	NA	RWA is not significantly different pre-audit for those participants with efficient vs. moderately inefficient watering schedule.
Improper Pressure	ANOVA	NA	0.97	NA	RWA is not significantly different pre-audit for those participants with a small amount of improper pressure vs. a moderate amount of improper pressure.

The final set of tests evaluated the factors that contribute to water savings in the first year post-audit. This set of tests essentially measures how much each independent (X) variable helps to "predict" water savings. The complete results are detailed in Table 10. Outdoor water usage pre-audit is a significant predictor of water savings with higher outdoor usage relating to higher savings. Pre-audit RWA also helps to predict water savings, but to a slightly weaker degree. Efficiency of a participant's watering schedule, based on the auditor's assessment of the control clock schedule, does not have a significant relationship to water savings.

Table 10. Results of statistical tests to evaluate what factors contribute to water savings one year post audit. Significant results are in **bold.** NA = Not Applicable.

Independent (X) Variable	Test Used	Regression Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Outdoor usage pre-audit (kgal)	Regression	Adj R2 = 0.11	3.34E-22	Intercept = -12	Outdoor use pre-audit is significantly and positively related to water savings. As outdoor use pre-audit increases, water savings also increase.
			1.38E-55	Slope = 0.20	
Pre-Audit RWA	Regression	Adj R2 = 0.06	2.61E-02	Intercept = -2.0	RWA is weakly and positively related to water savings. As RWA increases, water savings also increase.
			7.70E-30	Slope = 7.4	
Efficiency of pre-audit watering schedule (rank 0-3, 0=efficient)	ANOVA	NA	0.057	NA	Water savings are not significantly different based on the efficiency of the pre-audit watering schedule.

Figures 9 and 10 contain the plotted water savings values against outdoor water use and RWA. Both plots demonstrate the positive relationship between water savings and the two X variables.

Figure 9. Outdoor water use (kgal) vs. water savings (kgal) and predicted values.

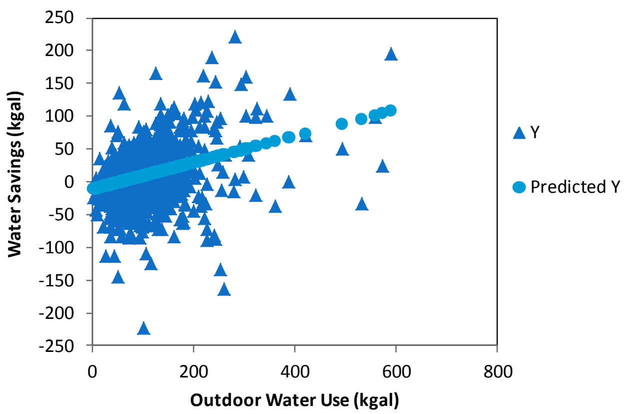
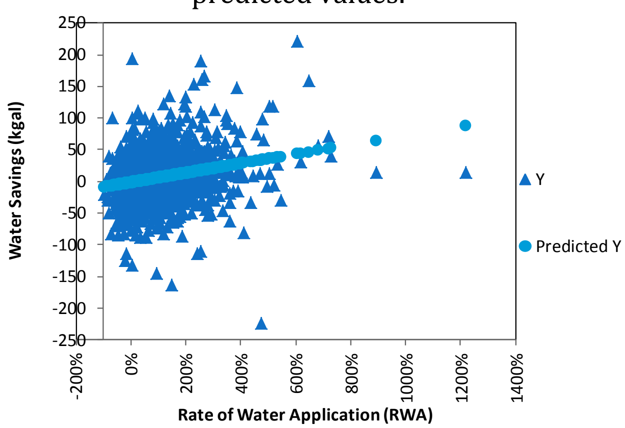


Figure 10. RWA vs. water savings (kgal) and predicted values.



STF IA Conclusions

Overall, the results from this analysis indicate that the STF program is an effective water conservation program for the majority of the participants. Despite the fact that the program does not use targeted advertising, it reaches customers who are over-watering (Figures 2 and 3) and who tend to be watering at levels above the average resident from other Front Range utilities (Figure 5). Water savings persist for several years beyond the audit for the average participant, but not for all (Table 5). While an ideal outdoor water conservation program would secure water savings into perpetuity, our findings suggest that sprinkler systems do not operate efficiently just because the components of the system are well maintained (Table 9, Figures 7 and 8). Our results show that outdoor water use is strongly related to weather (Table 8, Figure 6). They also show that water savings are significantly related to pre-audit RWA and raw outdoor usage. Both of these findings are informative, but not surprising. One finding that was quite surprising was that the Rate of Water Application does not have a significant relationship to most basic sprinkler system attributes (Table 9, Figures 7 and 8). This finding is surprising both because it is counterintuitive, and also because the audits still, overall, produced measurable water savings. One plausible explanation for this phenomenon is that watering behaviors outweigh factors related to sprinkler system health when it comes to the amount of over- or under-watering by a participant. Reducing outdoor water use may therefore be dependent more upon education of the homeowner on how and when to use their sprinkler system, rather than sprinkler system optimization and technological fixes. Future work should focus on evaluating and quantifying the impact of educational components of water conservation programs to help gain a better understanding of these findings. Future work also needs to evaluate outdoor use, watering efficiency, and water savings as multifactorial variables. While many of the variables tested showed little to no relationship to these parameters on their own, together they may significantly contribute to water usage.

Our results highlight the positive impacts of the STF program, such as the water savings (Table 5) and competitive cost of the program (Tables 6 and 7). They also make apparent room for improvement, such as through increased efforts to enhance the sustainability of the savings and reduce participant over-watering by even greater degrees. For a preliminary investigation of the impact of the program post-programmatic changes in 2012, we provide the results of an analysis from a small sample of 2012 participants.

Preliminary findings from 2012 STF Participants

Table 11. Number of participants (N) by water provider.

Water Provider	N
Broomfield	43
Willows Water	71
Total	114

Two water providers gave the CRC data from participants from the 2012 audit season. Table 11 contains the break down in participant numbers by provider. Due to the small sample size, results in this section are only preliminary and may not represent the actual savings values of the average STF participant from 2012.

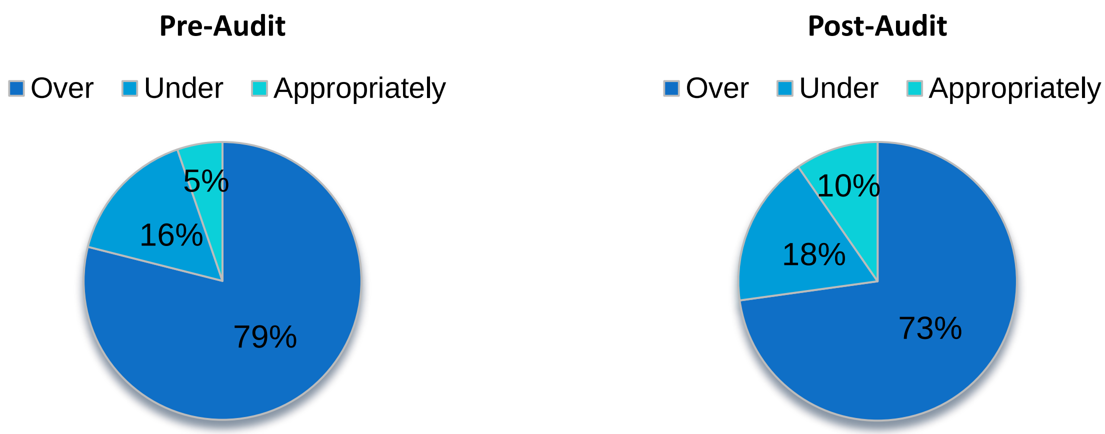
Average annual indoor and outdoor use decreased slightly between the two pre-audit years and post-audit year (Table 12); however these decreases were not statistically significant. Total annual use could not be evaluated due the fact that data for 2013 was received in October, and therefore we choose to only evaluate January-October data.

Table 12. Average annual indoor and outdoor use (kgal)

		Indoor Use		Outdoor Use	
	Year	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
Pre-Audit	**2010**	43	24	71	41
	2011	45	20	70	36
Post-Audit	**2013**	43	21	61	31

The percent of those over-watering prior to the audit was 79%, while 16% were under-watering, and 5% were watering at appropriate levels (within ± 10% of ET demand) (Figure 11). In 2013, the year following the audit, the percentage of those who over-watering dropped, while the percentage of those who were under-watering and appropriately-watering both increased.

Figure 11. Precent watering over, under or at (within ± 10%) of ET demand.



Comparing these proportions to those in Figure 2, a slightly higher percentage of participants from the 2012 audit year went from over-watering to under- or appropriately-watering between pre- and post-audit, with 6% leaving the over-watering category from the 2012 participants, and only 4% leaving the over-watering category from the 2007-2011 participants.

Not only did the percentage of participants who were over-watering decrease, but also the amount that they were over-watering also decreased. In 2010 and 2011, before the audit, participants averaged 26 kgal above their calculated landscape need (Table 13). In 2013, they only over-watered on average by 20 kgal.

Table 13. Amount of over/under watering (kgal)

	Mean	St. Dev.	Median	Min	Max
2010	26	37	21	-85	146
2011	26	33	23	-41	169
2013	20	27	16	-40	110

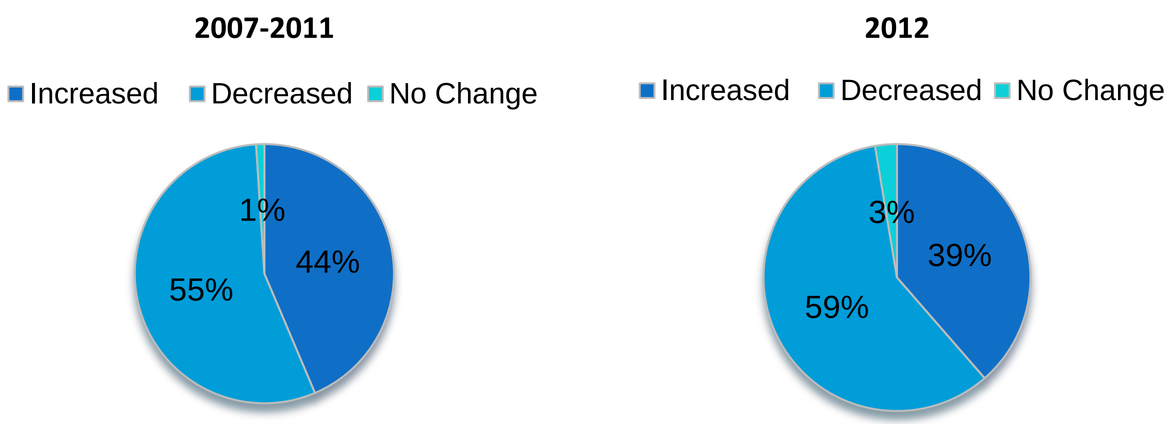
The average RWA decreased from 87% to 67%, a 23% decrease between the year before to the year after the audit (Table 14). This rate of change is nearly twice as large as the 12% decrease found for the 2007-2011 participants. This suggests that the audits in 2012 may have had a larger impact on watering efficiency than in previous audit years. However, between the audit year ET demand (25.4 in) and the post-audit year (19.2 in) had a change of similar magnitude, 24%, which most likely also influenced a improvement in watering efficiency during this time period.

Table 14. Average RWA pre- and post-audit

	Years	Mean	St. Dev.	Median	Min	Max
Pre-Audit	**2010**	78%	110%	55%	-84%	550%
	2011	87%	128%	61%	-72%	847%
Post-Audit	**2013**	67%	99%	47%	-69%	537%

The evaluation of 2012 data separate from the 2007-2011 data is to assess whether any differences occurred due to the programs switch in watering recommendations. Prior to 2012, the program was more focused on landscape health, and therefore, when a participant was found to be over- or under-watering relative to their landscape's calculated need, we would teach them techniques and provide them with a watering schedule to get them to more closely match their landscape's ET demand. At times, this resulted in our recommendation to those who had healthy landscapes to increase water use. In 2012, we changed our recommendations to suggest a new watering schedule only to those who were over-watering and to those who were under-watering and did not have a healthy landscape. Figure 12 provides some evidence that our change in recommendations had at least a small impact on affecting appropriate watering habits.

Figure 12. Comparison of 2007-2011 & 2012 audit year percent of participants that increased, decreased, or had no change in their RWA between pre- and post-audit.



Of the sample surveyed from pre-2012, 55% decreased and 1% had no change in RWA. However, of those surveyed in 2012 59% decreased and 3% had no change in RWA. These results are encouraging, however they also indicate that there is still room for improvement.

When evaluating the water savings of the participants from 2012 we found that they had the same average savings in their first year post-audit, 4.8 kgal, as the 2007-2011 participant group (Tables 15 and 5). Median savings in the 2012 group are higher at 4 kgal, relative to 2 kgal in the other group.

Table 15. Water savings (kgal)

	Mean	St. Dev.	Median	Min	Max
Savings Per Participant	4.8	23	4	-72	84

Preliminary Conclusions from the 2012 Participants

While the sample size for the analysis of 2012 STF participants was too small for conclusive results, the preliminary results suggest that the changes to the recommendations may have increased the conservation benefits of the audits. The reduction in RWA between pre- and post-audit was larger for the 2012 participants than for 2007-2011 participants and a slightly higher proportion of participants decreased their over-watering habits in the 2012 participant group. Water savings in the 2012 participant group were similar to the 2007-2011 group, which points to at least equal, if not improved program impact.

Adaptation and Analysis to Other Programs

There were three other main water conservation program areas that we evaluated for water savings: Slow the Flow Indoors, Garden-In-A-Box, and a rotor nozzle retrofit program. While we were unable to retrieve sufficient data for a full-scale analysis as we performed for STF, we did different analyses that, in their own way, allow us to evaluate the savings and potential savings of these three programs. We provide a description of the methodology that we used to get the results that we do present below as well as an explanation of how to adapt the STF impact analysis methodology to other programs. We hope to be able to apply these methodologies in the future, and that other entities with similar questions can use these methodologies for their own water conservation programs.

Slow the Flow Indoors

Slow the Flow Indoors (STF Indoors) is a residential water audit program to help educate customers on practical and easy methods for making their indoor environment more water efficient. We provide all participants with a free low-flow shower heads and faucet aerators, if desired, and a report that includes a cost-benefit analysis of the recommended fixture and appliance upgrades.

Methods

The CRC has used an established methodology for evaluating water savings of STF Indoors since the inception of the program in 2010. This methodology essentially compares the water use of measured and reported manufacturer flow rates of the existing fixtures to those of recommended fixtures. If any low-flow shower heads or faucet aerators are installed during the audit, we count the water savings of those adaptations. Finally, we also estimate the water savings potential if each participant is to make all recommended upgrades and fix all leaks found during the audit. From our most recent follow-up survey in 2013, 40% of respondents reported having followed at least one of the recommended upgrades from their audit. To expand upon this analysis we will present the aggregated water savings from all audits performed since September, 2010 through May, 2013.

In order to adapt the STF Outdoors methodology to STF indoors we would simply need to use Equation 2 to calculate the annual indoor use for all years pre- and post-audit. Because indoor use is not weather dependent, we would not need to modify the value based on this criterion, however we would need to take into account the number of full time residents and adapt the value if that number changed throughout the year. This would also introduce some amount of error assuming that we were unable to find out if any changes had occurred to the number of residents since the audit.

Results

Since the first year of indoor audits in fall of 2010, the CRC has performed 920 audits (Table 16). Overall the program has directly saved 4,726 kgal (15 AF) of water through low-flow shower head and faucet aerator replacements. This indicates that the STF Indoor audits save an average of 5 kgal of water per participant. If participants had followed all recommendations after the audit, the program had potential savings of 15 kgal, equivalent to 47 AF of savings since 2010.

Table 16. Summary of STF Indoor audits, water savings (in kgal and AF), number of retrofits, and potential savings (in kgal and AF) by audit year.

Audit Season	No. of Audits	Faucet Aerators Installed	Low-Flow Shower Heads	Water Saved (kgal)	AF Water Saved (gal)	Potential Savings	AF Potential Savings
Sept 2010-May 2011	228	419	137	866	3	5,395	17
Sept 2011-May 2012	454	1363	502	2,849	9	5,659	17
Sept 2012-May 2013	238	727	283	1,011	3	4,152	13
Totals	920	2,509	922	4,726	15	15,206	47

Because this program works to make permanent replacements and adjustments to water fixtures and appliances, water savings are also essentially permanent. Figure 13 displays the nature of the savings over time, which accumulate each year.

Figure 13. Stacked bar plot showing the accumulation of water savings (kgal) from low-flow shower head and faucet aerator replacements.

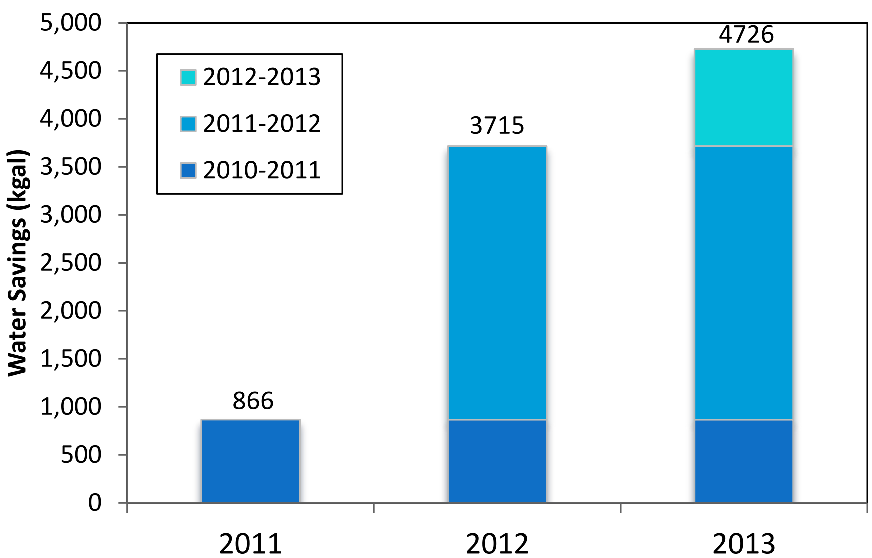
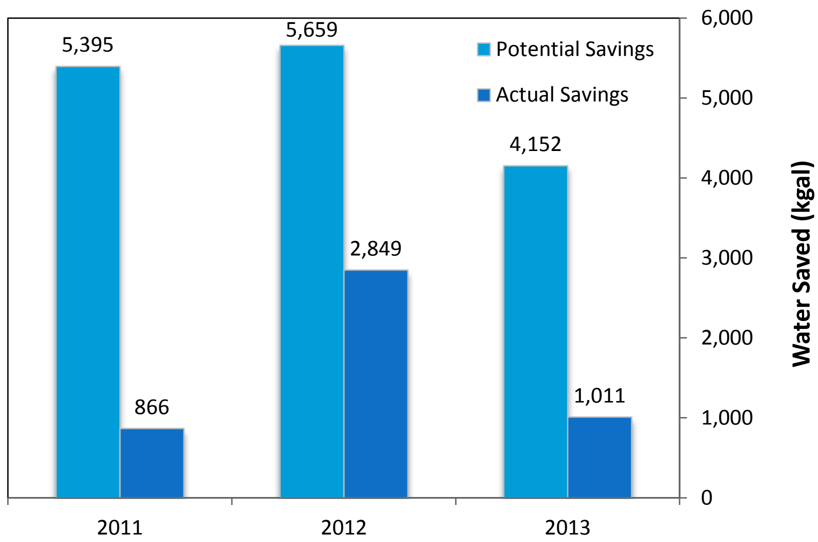


Figure 14. Actual (dark blue) vs. the potential (light blue) water savings from STF Indoors for 2011-2013.



While these savings are significant, the total potential savings of the program are nearly three times the size of the total actual savings. Some potential savings are most likely realized based on our finding that approximately 40% of participants do follow through with at least one recommended upgrade or fix within their home after the audit (and this proportion is similar in other years). However, Figure 14 gives a good visual representation of the untapped potential savings from indoor water conservation. This finding shows the CRC that work still needs to be done to address the difference between potential and actual savings, possibly through increased customer outreach post-audit.

Garden-In-A-Box

The Garden-In-A-Box (GIAB) program offers professionally designed plant-by-number gardens that make water-wise gardening an approachable project for a homeowner. The program is offered in approximately 10 water districts across the State. It has operated in its current form since the early 2000's as a retail operation, primarily run through an online store, with designated pick-up events throughout the spring and early summer of each year. Since 2003, the CRC has sold over 6,000 xeric gardens through the program. The methodology below will describe how we measure water savings from the program as well as a current experimental project through a partnership with Northern Colorado Water Conservancy District (Northern Water) to directly measure the water needs of three gardens from the program.

There would be little required changes to the water savings calculations presented above for STF outdoors to use them for the GIAB program. However, other challenges may make measuring direct water savings from the program difficult. The greatest challenge would be caused by the fact that we do not currently have the ability to monitor whether or not the new gardens were used to replace turf, other shrubs, or non-live landscape (such as a patio). If we want to measure direct water savings from this program we would want to pursue a study similar to that run by Southern Nevada Water Authority who performed a full-scale monitoring project to evaluate water-use change of their turf replacement program (Sovocool, 2005).

Methods

Our current method for measuring water savings from the GIAB program uses an empirically-derived landscape coefficient , cited by Northern Water in their *Xeriscape Irrigation Recommendations* online document[12], with our calculated annual ET_r values to establish the ET demand for the planted gardens. This calculated value is a *potential* water savings, not an actual water savings value. Northern Water recommends an average landscape coefficient of 0.3 (30% of alfalfa reference ET) or 0.35-0.38 (35%-38% of bluegrass turf reference ET) for calculating the ET demand of xeriscape gardens. We have chosen to use the landscape coefficient of 0.38 to be as conservative as possible with our water savings estimates. We multiply this landscape coefficient by the calculated N (Need) from Equation 4, using the area specified by the garden design for T (Turf area). The difference between the N and the modified N value are the water savings from the program.

Several assumptions must be made in order for these estimates to be valid. First, we assume that each garden is planted following the recommended planting design, with a set area. We also assume that every garden is replacing an equivalent area of turf. Therefore, the values that we estimate for savings are most likely higher than actual savings as many of the gardens purchased may not have been planted according to the design and may not have been used to replace. Finally, we have to make the assumption that each xeric garden was watered at the appropriate level.

Our second method for calculating water savings from the GIAB program is focused on better quantifying the actual water needs of the offered gardens through a full-scale experiment at the Northern Water headquarters in Berthoud, Colorado. Northern Water and the CRC have partnered to use three GIAB gardens to better define the recommended watering requirements of xeric gardens. Experimental gardens were planted in June of 2013, making the 2013 season the establishment year for the plants. Beginning in spring of 2014, when watering of the landscape commences, three different watering treatments (irrigation levels) will be applied to each of the three types of gardens, with three replicates of each treatment, totaling 27 separate garden plots. The levels of watering will be determined based on observations made during summer of 2013. The irrigation systems for the garden plots are effectively identical, utilizing on-surface drip irrigation grids (with in-line emitters). All water flows are measured through flow meters connected to data loggers. A co-located weather station will be used to measure ET_o, allowing us to compare the three measured watering levels to both ET_o and to standard bluegrass turf water use. Results are not yet available, however findings will be presented at WaterSmart Innovations conference in Las Vegas in October, 2014.

Results

Since 2003, the GIAB program has sold 6,097 xeric gardens. Using the square footage from each garden's designated plot size, these gardens have potentially covered 562,398 sq. ft. of land. Table 17 shows how much water a turf area of this amount would require, how much water a xeriscape area of this amount would require, and the difference between the two, which are the potential water savings from the GIAB program.

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[12] *Xeriscape Irrigation Recommendations*. Published by Northern Colorado Water Conservancy District. Accessed on 6/1/2013. <http://www.northernwater.org/docs/WaterConservation/ConservationGardens/XeriscapeRecommendations.pdf>

Table 17. Estimated amount of landscape converted to xeriscape (sq ft) through the GIAB program since 2003, with estimated Need (kgal) of turf for the landscape, estimated Need (kgal) of xeriscape for the landscape, and total potential water savings (kgal & AF) (difference between turf and xeriscape Need).

Landscape Converted to Xeriscape (sq ft)	Need for Turf landscape (kgal)	Need for Xeriscape landscape (kgal)	Total Potential Water Savings (kgal)	Total Potential Water Savings (AF)
562,398	9,465	3,597	5,868	18

These results show the conservation benefits of converting landscape from turf to xeriscape in the Front Range. Our future work will provide us with even more accurate estimations of the potential savings of the program and will allow us to more effectively communicate the conservation benefits of xeriscape conversion to our customers.

Rotor Nozzle Retrofits

In a limited number of water districts where the CRC has offered the Slow the Flow outdoor program, the CRC has also offered a rotor nozzle retrofit program. For participants in STF in these water districts, we have done some preliminary analysis of the impact of the retrofits on the participant's outdoor water use. The challenge of this analysis was the same as for the two programs above, the data set was small, with only 23 usable participant records. Furthermore, there was little consistency between audit years and retrofit years such that between the 23 samples there were participants who were audited in all years from 2007-2011 and there were participants who received retrofits in 2010 and 2011. This mixture made it very difficult to ascertain the changes in outdoor usage due to audits versus changes due to retrofits. The results below should therefore only be viewed as preliminary and may not reflect the true impact of the sprinkler retrofit program on the larger population from which the sample was taken.

Methods

The City of Thornton provided the CRC with water use records for their STF and the rotor nozzle retrofit program participants. All variables calculated for the STF program were used for this analysis. Although more records were provided than the final 23 used in the analysis, many of these records had to be removed due to incompleteness. Due to the extremely small sample size, care was taken to evaluate each individual participant's pre- and post-retrofit RWA along with their pre-and post-audit RWA, as well as the percent change from one year pre- to one year post-service. The percent change is calculated following Equation 10:

(RWA pre-service – RWA post-service)/ABS(RWA pre-service) = Percent Change Eq. 10

The ABS() notation indicates that the absolute value of RWA pre-service was used in this part of the equation. The percent change provides some indication of any watering efficiency gains or losses from the two services.

Results

The results of this analysis were mixed. The pre- to post-audit (Table 18) and pre- to post-retrofit (Table 19) mean RWA values indicate a reduction (i.e. improvement) in the average RWAs. However the average percent change was positive for the mean RWA values (i.e. disimprovement). The median RWA values also suggest an increase (i.e. disimprovement) in RWA between pre- and post-service. Yet, the median percent change was negative, indicating that over 50% of the sample had at least a 27%-28% reduction in their RWA between pre- and post-services.

Table 18. Pre- and post-audit summary statistics.

Statistic	Per-Audit RWA	Post-Audit RWA	Percent Change
Mean	57%	48%	33%
St. Dev.	85%	66%	
Median	48%	50%	-27%
Minimum	-72%	-68%	
Max	245%	226%	

Table 19. Pre- and post-retrofit summary statistics.

Pre-Retrofit RWA	Post-Retrofit RWA	Percent Change
60%	43%	17%
93%	64%	
42%	46%	-28%
-61%	-57%	
315%	206%	

Conclusions

These findings essentially suggest that for this small set of participants, very little consistent outcome from either service was realized. It should be noted that these results follow the findings reported in Table 9 that show no significant relationship between the presence of MP Rotors and the pre-audit RWA. Furthermore, other researchers have also found similar results[13]. Further work is needed for any conclusions to be drawn about the impact of the nozzle retrofit program on participant water use.

Report Conclusions

Analyzing the impact of water conservation programs on water use is essential to ensuring successful programs. The Center for ReSource Conservation (CRC) began the impact analysis of our largest water conservation program, Slow the Flow (STF), in 2012 with a pilot-scale analysis. The findings from the pilot analysis were promising and suggested that the program was saving the average participant several thousands of gallons of water per audit. The results also suggested that there were other questions that could be answered in a more thorough analysis. Through the generous support of the CWCB and several of our water utility partners in 2013 we began a rigorous analysis of the STF program as well as of several other programs that we offer. This report has detailed the methods and results of these analyses, providing the Colorado Water Conservation Board, our partner utilities, and the rest of the water conservation community with information on the impact of several water conservation programs here in Colorado.

Overall the project ran smoothly and only a few small challenges were encountered. Our greatest challenge was obtaining the data we needed in order to use the methodology that we came up with for each of the various programs that we had hoped to investigate. Fortunately, we were able to obtain a good sample size for the main analysis of the STF program. For the other programs we found other methods and means of measuring and assessing their impact.

[13] Petersen & Eugene Water & Electric Board (2013) *Reducing Peak Hour Demand With Nozzle Retrofits: Three Year Evaluation*. Presentation at WaterSmart Innovations, Las Vegas. Oct. 3, 2013. AND Sovocool, Morgan, and Drinkwine, SNWA (2013) *Observed Long-Term Results of Multi-Stream Rotational Spray Heads and Associated Product Retrofits*. Presentation at WaterSmart Innovations, Las Vegas. Oct. 3, 2013.

The methodology that we developed is by no means very complex or challenging. It functions on the basic premise that if the program had an impact on a participant's water use then a measurable difference in water use and/or the efficiency of use should exist between their water use and/or efficiency of use pre- and post-program. Our methodology takes into account participant landscape size, landscape type (turf vs. shrub), and, most importantly, weather (ET demand) when evaluating outdoor programs. For indoor programs, these factors may not be important to account for, but others, such as number of full-time residents, is important to consider. We are confident that the methods that we have developed are applicable to many kinds of water conservation programs, with modifications.

The main analysis focused on the impact of STF, a sprinkler inspection program, offered in 25+ water districts across Colorado every year. Using 2,054 participant water records from five years of audits and from nine different utilities we measured the water savings of the program at the individual participant level. The average participant received 4.8 kgal of water savings in their first year post-audit. Multiplied by all participants from the program since its start in 2003, we estimate that the program has offered a minimum of 76,421 kgal of savings. This is a minimum estimation because the longitudinal analysis that we presented showed that as time goes on, average water savings increase, through at least 5 years post-audit. This was surprising, but did occur due to the effectiveness of the audit for the higher-users. The higher users tended to come down more often, and by larger amounts then those who were only over-watering by small amounts. These participants also tended to continue using water at a lower rate than they had pre-audit, therefore keeping the average savings high as time proceeded. We were pleased to find this result, but also took note that after the audit 3/4's of the participants were still overwatering, and on average they were overwatering at relatively high rates (average Rate of Water Application of 81% post-audit). Work is needed to enhance the conservation benefits of the program.

In order to better understand residential outdoor water use, watering efficiency (measured as RWA), and water savings from the audits we ran a set of statistical tests to evaluate which factors effect and/or help "predict" these variables. The results from these analyses were some of the most interesting and surprising of the whole project. Within our sample, outdoor watering is not significantly different based on sprinkler run times or number of days of watering per week, but it was strongly related to ET demand. The Rate of Water Application, a measurement of watering efficiency, was not related to any measurements of sprinkler system efficiency or health. The presence of conservation features such as MP Rotors an ET and Rain Sensors had no significant relationship to pre-audit RWA. Other factors that had no relationship to pre-audit RWA included sprinkler system age, DU, PR, presence of broken valves, clogged heads, overspray, and other variables often cited as important to sprinkler system health. We conclude from these findings that RWA (watering efficiency) is a more complex variable that is related to many factors simultaneously, and therefore more work is needed to evaluate multiple factors at one time. Furthermore, we also believe that these findings, along with our results that show that our audits are successful at improving the average RWA, indicate that the education component of the audits is possibly the most impactful part of the program on water use.

Changes made to the STF program recommendations in 2012 were aimed at increasing the conservation benefit of the program did appear to have a positive impact to water use and water usage rates. From a small sample of 114 participants from 2012 the average RWA decreased by 23% between pre- and post-audit. The average savings for these participants were equal to those found from the 2007-2011 sample group, but the median savings for the 2012 participants were slightly higher. These results are preliminary, but do suggest that the updated recommendations have had a positive impact on the program.

When measuring water savings from the STF Indoors program we found that since the program's inception the water savings have totaled 4,726 kgal. Potential savings of the program are three-times that amount, providing us with a clear opportunity for program improvement to capture these potential savings. The Garden-In-A-Box program has total potential savings of 5,868 kgal since 2003. We are excited about the opportunity to improve this estimation with information that we gain from our experiment with Northern Water to measure the water needs of our gardens. The water savings from the rotor nozzle sprinkler replacement program were not as conclusive. Future work is needed to gather more samples to better evaluate all three of these program areas.

Acknowledgments

We would like to thank and acknowledge the support of the CWCB through grant # OE PDA 13000000102, which gave us the opportunity to pursue this analysis. We would also like to thank the City of Broomfield, City of Boulder, Town of Castle Rock, Centennial Water & Sanitation District, Town of Erie, City of Lafayette, City of Loveland, Parker Water & Sanitation District, City of Thornton, City and County of Westminster, and Willows Water for providing us with all of the participant water use data in a timely manner so that we could use it in the analysis.

Appendix A – Bibliographic Sources

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Impact Analysis
2013 Final Report

Prepared for
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Executive Summary

Assessing and measuring the impact of the Slow the Flow (STF) program has been an important goal of the CRC's for the past several years. Our effort began in early 2012 with a pilot-study that revealed a strong potential for water savings from the program. Along with the support from the CWCB, City of Lafayette, and our other municipal partners, the CRC expanded the pilot analysis by including additional data and several new questions. Not only did we seek to more completely address the question of how much water does STF save each participant, but we also sought to assess the longer term viability of the savings, to perform a cost-benefit analysis, to compare the average STF participant GPCD to single-family GPCD, and to evaluate the factors that most affect outdoor water use, watering efficiency, and water savings.

Key Findings

The analysis re-confirmed the results of the pilot study; **the average STF participant from Lafayette saved approximately 16 kgal of water in the first year after the audit**. More key findings are listed below.

- Looking at water savings over time we discovered an interesting trend –the average savings actually increased over time. More work needs to be done to better understand the reasons for this trend, but it is important to note that it does appear to be the result of a real phenomenon: those who benefit most from the program are those who used the most water outdoors before the audit (see Table 9, Figures 8 and 9) – and their savings appear to be sustained, having a long term and increasing benefit on the average program savings.
- The cost-benefit analysis revealed the approximate value of the audits to be $6,789 per AF (Table 6), showing that conservation in Colorado is a very competitive option when compared to supply expansion and new construction projects.
- The comparison of STF participant GPCD relative to Lafayette's single-family GPCD data (Figure 4) relayed two important messages: 1) the program is reaching the correct audience, those who have above average use; and 2) water use is closely linked to weather.
- When assessing factors that contribute to outdoor water usage we found that turf, shrub, landscape area, and ET demand all positively correlated with it, while the presence of xeriscaping seemed to have the opposite relationship with post-audit outdoor use (Table 7, Figure 5). This may be due to the program's focus on turf health and could signal an area where we could improve our program's influence by including better recommendations for low water plants.
- We were surprised to find that few factors were significantly related to watering efficiency, which we measure using the Rate of Water Application (amount of water applied vs. water needed) (Table 8, Figure 6 and 7). We concluded from these findings that outdoor watering is controlled primarily by behavioral factors, and therefore may be affected more by participant education than by sprinkler system optimization and technological fixes. It is also possible that watering efficiency is affected by many different influences at one time. More work needs to be done to evaluate the cumulative effect of multiple factors on watering efficiency at a single time.
- Finally, we found that water savings are positively related to high outdoor use and inefficient use pre-audit (Table 9), suggesting that the audits are helping those higher users to reduce their use by the greatest amounts.

We hope that this analysis provides our partner utilities with useful and insightful information on the Slow the Flow program and the impact it has on their customers. We will continue to use the lessons learned from this analysis to update and improve the program so that our future work will help to save even more water. We are happy to answer any questions that may arise from this analysis, or provide further detail on the methodology used to calculate the results. Feedback is always welcome, so do not hesitate to contact us.

Introduction

Slow the Flow Colorado (STF) is a residential and commercial outdoor water conservation program administered by the Center for ReSource Conservation (CRC) in Lafayette's water district. The program's main goal is to provide customized, pragmatic advice and one-on-one education for homeowners and property managers about their outdoor sprinkler system. The STF program began in 2003 in partnership with the City of Boulder, and has since expanded to over 20 municipalities across the Front Range, onto the Western Slope, and up to northern Wyoming. In 2011, the CRC took notice of the growing trend in the water conservation field to measure and assess the impact of water conservation programs, such as STF, on actual water use. The CRC decided to try to answer the question, how much water has the STF program saved each participant? We launched a pilot assessment of the impact of the program in 2012. The results were promising, showing that the program saved the average participant several thousands of gallons of water per year, however the pilot-study also revealed more questions about the program and the need for additional rigor to be applied to our methodology. In early 2013 the CRC applied for and received a grant from the CWCB to fund a full-scale analysis of the impact of the STF program.

Since the Pilot Impact Analysis that the CRC provided to Lafayette in February 2013, we have been working hard to expand our evaluation, include more data points, ask and answer more questions, and provide our water utility partners with more useful information on how the STF program has affected the water use of the participants of the program. The focus of the Impact Analysis continues to be the residential Slow the Flow (STF) program, both because of the program's reach and because it addresses an important area of use: outdoor watering. This program is the largest outdoor residential water conservation program in the state of Colorado, reaching approximately 2,400 residential customers in 2013. Therefore, the impact of this program is the most widely felt of all programs run by the CRC. This program also addresses an area of water use that has a significant need for conservation. While technological improvements and enhanced federal standards on water-using fixtures and appliances have led to significant passive savings in indoor water usage (Vickers, 2001; CWCB, 2010), technological advancements in outdoor watering devices have not been as successful (Aquacraft, 2011). Research shows that underground sprinkler systems use 30-40% more water than simple hose watering of the landscape (Mecham). The STF program aims to educate homeowners on care, maintenance, and proper and efficient use of their underground sprinkler system.

Until 2012, the STF program had a strong emphasis on landscape health, at times at the expense of conservation. Stemming from results from this analysis and from the increasing demand of our partners, we have re-oriented the program to increase it's conservation benefit. In order to do this while not sacrificing landscape health, we have changed our recommendations to participants who are found to be under-watering prior to the audit. Rather than encourage these participants to increase use, we evaluate the landscape health and if it is sufficient and the participant is also satisfied with the health of their landscape, then we directly encourage them to continue their watering schedule as-is, rather than recommending an increase. The following analysis is of audits performed prior to this change in 2012, therefore, please remember that while not all participants saved water, other benefits, such as landscape health, were also a part of the program.

The STF annual report that the CRC provides for the City of Lafayette details and summarizes the information gathered by the auditors including property information, water conservation features, specifications of the sprinkler system, and customer satisfaction. This report provides the additional analysis of water usage change between pre- and post-audit and water savings. Also included in this report is a cost-benefit analysis of the program, allowing Lafayette to directly compare the STF program to the cost of other water supply options. In addition, there is a section on the comparison of STF participants to all Lafayette residents, using GPCD data that was provided to us by the City of Lafayette. Furthermore, results from an analysis of the factors that contribute to outdoor watering, efficient water use, and water savings are provided.

Methods

The methodology presented here was designed to quantify the amount of water saved by the STF program at the participant level, using participant record data collected by the CRC during the audit as well as water usage data from Lafayette, and weather data from local weather stations. Below is a brief description of the methodology used in our impact analysis calculations. A description of the full details of this methodology can be requested through the CRC.

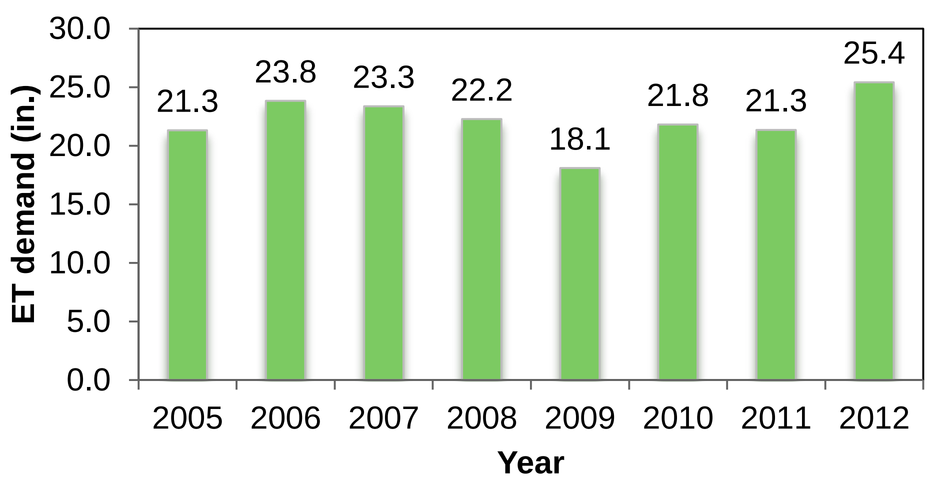
Table 1. Number of participants (N) in analysis by audit year

Audit Year	N
2007	32
2008	63
2009	46
2010	42
Total	**183**

The City of Lafayette provided the CRC with household-level water usage data for those customers who were audited between 2007 and 2010 (Table 1). The CRC considers April through October outdoor irrigation months, November and March as months with little to no irrigation, and December through February indoor months in which no irrigation is required. Outdoor water use was compared to the property's landscape size to determine the amount of water, in inches, that was applied to the landscape during the irrigation season. To determine water usage during outdoor irrigation months the CRC subtracts the average water consumption during indoor months from the total annual consumption.

The CRC then calculated the annual growing season evapotranspiration (ET) demand (Figure 1) for each home using reference evapotranspiration[1] and measured precipitation values from eight regionally located weather stations and the proportions of turf and non-turf areas of landscape on each property. The CRC assumes non-turf areas need roughly two-thirds the amount of water as turf based on a 2004 study conducted by the Northern Colorado Water Conservancy District and Colorado State University. The study looked at ET requirements for common shrubs found in landscapes along the Front Range.

Figure 1. Annual growing season ET demand (inches).



The amount of water applied to the landscape was compared to the ET demand. Results are reported as over/under the landscape need, as a volume (in kgal), and as a percent called the Rate of Water Application

[1] Daily reference evapotranspiration (ET_O) (in inches) was summed for April 15-Oct 15 of each calendar year. The final value was adjusted with a crop coefficient (k_c) in order to estimate turf ET demand. Measured precipitation (in inches) from the same time period was adjusted by 50% to account for the amount that either evaporates prior to entering the soil or runs off during heavy rains. The adjusted precipitation was subtracted from the estimated turf ET to give a final, annual ET demand value for each year in the study – 2005-2012.

(RWA). For example, a property that watered 120 percent of ET is over-watering by 20 percent, and therefore has a Rate of Water Application of 20 percent. Similarly, a property that watered at 70 percent of ET is reported to have under-watered by 30 percent, and a Rate of Water Application of -30 percent. Any participant with a percentage below the 1st quartile plus 1.5 times the inter-quartile range (IQR), or above the 3rd quartile plus 1.5 times the IQR for all RWA values in all years for which there was data, was considered an outlier and was removed. One participant from the City of Lafayette data set was removed following these criteria.

Each participant's average pre-audit RWA was used to calculate the projected water use for each post-audit years, in kgal. The projected use is essentially how much water the participant would have used if they had not received a STF audit. The difference between the projected use and the actual outdoor use were determined to be the water savings. A full example below is provided to help to elucidate these calculations.

Water Savings Calculation Example

This example includes made-up data for two pretend participants to demonstrate how we arrive at our calculation of water saved. This example assumes that ET demand for both pre- and post-audit years is 27 in.

One Year Pre-Audit

ID	Outdoor Use (kgal)	Landscape ET Demand (kgal)	Over/Under Landscape Need (kgal)	RWA	
Participant1	68	60	8	13%	← Over-watering
Participant2	110	138	-28	-20%	← Under-watering

One Year Post-Audit

ID	Outdoor Use (kgal)	Landscape ET Demand (kgal)	Over/Under Landscape Need (kgal)	RWA	
Participant1	65	60	5	8%	← Reduced water use
Participant2	115	138	-23	-17%	← Increased water use

Calculating Savings in the Post-Audit year

ID	Pre-Audit RWA	Projected Use (kgal)	Actual Use (kgal)	Water Savings (kgal)
Participant1	13%	60*113% = 68	65	68 - 65 = **3 kgal savings**
Participant2	-20%	138*80% = 108	115	108 - 115 = **-7 kgal no savings**

This example demonstrates how a participant who is over-watering may still generate water savings (e.g. Participant1) while a participant who is under-watering might not generate water savings (e.g. Participant2). The example does not, of course, take into account potential landscape health improvements related to increasing the water use of the participant who was under-watering their landscape prior to the audit.

While this method gives helpful results, it is not perfect and calculated values should be viewed as approximations. This is mainly because the technique used to determine outdoor water usage cannot provide exact outdoor usage, but rather a best-estimate of outdoor water usage. Also, while we are attributing the calculated savings (or lack-there-of) to the STF program, many other factors likely impacted participant outdoor water usage in the years following the audit. For example, water restrictions, both mandatory and recommended, have been imposed in many of our partnering municipalities in the past 5 years, possibly impacting participant outdoor water use. The assumptions that no outdoor water use occurred between November and March, that no changes were made to the landscape after the audit, and that the evaporative needs of turf and shrub areas, respectively, were uniform within and between each participant household, may also influence the accuracy of the results.

Results and Discussion

First we present the general water usage trends from before and after the audits were performed. Next, we summarize water savings and the longitudinal, or long-term water savings of the program. A cost-benefit analysis then follows with estimations of the cost per acre-foot of water saved. Next we summarize the information that we gained from comparing Lafayette GPCD for single-family households to GPCD of STF participants in Lafayette. The last section of the results presents findings from our analysis of factors that may affect outdoor water use, outdoor water use efficiency, and water savings from the STF program.

Water Usage Trends Pre- and Post-Audit

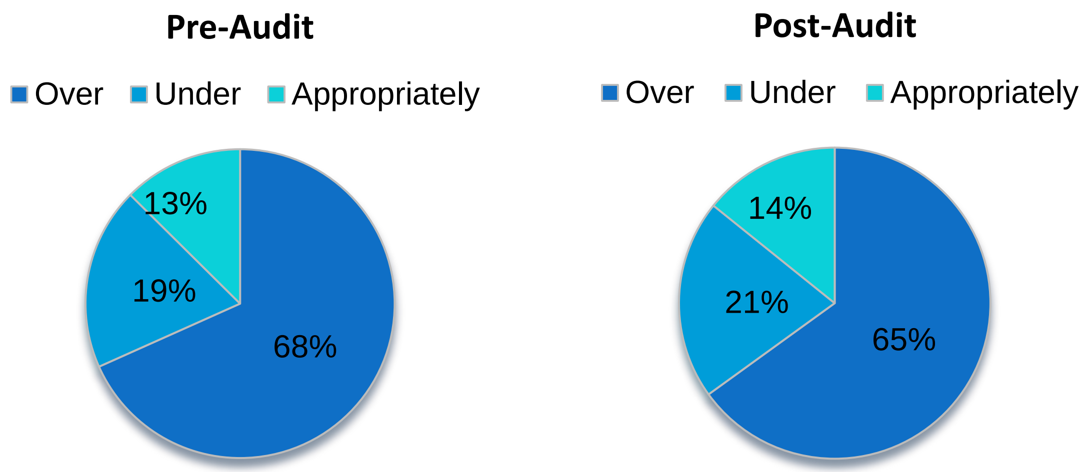
Total, indoor, and outdoor annual water use were calculated for each participant. The average total water use showed a minor decrease between 1 year pre- and 1 year post-audit from 134 to 131 kgal. Average indoor use showed a slight increase between 1 year pre- and 1 year post-audit from 50 kgal to 55 kgal. This finding was surprising and we are not sure at this time as to why this may have occurred. Average outdoor water use is summarized in Table 2. While outdoor water use is not a weather controlled calculation, the mean outdoor use of the STF participants from 2007-2010 in the first year post-audit was significantly lower than the mean outdoor use in the year prior to the audits, suggesting a positive impact by the program.

Table 2. Outdoor Water Use (kgal)

	Years Pre/Post	Mean	St. Dev.	Median	Min	Max
Pre-Audit	2 Years	86	55	79	2	364
	1 Year	84	64	75	5	559
Post-Audit	1 Year	76	63	60	2	567
	2 Years	72	63	58	1	656
	3 Years	75	50	67	1	258
	4 Years	66	43	62	3	301
	5 Years	86	49	81	9	257

When weather (ET demand) and landscape size and type are taken into account, 68% of STF participants were over-watering prior to their audit, 19% were under-watering, and 13% were watering appropriately (within ± 10% of ET demand)(Figure 2). After the audit, the percentage of those who were over-watering decreased slightly, while the percentage of those who were under-watering and appropriately-watering both increased.

Figure 2. Precent watering over, under or at (within ± 10%) of ET demand



A Rate of Water Application (RWA) of 0% indicates that the participant is watering their landscape at the exact amount needed based on their landscape type (turf and non-turf), landscape size, and the ET demand. This value is essentially a measurement of outdoor watering efficiency. While some participants water efficiently, at or near 0%, the average participant from Lafayette in pre-audit years was watering at 71% above ET demand (Table 3). Post-audit, the average rose to 79% above ET demand. Median RWA decreased from 40% pre-audit to 38% post-audit. The differences in the change in the mean and median indicate that while over 50% of the participants in the sample group decreased their RWA, those who increased had relatively large increases, thus affecting the mean. The large standard deviation on these mean values indicates that there is a large amount of variability in the RWA between all participants. The minimum and maximum values reveal the variability in the RWA as well.

Table 3. Rate of Water Application (RWA)

	Mean	St. Dev.	Median	Min	Max
Pre-Audit	71%	108%	40%	-85%	619%
Post-Audit	79%	197%	38%	-90%	2131%

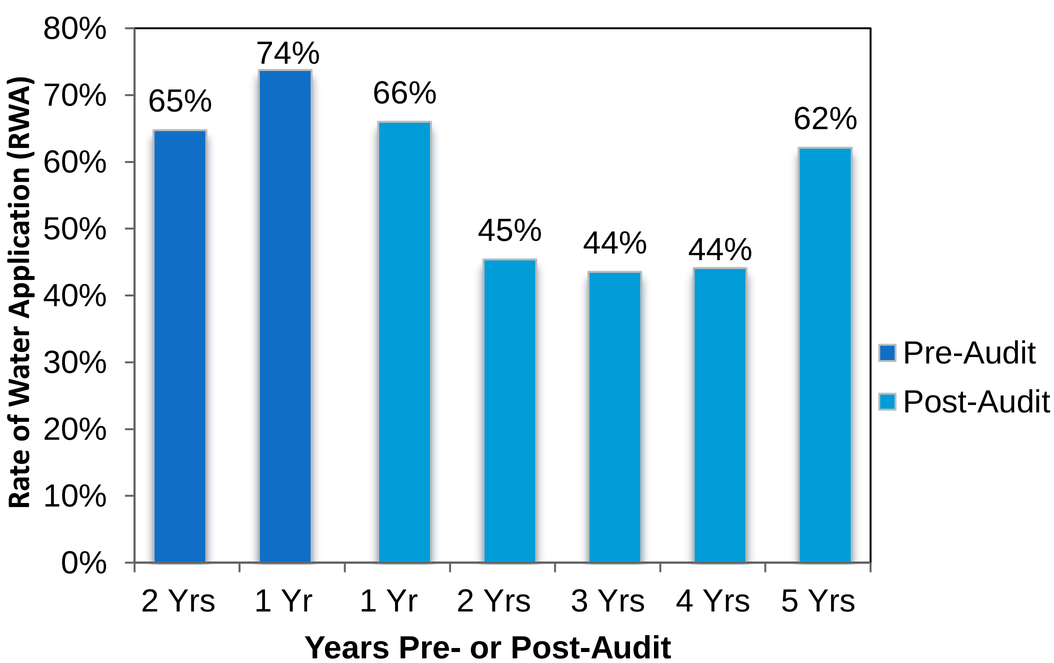
Longitudinal Water Savings

Longitudinal water savings are those water savings that appear to last over time, beyond the first year after the audit was performed. For the average participant from the City of Lafayette, water savings appear to last up to 5 years post-audit (Table 4). Results also show that Lafayette participants tended to water more efficiently for up to 5 years post-audit, relative to the average RWA in the pre-audit year (Figure 3). Looking at RWA over time (Figure 3), STF participants slowly lose their efficiency gains from the audit over time. The large increase in RWA in the 5th year post-audit is most likely due to a combination of hot and dry weather (the 5th year post-audit data is all from 2012) and the inability of most participants to retain the education gained from the audit.

Table 4. Water savings (kgal)					
Years Post Audit	**Mean**	**St. Dev.**	**Median**	**Min**	**Max**
1	0.1	38	0	-223	122
2	11.0	37	9	-82	155
3	14.9	43	12	-64	135
4	32.1	57	21	-70	208
5	16.7	34	11	-51	80

Despite the average participant becoming less efficient over time (Figure 3), the water savings for the average participant increased over time (Table 4). This seemingly incongruous result is due to the phenomenon that those who benefited from the audit by becoming more efficient and saving water, tended to be participants that were over-watering by the largest amounts before the audit. Therefore the water savings from these individuals were relatively large. These participants also tended to maintain their improvements over time, whereas those who did not seem to benefit from the audit were more volatile over time. Also, those who had little to no improvement in their RWA, and saw little to no water savings, tended to be those who were over-watering by small amounts pre-audit. Therefore their return to, or lack of inefficient water use had a weaker overall impact on average water savings, but directly influenced the rise in the RWA values.

Figure 3. The average RWA from two years pre- to five years post-audit.



Cost-Benefit Analysis

The cost-benefit analysis seeks to help water conservation professionals translate the water savings from the program into a monetary value that can be directly compared to estimations of alternative options to conservation for increasing water supply. For calculating the cost of saving one acre foot (AF) of water from the STF program we used an assumption of 100 total participants and 4.8 kgal of savings per participant. This savings value comes from the average savings from 1 year post-audit of all 2054 participant records provided to the CRC by 9 different water providers for the Impact Analysis. The cost per audit is representative of the actual cost paid by our partner water providers in 2007-2011 for each audit.

Table 5. Water savings assuming 100 participants and average water savings from the entire impact analysis sample of 2054 participant records in the first year post-audit.

Number of Participants	Avg Savings (kgal)	Annual Savings (kgal)	Annual Savings (AF)
100	4.8	480	1.47

Table 6. Cost of audits and of saving 1.47 AF or water using this hypothetical example.

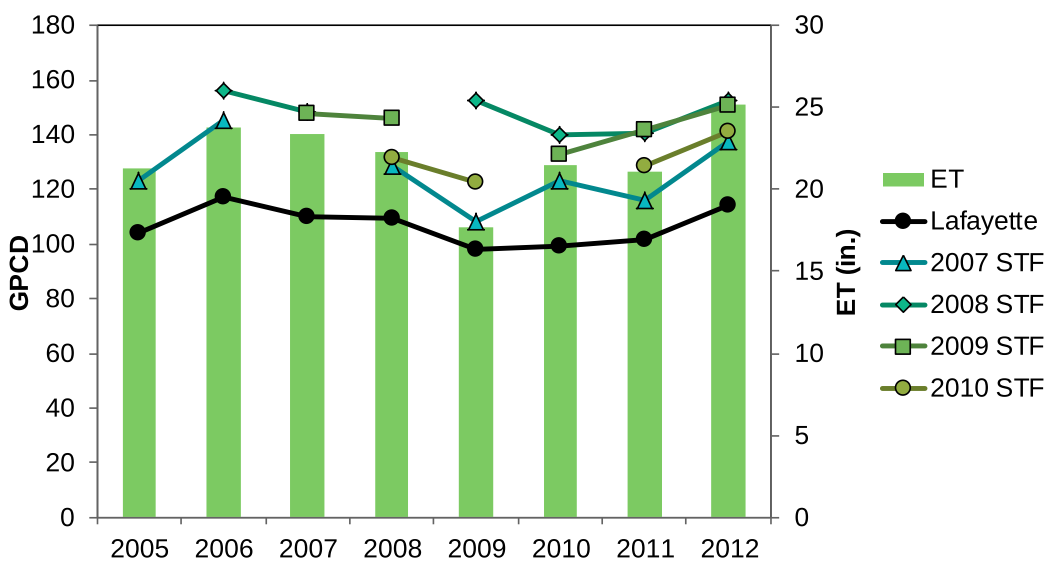
Cost per Audit	Cost All Audits	Cost per AF of Water Saved
$ 100	$ 10,000	$ 6,789

These numbers indicate that with 100 participants, the program would be worth 1.47 AF of water savings, at the cost of $6,789 per acre foot.

Comparison to the Average Resident

From the City of Lafayette we used single family residential gallons per capita per day (GPCD) data to compare to GPCD of the STF participants (Figure 4). We learned two lessons from this comparison. First, those participating in STF were using more water, on average, than the general population. This indicates that the program is being delivered to the correct population. Second, the juxtaposition of GPCD data with annual ET demand shows how closely the general population and STF participants follow the weather with their outdoor watering habits. During years with high ET demand, GPCD is also high, and during 2009 when ET demand was low, GPCD numbers reach their lowest point.

Figure 4. Average GPCD of single-family residential accounts for City of Lafayette and STF participants by audit year (left-hand axis). Gaps occur for the year participants were audited. ET demand is plotted on right-hand axis.



Factors that contribute to outdoor usage, watering efficiency, and water savings

We conducted an analysis of some of the factors that may contribute to outdoor water usage, water use efficiency, and water savings from the STF program. The analysis included a sample of 2,054 participants and incorporated descriptive and parametric statistical tests[2] for significant[3] differences in water use, watering efficiency, and savings in post-audit years based on a variety of landscape and irrigation system factors. Factors included in the analysis were sprinkler system age, presence of drip systems, amount of xeriscape landscape, severity of irrigation system problems (e.g. broken/tilted heads/overspray/poor spacing), distribution uniformity, precipitation rate, and other factors that may contribute to inefficient water use. The three main questions that we have tried to answer with this analysis are:

1. What factors contribute to outdoor water usage?
2. What factors are related to outdoor watering efficiency?
3. What factors help to predict water savings from the Slow the Flow program?

In order to answer these questions we used Single-Factor Analysis of Variance (ANOVA) and linear regression. Both of these tests are used to evaluate the significance of a single factor (the independent variable, X) on the outcome of another factor (the dependent variable, Y). With the ANOVA test, the conclusion that can be drawn is whether or not there is a significant difference in the dependent variable's mean based on the categories designated by the independent variable. Linear regression provides both the proportion of total variability explained by the model (the Adjusted R^2), as well as the intercept and slope of the model, with associated significance levels.

A summary of the results are presented below. These findings are not specific to City of Lafayette residents, but include the data from 2,054 participants from 5 audit years, 2007-2011. This sample size allows for statistically significant conclusions to be drawn from the tests. Preliminary results show that variation in trends can occur between different water providers. Future work is needed in order to evaluate geographic differences in outdoor water use, watering efficiency, and savings from the STF program.

To answer the first question we evaluated the participant outdoor water usage with landscape type and size, the weather (represented by ET demand), the number of days that the irrigation system runs per week, and number of cycles that the irrigation system runs. Table 7 presents the detailed results of each test. From the tests it was found that outdoor use pre-audit was not significantly different based upon the presence of xeriscape in the yard (none vs. some), however post-audit, outdoor use was significantly different based upon the presence of xeriscape. Participants without xeriscape had a significantly lower mean outdoor water use of 77.3 kgal per year than participants with xeriscape, who had a mean of 83.7 kgal per year. This difference may be caused by the greater reductions in outdoor use experienced by participants with larger proportions of turf, as the audit and recommendations are focused on applying appropriate water to turf landscapes. The amount of turf, shrub, and total landscape area (in square feet) were all significantly and positively related to outdoor water use. Furthermore, turf and total landscape area had a stronger effect on outdoor water use, with adjusted R^2 values around 0.25, relative to shrub area, which had an adjusted R^2 value less than 0.1. The weather, represented by ET demand (in inches), was highly positively related to outdoor use (Figure 5).

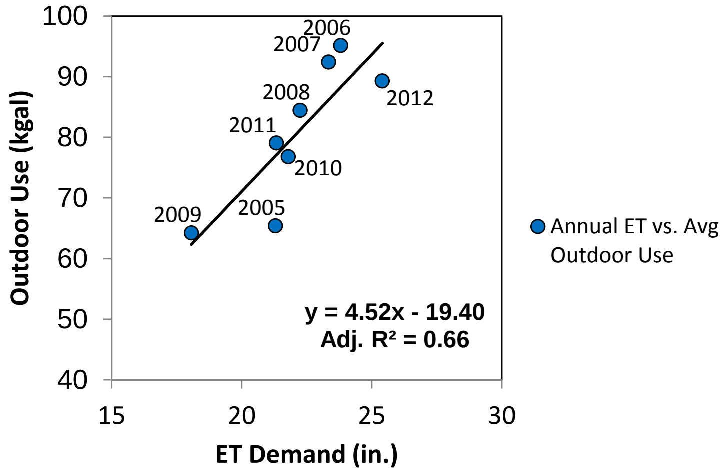
[2] Descriptive statistics are used to assess the range, central tendency (i.e. mean, median), and other general attributes of the data. Parametric tests are used for data that come from a normal probability distribution.

[3] Significance is reported as a P-value. The P-value is the probability that the outcome that is being tested has occurred by random chance. A P-value of 0.05 or less was required for the outcome to be considered significant; this assures a 95% or greater probability that the outcome did not occur by chance.

Table 7. Results of statistical tests to evaluate what variables (X) contribute to outdoor water usage(Y). Significant results are in **bold**. NA = Not Applicable.

Independent (X) Variable	Test Used	Regression Statistic	Significance (p-value)	Regression Coefficients	Conclusion
Xeriscape (None, Some)	ANOVA	NA	0.276	NA	Outdoor water use pre-audit is not significantly different based on presence of xeriscape (some or none).
Xeriscape (None, Some)	ANOVA	NA	**0.007**	NA	Outdoor use post-audit is significantly different based on presence of xeriscape (none or some). When there is no xeriscape, participants had significantly less outdoor water use post-audit than those who had some xeriscape. This may be because the audit is mostly focused on turf irrigation rather than on xeriscape.
Turf area (sq. ft)	Regression	Adj. R2 = 0.25	**4.22E-01**	**Intercept = 113**	Outdoor use pre-audit is significantly and positively related to Turf area. As turf area increases, outdoor usage increases.
			<0.0001	**Slope = 35**	
Shrub area (sq. ft)	Regression	Adj. R2 = 0.09	**1.11E-04**	**Intercept = 294**	Outdoor use pre-audit is significantly and positively related to shrub area. As shrub area increases, outdoor usage increases.
			<0.0001	**Slope = 10**	
Total Landscape area (sq. ft)	Regression	Adj. R2 = 0.28	**3.81E-04**	**Intercept = 536**	Outdoor use pre-audit is significantly and positively related to total landscape area. As total landscape area increases, outdoor usage increases.
			<0.0001	**Slope = 43**	
ET Demand	Regression	Adj. R2 = 0.66	**0.03**	**Intercept = -19.4**	Outdoor use is significantly and positively related to ET Demand. As ET demand increases, outdoor use increases.
			0.01	**Slope = 4.5**	
Number of Cycles	ANOVA	NA	0.75	NA	Outdoor use is not significantly different based on the number of cycles.
Watering Days per Week	ANOVA	NA	0.98	NA	Outdoor use is not significantly different based on the number of watering days per week.

Figure 5. ET demand (in.) vs. outdoor use (kgal) from pre-audit. Each point is labeled with the year that it represents.



This finding is not surprising, but highlights the importance that the weather has on influencing outdoor watering habits of Front Range residents. Neither the number of cycles, nor the number of watering days per week were found to significantly affect outdoor use.

The Rate of Water Application, a pseudonym for watering efficiency, is calculated as the amount of water applied to the landscape relative to the amount of water that the landscape needs, based on it's size, type (turf vs shrub), and the weather (ET demand), and it is a percentage that describes the proportion of over- or under-watering that occurred. For this analysis we used each participant's average pre-audit RWA. We choose to evaluate pre-audit RWA as we have no information as to whether homeowners made changes to the various sprinkler system parameters after their audit or not. Table 8 contains the results of comparing RWA pre-audit to 20 different factors that are often assumed to be directly related to irrigation system health. Surprisingly, of these 20 factors, only one, presence of a drip system (yes/no), was found have a significant relationship to RWA. Furthermore, the results from this test indicate that those participants with drip systems had lower (worse) RWA pre-audit than those who did not. It is not understood what may have caused this. The most likely reason that so few of the factors were significantly related to RWA is because it is dependent upon multiple factors, and therefore the ANOVA and linear regression tests that only evaluate the influence of a single factor at a time do not provide accurate results. Future work needs to incorporate a multiple regression analysis that takes into account multiple factors at once. Another job for future investigation is to address the datasets with unequal variances, which made them unsuitable for the Single-Factor ANOVA test. Below, in Figures 6 and 7, RWA is plotted as a function of sprinkler system age and PSI. The predicted Y values show that there is little relationship between the independent variables (X) and the dependent variable (RWA (Y)).

Figure 6. Sprinkler system age (years) vs. RWA with actual (Y) and predicted values.

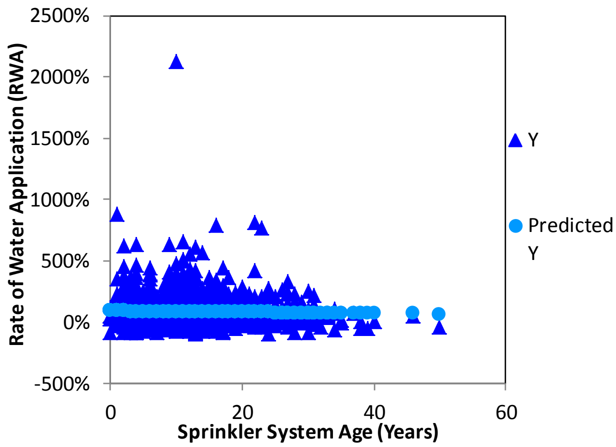


Figure 7. PSI vs. RWA with actual (Y) and predicted values.

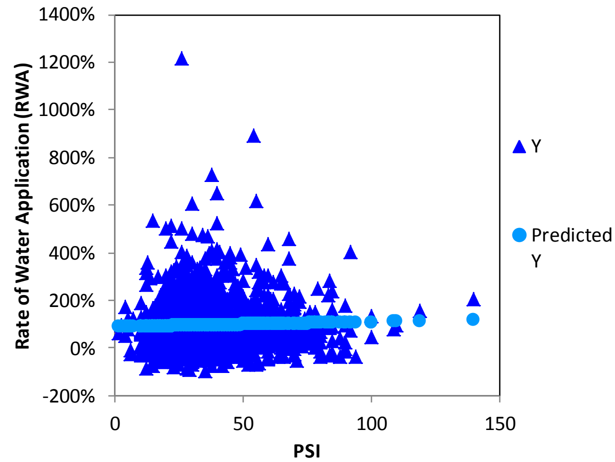


Table 8. Results of statistical tests to evaluate what factors contribute to RWA pre-audit. Significant results are in **bold**. NA=Not Applicable.

Independent (X) Variable	Test Used	Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Sprinkler System Age	Regression	Adj R2 = 0.0	NA	NA	RWA is not significantly related to sprinkler system age.
Backflow preventer	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
Drip system presence (yes/no)	ANOVA	NA	**0.01**	NA	RWA is significantly lower (i.e. worse) pre-audit for those participants who have a drip system in at least part of their yard.
MP Rotators	ANOVA	NA	0.39	NA	No detectable significant difference exists in RWA based on presence of MP Rotators (Some vs. None).
Check Valves	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
ET/Soil moisture sensor	ANOVA	NA	0.45	NA	No detectable significant difference exists in RWA based on presence of ET or soil moisture sensors.
Rain Sensor	ANOVA	NA	0.88	NA	No detectable significant difference exists for RWA based on presence of a rain sensor.
PSI Zone A	Regression	Adj R2 = 0.0	1.02E-39 0.19	Intercept = 0.88 Slope = 0.0	RWA is not significantly related to PSI in Zone A or Zone B.
PSI Zone B	Regression	Adj R2 = 0.0	0.99 0.00	Intercept =0.0 Slope = 0.14	
DU Zone A (Poor, Acceptable, Good, Excellent)	ANOVA	NA	0.14	NA	No detectable significant difference exists in RWA based on the DU in Zone A.
DU Zone B (Poor, Acceptable, Good, Excellent)	ANOVA	NA	0.98	NA	No detectable significant difference exists in RWA based on the DU in Zone B.
Broken heads	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.

Table 8. Continued

Independent (X) Variable	Test Used	Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Low heads	ANOVA	NA	0.44	NA	RWA is not significantly different pre-audit for those participants with some, few or no low sprinkler heads.
Clogged heads	ANOVA	NA	0.17	NA	RWA is not significantly different pre-audit for those participants with none, few or some clogged sprinkler heads.
Overspray	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with parametric tests.
Unmatched Precipitation Rates	ANOVA	NA	0.12	NA	RWA is not significantly different pre-audit for those participants with none vs few unmatched precipitation rates.
Poor head spacing	ANOVA	NA	0.45	NA	RWA is not significantly different pre-audit for those participants with few vs some vs many poorly spaced sprinkler heads.
Broken/leaking valve	Failed F-Test for equal variances			NA	Unequal variances, cannot compare with ANOVA.
Inefficient Watering Schedule	ANOVA	NA	0.28	NA	RWA is not significantly different pre-audit for those participants with efficient vs. moderately inefficient watering schedule.
Improper Pressure	ANOVA	NA	0.97	NA	RWA is not significantly different pre-audit for those participants with a small amount of improper pressure vs. a moderate amount of improper pressure.

The final set of tests evaluated the factors that contribute to water savings in the first year post-audit. This set of tests essentially measures how much each independent (X) variable helps to "predict" water savings. The complete results are detailed in Table 9. Outdoor water usage pre-audit is a significant predictor of water savings with higher outdoor usage relating to higher savings. Pre-audit RWA also helps to predict water savings, but to a slightly weaker degree. Efficiency of a participant's watering schedule, based on the auditor's assessment of the control clock schedule, does not have a significant relationship to water savings.

Table 9. Results of statistical tests to evaluate what factors contribute to water savings one year post audit. Significant results are in **bold.** NA=Not Applicable.

Independent (X) Variable	Test Used	Regression Statistic	Significance (P-value)	Regression Coefficients	Conclusion
Outdoor usage pre-audit (kgal)	Regression	Adj R2 = 0.11	**3.34E-22**	Intercept = -12	Outdoor use pre-audit is significantly and positively related to water savings. As outdoor use pre-audit increases, water savings also increase.
			1.38E-55	Slope = 0.20	
Pre-Audit RWA	Regression	Adj R2 = 0.06	**2.61E-02**	Intercept = -2.0	RWA is weakly and positively related to water savings. As RWA increases, water savings also increase.
			7.70E-30	Slope = 7.4	
Efficiency of pre-audit watering schedule (rank 0-3, 0=efficient)	ANOVA	NA	0.057	NA	Water savings are not significantly different based on the efficiency of the pre-audit watering schedule.

Figure 8 and 9 contain the plotted water savings values against outdoor water use and RWA. Both plots demonstrate the positive relationship between water savings and the two X variables.

Figure 8. Outdoor water use (kgal) vs. water savings (kgal) and predicted values.

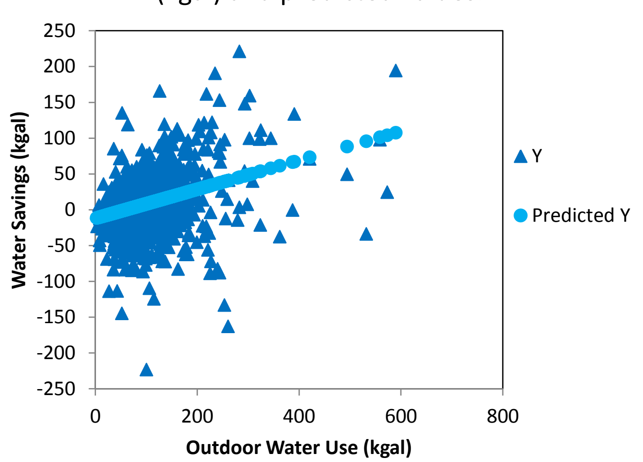
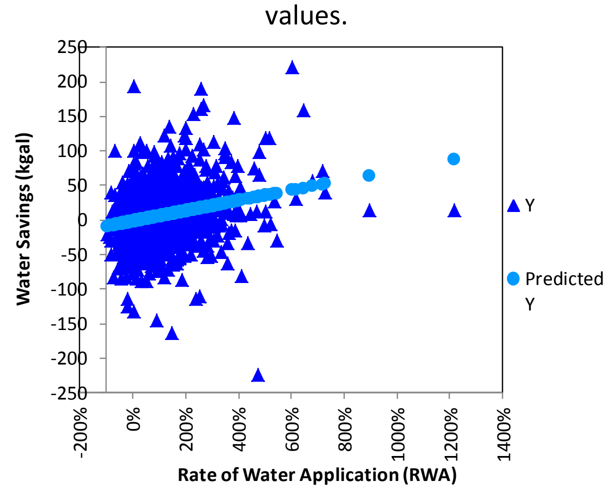


Figure 9. RWA vs. water savings (kgal) and predicted values.



Conclusions

Overall, the results from this analysis indicate that the STF program is an effective water conservation program for the majority of the participants. Despite the fact that the program does not use targeted advertising, it reaches customers who are over-watering (Figure 2) and who tend to be watering at levels above the average City of Lafayette resident (Figure 4). Water savings persist for several years beyond the audit for the average participant, but do not last forever (Table 4). While an ideal outdoor water conservation program would secure water savings into perpetuity, our findings suggest that sprinkler systems do not operate efficiently just because the components of the system are well maintained (Table 8, Figure 6 and 7). Our results show that outdoor water use is strongly related to weather (Table 7, Figure 4 and 5). They also show that water savings are significantly related to pre-audit RWA and raw outdoor usage. Both of these findings are informative, but not surprising. One finding that was quite surprising was that the Rate of Water Application does not have a significant relationship to most basic sprinkler system attributes (Table 8, Figure 6 and 7). This finding is surprising both because it is counterintuitive, and also because the audits still, overall, produced measurable water savings. One plausible explanation for this phenomenon is that watering behaviors outweigh factors related to sprinkler system health when it comes to the amount of over- or under-watering by a participant. Reducing outdoor water use may therefore be dependent more upon education of the homeowner on how and when to use their sprinkler system, rather than sprinkler system optimization and technological fixes. Future work should focus on evaluating and quantifying the impact of educational components of water conservation programs to help gain a better understanding of these findings. Future work also needs to evaluate outdoor use, watering efficiency, and water savings as multifactorial variables. While many of the variables tested showed little to no relationship to these parameters on their own, together they may significantly contribute to water usage.

Our results highlight the positive impacts of the STF program, such as the water savings and competitive cost of the program. They also make apparent room for improvement, such as through increased efforts to enhance the sustainability of the savings and reduce participant over-watering by even greater degrees. We look forward to continuing to provide all of our municipal partners with an annual impact analysis, which will keep us honest and working hard to make our programs as impactful as possible.

Acknowledgments

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Appendix D – Impact Analysis Presentations

In order of date presented

Stellar, Dan; Luscan, Ashley; and Zeliff, Morgan. November, 2012. *Beyond Implementation: Measuring a Region-Wide, Municipal Landscape Water Conservation Program*. Upper Colorado River Basin Water Conference. Presentation. Grand Junction, Colorado.

Stellar, Dan; Luscan, Ashley; and Zeliff, Morgan. March, 2013. *Manage What You Measure: Measuring a Region-Wide, Municipal Landscape Water Conservation Program*. Rocky Mountain Land Use Conference. Presentation. Denver, Colorado.

Zeliff, Morgan. June, 2013. *Measuring the impact of a municipal landscape water conservation program*. American Water Works Association Annual Meeting. Session title: Conservation Programs That Deliver Results. Short presentations and panel discussion. Denver, Colorado.

Zeliff, Morgan; Lander, Paul; Stellar, Dan; and Luscan, Ashley. October, 2013. *Quantifying Water Savings of a Region-Wide, Municipal Sprinkler Audit Program*. WaterSmart Innovations Conference. Poster. Las Vegas, Nevada.

Zeliff, Morgan and Stellar, Dan. November, 2013. Where's the water going? *An analysis of factors contributing to outdoor residential use*. Upper Colorado River Basin Water Conference. Presentation. Grand Junction, Colorado.