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Residential Landscape Water Check Programs: Exploring a Conservation Tool

Diana T. Glenn
Utah State University

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RESIDENTIAL LANDSCAPE WATER CHECK PROGRAMS:

EXPLORING A CONSERVATION TOOL

by

Diana T. Glenn

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Human Dimensions of Ecosystem Science and Management

Approved:

Joanna Endter-Wada
Major Professor

Roger K. Kjelgren
Committee Member

Christopher M. U. Neale
Committee Member

Peggy Petzelka
Committee Member

Byron R. Burnham
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2010
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ABSTRACT

Residential Landscape Water Check Programs:
Exploring a Conservation Tool

by

Diana T. Glenn, Master of Science
Utah State University, 2010

Major Professor: Dr. Joanna Endter-Wada
Department: Environment and Society

In response to drought and regional growth in the arid western United States, urban water demand management is increasingly important. Single family residences use approximately 60% of their water consumption to irrigate landscapes often in excess of plant water requirements. This study utilized a quasi-experimental design to investigate outdoor water consumption and assess the effectiveness of a landscape water check conservation program. Study objectives included describing a contextualized landscape system to reveal variables influencing water use, identifying better ways to evaluate landscape water use, and more effectively targeting and delivering water conservation programs.

The study was conducted during the 2004 and 2005 irrigation seasons in Logan City, Utah, in connection with a city-sponsored water check program. In Utah’s sixth year of drought, free water checks were offered to all city households and delivered to
148 self-selected volunteers (2004) and 101 recruits from a target sample of above-average water users (2005). The site-specific approach incorporated landscape water checks to inspect residential landscapes, historical ET$_o$ data to create irrigation water schedules, survey data to assess water conservation behavior and the effectiveness of a water check program as a conservation tool, remote sensing data to develop household water budgets, and city water billing records to evaluate water consumption during a six-year period (2002 – 2007).

The data analysis informed creation of a conceptual framework of the residential landscape system that describes the complex systems thinking required to use water effectively. Water use case studies illustrate the interplay of system domains; site, plant material, irrigation technology, and behavior. Several assessment and monitoring tools were developed to aid in data analysis, which include the Urban Landscape Water Index and Conservation Outcomes Assessment and Intervention Evaluation Tools. Key research findings reveal the influence of sprinkler system controllers, adoption of recommended water schedule and conservation measures, and residential mobility on subsequent water use.

Research findings shed light on the complex and contextualized nature of water use in relation to residential landscapes and on methodological issues involved in evaluating conservation program effectiveness. These findings have important implications for the design and implementation of outdoor water conservation programs.

(163 pages)
In memory of Ronald B. Glenn (1957 – 1999),
who first introduced me to the concept
that all things are connected . . .
ACKNOWLEDGMENTS

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I am grateful to my son, Timothy, for his continual encouragement and support for me and to all of my family for their enduring patience and sacrifice during my many absences and lapses in my family responsibilities while pursing this degree.

Diana T. Glenn
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CHAPTER 1

LITERATURE REVIEW

Introduction

Urban water demand management is increasingly important to ensure adequate water supplies to accommodate growth. Water conservation campaigns have focused on providing conservation information to residents aimed at changing attitudes and behaviors in order to help them voluntarily reduce consumption or to improve the efficiency of their water use. Identifying the most effective components of these programs often is problematic because many strategies to meet various goals are implemented at once and the methodology for measuring actual water savings attributable to any particular strategy is inconsistent across programs (Michelsen et al. 1999; Syme et al. 2000, 540; Barta 2004). Documenting the effectiveness of various program components through water savings are of vital importance to the design of water conservation programs.

In 2004, the State of Utah amended the Water Conservation Plan Act. The 2004 amendment requires water conservancy districts and retail water providers to implement plans that require water conservation to be practiced. Each plan must state a water use reduction goal for each conservation measure used, a time line for implementing the measures, and a monitoring process (Utah Code Annotated 73-10-32, 1953 As Amended). Water providers are in need of comprehensive, relevant scientific research results to inform decisions and guide the development of water conservation plans. This
issue has particular saliency in Logan, Utah where the municipal and industrial water
system is “already operating at or near the limits of [its] reliable system/source capacity”
(UDWR 2004, 21-23).

Literature Review

Water conservation campaigns are initiated for a few common reasons such as a
short-term response to drought or scarcity or as a long-term demand management tool.
These campaigns utilize various kinds of approaches, including education, aimed at
changing attitudes and behavior or to provide practical information on how to conserve
water. Other campaigns rely on technological solutions to encourage residents to improve
their water use efficiency by offering various kinds of financial incentives to replace
appliances (clothes washers, dishwashers, etc.) and irrigation systems. Still others focus
exclusively on outdoor, landscape irrigation since it comprises the majority of household
water consumption in the West and is often identified as “luxury water” use, especially
during times of scarcity. Researchers have used many approaches to evaluate the
effectiveness of these campaigns and a variety of social and environmental psychology
theories to understand and influence people’s water use.

Social-Ecological Framework of Environmentally Sustainable Landscapes

The maintenance of residential landscapes is a complex activity that is socially
embedded and not simply a task (Kurz 2002). Landscapes are maintained to meet
neighborhood expectations, as a means of self-expression, or to enhance a property’s
value. People are guided by their psychological relationship with their landscape as well as their social relationships within the community (Kurz, Donaghue, and Douglas 2005). Kurz et al. brought together Hormuth’s (1999) ecopsychology approach and Baron and Misovich’s (1993) social-ecological framework to gain a more holistic understanding of attitude and behavior change towards water conservation.

Hormuth’s (1999) ecopsychological approach views the individual as part of their environment and asserts that use of objects mediate behavior that affects the environment and social experiences. Objects have instrumental, self-presentational, and symbolic functions. For example, a sprinkler system’s instrumental function is to water the landscape, its self-presentation function is to maintain a landscape that reflects who the owner is, and its symbolic function is to affirm (or not) the shared neighborhood aesthetic. An individual can choose a xeriscape that identifies them as a conservationist and challenges the predominant “green grass” aesthetic. Often the instrumental function of an object has unintended environmental consequences. A sprinkler system’s purpose may be to efficiently water a landscape, but it can also increase the likelihood of overwatering a landscape when improperly used. Objects are usually perceived for their instrumental function, rather than their environmental impact. Conserving water is a secondary goal to the sprinkler system’s instrumental function of watering the landscape.

Baron and Misovich (1993) present three key principles that help illuminate interactions with physical and social environments – affordances, attunements, and effectivities. Affordances are the potential utility (positive and negative) of an object in meeting a goal; e.g., a sprinkler system may provide a more effective watering tool, but it
also can increase the likelihood of wasting water. *Attunements* are the array of perceptions one has toward an object; e.g. one may be attuned to the perception that a sprinkler system has improved the quality of their landscape, but not perceive the potential for over use and higher water bills. *Effectivities* are the skills and knowledge required to utilize an object’s affordances once they are perceived. Does one know how to program the sprinkler system controller, read ecological cues on the landscape, or recognize maintenance problems? Does one have the knowledge necessary to appropriately water a landscape related to plant water requirements, sprinkler system precipitation rate, and distribution uniformity? Affordances, attunements, and effectivities work in concert to effect environmentally sustainable behavior. Kurz (2002) asserts that these perceptions are socially embedded. Individuals exchange ideas, information, and skills through interactions and conversations with their neighbors and observations of others’ practices.

A landscape water check provides the educational opportunity to address how people utilize their sprinkler systems, their perceptions of its utility, and their landscape watering skills and knowledge. One individual can potentially attune an entire neighborhood to environmental impacts of landscape water use and improve watering skills throughout the neighborhood. The social-ecological framework provides a holistic approach to analyzing these interactions.
Conservation Attitudes, Behavior, and Values

Studies of attitude-behavior relationships have documented inconsistent findings regarding the nature of this relationship and how to analyze it. Wicker (1969) documented a number of early studies and their varied results in a review of articles spanning 1934 to 1969. Aitken et al. (1994), in a study specifically assessing cognitive dissonance as a means of motivating water conservation, concluded that attitudes, habits, and values were poor predictors of water conservation behavior. Syme, Seligman, and Thomas (1991) reviewed the environmental and conservation literature with regard to the interaction of attitudes and behaviors. General environmental attitudes were not found to predict environmental behavior; however, specific attitudes toward factors such as comfort and health did influence energy consumption. In a San Antonio, Texas study of water conservation attitudes and actions, de Oliver (1999) found that participants expressed conservation as a valued ethic but it did not translate into action. The Edwards Aquifer Management Plan was designed as a demand management plan that advanced through four stages in response to aquifer levels (pp. 373-375). de Oliver’s analysis revealed that wealthy, educated, Anglo Republicans had the poorest response to voluntary water conservation. During the later mandatory stages of the plan, those with higher income and educational attainment responded well to increasing restrictions, but only achieved parity with those who began conserving during the voluntary stage (p. 386). However, general support of conservation was seen as being socially desirable. The community’s response to the conservation plan failed to meet its goals. Corral-Verdugo, Bechtel, and Fraijo-Sing conducted a study which linked general environmental beliefs to
specific beliefs regarding water and found that “attitudes [did] predict behavior when measured at the same level of specificity” (2003, 255). They had revised general statements in the New Environmental Paradigm-Human Exemption Paradigm, an environmental attitudes measurement scale, to be explicit statements regarding water. Syme, Nancarrow, and Seligman (2000) noted the failure of researchers to conduct pre- and post- test attitude studies to evaluate water conservation programs. Kaiser and Wilson (2003) criticized past environmental research claiming “an existing attitude-behavior gap” on the basis of poor statistical rigor. The trend of inconsistent findings related to the connection between attitudes and behavior continues.

Cognitive dissonance plays an important role in motivating an individual to change consumptive behavior and adopt conservation strategies. Dissonance is a disagreeable psychological state that occurs when a person holds inconsistent cognitions; e.g., a person believes that (s)he is a conservationist who is saving water but discovers (s)he is actually wasting water. When this occurs, a person acts to reduce dissonance by changing either their attitude or their behavior (Festinger 1957). This mental state involves a person’s self-concept and results in self-persuasion to reconcile the dissonant state. This type of change tends to be persistent and enduring and can lead to behavior more consistent with a person’s attitudes and beliefs (Aronson 1980; Thibodeau and Aronson 1992; Dickerson et al. 1992). Dissonance may be experienced as feelings of guilt (for having wasted water), which then motivates a person to take action to correct the wasteful behavior (D. O’Keefe 2002). Aitken et al. (1994) found that pro-conservation participants who received a dissonance trigger were able to achieve greater water savings than pro-
conservation participants who only received feedback on their water use. Other research has shown that the motivation to conserve can be reduced when a person believes others are wasting water (Corral-Verdugo et al. 2002) and that the lack of social support from one’s peers can act to reduce the level of cognitive dissonance experienced (McKimmie et al. 2003).

Ajzen’s 2001 Theory of Planned Behavior (TPB) posits that people act based on their intentions. A person’s intention is influenced by their attitude, peer pressure (subjective norm), and their perception of control over the intended action (p. 43). When a person’s intention and perception toward an act are stable, TPB has good predictive potential (p. 46). In a study of water conservation, Lam added two variables believed to interact with TPB, a perceived moral obligation to society and one’s perceived right to use water. Lam also examined two types of behavior: *curtailment*, described as changing water use habits; and, *efficiency*, described as the adoption of water saving technology (1999, 1060-1062). Curtailment requires a person to change their habits and maintain the new behavior over time. Efficiency is a one-time decision regarding which water saving technology to adopt. This study established that curtailment and efficiency behaviors are distinct and should be studied separately (1999, 1069).

Trumbo and O’Keefe conducted a comparative study that used the theory of planned behavior (TPB) to evaluate the effects of environmental values and information on water conservation behavior (2001, 889). The study was conducted in three communities (Truckee, Reno-Sparks, and Newlands) in the Truckee River Watershed. The Truckee River Watershed was selected for its diverse environmental and social conditions (2001.
The Truckee River is 225 km long and traverses a variety of environmental conditions from the mountainous terrain of Truckee to the bowl-shaped valley of Reno-Sparks characterized by a wide range of precipitation. The watershed has a variety of economic bases including logging, tourism, and agriculture; a variety of interests including rural, urban, and Native American; and various types of populations, such as seasonal tourist populations in Truckee as well as the rapidly growing resident population of Reno-Sparks area.

In 1998, survey data were collected using 7-point Likert scale responses (ranging from disagree to agree) that measured behavioral intention, attitude, normative pressure, self-efficacy, environmental values, information seeking, information exposure, and dichotomous responses (yes/no) for water conservation practices (Trumbo and O’Keefe 2001, 892). A general comparison of the three communities on these variables revealed only a few differences (2001, 893). A specific finding of interest for this study is the role of information. Exposure to information did not play a very strong role in influencing a person’s knowledge, attitude, or behavior. However, actively seeking information on the part of a person did play a significant role, suggesting that how people access information is important when designing information campaigns (2001, 897).

In 2000, Trumbo and O’Keefe (2001) conducted a follow-up survey to document any changes over time in voluntary water conservation behavior. This study found that behavior was predicted by a person’s level of effort in seeking water conservation information. These results imply that information-seeking is an intermediary step between the intention to conserve and the act of conserving, which means it is likely that
the effect of conservation campaigns needs to be measured over a longer period of time. The effect of information was measured in three ways; the level of effort expended seeking information, how much exposure a person had to conservation information, and how much personal attention was given to the information (Trumbo and O’Keefe 2005). Habron (2004), in a study of agricultural landowners, also found a person’s information-seeking behavior to be a consistent predictor of conservation practices. Thus, it appears that it is not just having information, but actively seeking information that explains why people actually do conserve; that is, the predictor of conservation behavior is information-seeking behavior, and not necessarily attitudes per se.

Hamilton (1983) explored the relationship between attitudes and behavior in a study that assessed the effectiveness of a conservation campaign during a water shortage in Concord, New Hampshire in 1980. Hamilton developed a multivariate causal model in an attempt to identify which sociological variables had the most influence in achieving a 15% reduction in demand (p. 358). Hamilton contends that the study of water use is the best means of discovering the sociological variables influencing resource consumption because water costs are such a small part of a household budget and, therefore, economic incentives to conserve do not confound measurement of attitudes (p. 357). However, economic motives were found to be of some relevance in less affluent households where the cost of wasting water did create a financial burden. This study found that behavioral changes were the most effective way to reduce water use and that households with higher incomes, a greater number of occupants, and economic rather than idealistic attitudes proportionally conserved less because they had higher baseline consumption to begin
In order to change one’s consumptive behavior, a person must have the skills and resources necessary to achieve water savings. Landscape water use is a complex activity that requires both technical and ecological knowledge. Klien (2004, 86) concluded that teaching the skills necessary “to recognize technical and ecological cues . . . would empower individuals” to achieve their conservation goals. The ability to effectively employ and demonstrate conservation skills results in what Corral-Verdugo (2002) has termed “proenvironmental competency.” Competency is comprised of skill, the ability to carry out a conservation task, and a requirement, a pressing need or a conservation goal. Corral-Verdugo posits that “requirements are socially constructed (beliefs and norms) and individually grasped (motives, attitudes, perceptions)” (2002, 533). Requirement is the driving force in achieving competence. This study evaluated water conservation competence in two Mexican cities and found that participants in each city who had equal skills did not demonstrate equal competence because one city had abundant water supplies (no requirement) while the other experienced frequent water scarcity (requirement).

In summary, attitudes are likely to predict behavior when measured at the same level of specificity – attitudes toward water are compared to water consumption. Cognitive dissonance can act as a trigger in motivating behavior change that endures over time. In
order for a person to translate conservation attitudes into water-saving behavior, that person must have the skills and knowledge necessary to achieve his/her goals.

Conservation Programs

Syme, Nancarrow, and Seligman (2000) published a comprehensive review of studies evaluating the effectiveness of non-price water conservation campaigns, which they define as campaigns with “an identifiable component of information or persuasion” (p. 541). Generally, these campaigns focus on voluntary conservation and strive to change water use behavior or encourage the adoption of more water efficient appliances and technology through education or persuasive media campaigns. Voluntary conservation programs are seen to be more politically acceptable than other measures such as pricing or regulations. The review divides studies into two categories: “summative studies” were defined as those that evaluate the outcome of campaigns once initiated; and, “formative studies” were defined as those that explore the influences of behavior, attitude, and knowledge of water consumption in order to develop campaigns.

Summative studies have used descriptive case studies, various statistical approaches to identify the most effective campaign variables (education, pricing, regulation), exploratory data analysis to identify data trends, and quasi-experimental or experimental designs. The Syme, Nancarrow, and Seligman (2000) review identified the lack of systematic evaluation of information in reducing water consumption (p. 541) and a failure of statistical approaches to distinguish campaign components and their relative effectiveness (p. 543). An on-going problem noted by Syme et al. are the varied methods used for evaluating water conservation programs’ effectiveness (p. 559) and, as a result,
direct comparisons are problematic. In addition, these authors noted that the method of analysis seemed to have a great effect on the conclusions drawn (p. 551); e.g., narrative studies identify behavior modification as most effective while regression analysis studies often identify price as a primary motivation to conserve. Researchers have had difficulty defining robust water conservation campaign variables that are sensitive enough to measure change.

Formative studies have evaluated the reliability of self-reported behavior compared to actual behavior, distinguished water use habits from efficiency decisions, and assessed the ability of campaigns to increase awareness and knowledge of water conservation and to influence attitudes that motivate conservation (Syme, Nancarrow, and Seligman 2000, 552-553). Syme, Nancarrow, and Seligman note that no study has comprehensively evaluated the effect of conservation campaigns on knowledge, attitudes, and behaviors – variables remain poorly defined, the existence of possible external variables are acknowledged but unidentified, and monitoring has been periodic and imprecise (pp. 558-559).

Syme, Nancarrow, and Seligman (2000) conclude their review with a proposal to create a model to evaluate the effectiveness of communication in water conservation campaigns and recommend that its use should be implemented when initiating a campaign (p. 560). The authors suggest that input variables should include the credibility of the source (who is making the appeal), the persuasion techniques of the message (crisis, common good, economic), mode of delivery (media, demonstrations, neighborhood contacts), and the characteristics of the message receiver (age,
socioeconomic). Output variables should include various psychological processes (memory acquisition, information seeking), subjective normative beliefs, attitudes, moral obligation, perceived right to use, behavioral intention, and conservation ethic (pp. 560-569). In addition to specific future research described above, these authors issue a general call for more deliberative design of water conservation campaigns in order to achieve a greater role in demand management (p 573).

**Recent Summative Studies (1999 to Present)**

In the San Antonio, Texas study, de Oliver (1999) used spatial and statistical analysis of demographic data (income, education, political party, ethnicity, and home ownership) and water consumption data during the implementation of a four-stage conservation plan for the Edwards Aquifer. The conservation plan was designed as a demand management plan that began with an initial voluntary stage and advanced through increasingly restrictive stages in response to aquifer levels (1999, 373-375). Lawn watering accounted for the greatest consumption of residential water use and was a critical component of the Aquifer Management Plan. Homeowners (defined as residing in detached houses) were identified as having the greatest capacity to consume water and, therefore, it was believed homeowners would be more responsive to the conservation plan. The study found that homeowners responded poorly to voluntary conservation measures, but during mandatory restrictions made the greatest effort to conserve. Also, once mandatory restrictions were lifted, home ownership was the only demographic variable (compared to income, education, political party, and ethnicity) that was related to continuation to conserve.
The Saving Water Partnership (SWP) in the Seattle, Washington area provides an example of the type of on-going evaluation (formative) and long-term monitoring (summative) of conservation programs that is needed. The SWP initiated a regional water conservation program in 2000. Its goal is to reduce regional water consumption by 1% per capita per year. The program covers both indoor and outdoor conservation and sets annual water saving goals for each of its programs (Dethman and Tangora LLC 2001). In 1998, a Conservation Potential Assessment was conducted and the information was used to design its various programs (Seattle Public Utilities 2006).

The residential landscape program, named the Natural Lawn and Garden Program or “the Naturals,” began by promoting natural gardening techniques such as improving soil water holding capacity through composting, mulching and thatch control. The Naturals also made general recommendations to water between 7 pm and 10 am, use soaker hoses where appropriate, and to adjust automatic timers for temperature (Dethman and Tangora LLC 2001). Appropriate irrigation scheduling was recognized as an important means to achieving the landscape water savings goal. In 2002, the SWP conducted a research program to determine the most efficient and cost effective ways to change irrigation schedules; e.g. ET controllers, rain sensors, or a scheduling service. Evapotranspiration (ET) controllers are programmed to seasonally adjust the watering schedule with historical ET rates, while rain sensors shut off controllers when it rains a certain amount. The research included a customer satisfaction survey to determine which method best meet customers’ needs. The research found that an ET controller with a rain sensor achieved the greatest water savings. However, the irrigation scheduling service and ET
controller also achieved significant water savings. Most participants who received an ET controller and/or a rain sensor did not feel that their systems were easier to use or that they had learned much about efficient irrigation. In contrast, most participants who received the irrigation scheduling service felt they had learned more about plant water needs and how to efficiently irrigate their landscape (Smith and Brown 2003). In 2005, the Naturals focused on improving watering efficiency by targeting high peak users and offering them rebates for increasing irrigation system performance, offering on-line water scheduling tools, and publishing a regional plant list to aid in plant selection based on plant water needs (Seattle Public Utilities 2006).

The SWP engages in on-going evaluation and monitoring of its conservation measures and strategies. The quantitative and qualitative data that is gathered is then used to make adjustments and ensure that the program meets its annual water savings targets. The Saving Water Partnership 2007 Annual Report (the last report available) reports that conservation programs have met their targets 5 out of 7 years (Seattle Public Utilities 2008, 8).

Kenney, Klein, and Clark (2004) studied the response to conservation programs implemented by eight water providers along Colorado’s northern Front Range during the period of 2000 - 2002. Colorado’s Front Range experienced some of the worst drought conditions on record during this time period (p 77). Water providers used a multi-pronged approach of voluntary and mandatory landscape watering restrictions, pricing changes, and public education for demand management. This study focused primarily upon the effectiveness of landscape water restrictions. Although the drought crisis and the
accompanying water restrictions were widely publicized through a variety of mediums (TV, mailings, web pages), responses to voluntary restrictions were extremely poor throughout the study area and water consumption even increased in Boulder and Thornton (pp. 79 and 83). The cities that implemented strict mandatory restrictions saved the most water, but this approach was considered unsustainable and the researchers suggested that more lenient mandatory restrictions could balance customer impact and water savings (p. 86).

Recent Formative Studies (1999 to Present)

O’Keefe and Shepard (2002) have proposed a set of general principles tailored for environmental programs/campaigns that could be used to develop an effective water conservation program. Effective programs make use of a community’s information networks, knowledge, and engagement in the issue to build a program’s structural framework that addresses the community’s needs. Effective programs involve citizen groups in planning and implementation, are guided by measurable goals and objectives, seek broad support throughout the community recognizing that change is slow, and provide reinforcement and feedback to ensure that the program’s goals and objective’s continue to be met (pp. 670-673).

The Western Resources Advocates (WRA, 2003) conducted a comparative study of urban water use throughout the southwestern United States. Data were collected for 2001 in the six states of Arizona, Nevada, New Mexico, Texas, Utah, and Colorado, which are some of the fastest growing states in the country. From 1990 to 2000 population growth ranged from 20% to 66% throughout the region. Typically, most of this population
growth is concentrated in urban areas and populations in the Southwest are some of the most urbanized in the country. Water utilities are faced with the challenge of providing water for these new residents in an arid region that experiences cyclical droughts.

In the participant cities, residential water consumption accounted for the greatest proportion of retail water sales. Across the Southwest, more than fifty percent of residential water consumption occurs outdoors, primarily for landscape irrigation. The study identified outdoor water use as “the biggest target for future water savings” (p. 56) and focused exclusively on single family residential accounts. Interestingly, throughout the region, the study found little correlation between climate and outdoor water use. For example, Tucson, Arizona has the highest average summer temperatures (82°F) in the region and receives an average of 11.7 inches of precipitation annually. Yet, Tucson’s outdoor water use is estimated at only 38 gallons per capita per day (gpcd); while Taylorsville, Utah, a city with much more moderate summer temperatures and greater rainfall, used 124 gpcd.

WRA analyzed each city’s water conservation programs and found that all participant cities were making some efforts to conserve water. However, program components varied widely, on-going monitoring of program effectiveness was rare, and landscape water audits were usually offered as a self-audit kit, foregoing the opportunity for one-on-one education. In short, there are no recognized standards establishing essential elements of an effective water conservation program. However, WRA suggests that education is the foundation for all other conservation program components.
Keyes, Schmitt, and Hinckle (2004) conducted a national analysis of conservation programs and identified components necessary to create successful conservation programs. These include political leadership, stakeholder involvement, defined policy goals and conservation measures, detailed water use data, stable funding, sufficient personnel, and citizen education (p. 1). Broad-based education and outreach were identified as components essential to help improve citizens’ understanding of the need for conservation, methods for achieving water savings, and to gain public support for conservation efforts.

Literature Review Summary

As the literature review reveals, the maintenance of residential landscapes is a surprisingly complex activity encompassing personal attitudes, ecological constraints, and technological challenges. Ecopsychology and social-ecology provide a framework to help us understand and analyze peoples’ attitudes toward their landscapes as well as the challenges they face acquiring the knowledge and skills necessary to maintain a landscape in the arid West. People have a diverse array of motivations for conserving water and the methods for gaining participation in conservation programs should reflect this. Some people will seek information offered through voluntary educational programs, while others may need a cognitive dissonance trigger before seeking information. People often do not know how much water they use, but once brought to their attention, they desire to participate. In either case, conservation programs need to provide people with information and teach the skills necessary to achieve conservation goals over time. Residential landscape water checks provide water utilities with the opportunity to foster
conservation attitudes, provide information, and teach the skills necessary to recognize technological and ecological cues in order to maintain sustainable landscapes.

Purpose

The purpose of this research is to investigate urban landscape water consumption and assess the effectiveness of a landscape water check program as a conservation tool. It builds upon previous landscape water use research conducted by Endter-Wada et al. (2008) in Layton, UT investigating “situational waste” on residential and business landscapes and Kilgren et al. (2010) on institutional landscapes in Utah’s Granite School District, which investigated the effectiveness of several experimental interventions with varying levels of conservation education. Chapter 2 reports the results of the baseline characterization and the development of a conceptual framework of residential landscape systems, which includes site characteristics, irrigation technology, plant material, and human behavior. Chapter 3 assesses the effectiveness of a landscape water check program and development of several assessment and monitoring tools to better evaluate landscape water use. Both chapters offer recommendations for better conservation program design and further research into the subject.

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CHAPTER 2

URBAN LANDSCAPE WATER USE EFFICIENCY AS CONTEXTUALIZED SYSTEMS THINKING

Abstract

Our research investigates urban residential landscape water consumption. We conducted our research during the 2004 and 2005 irrigation seasons in Logan City, Utah, located in Cache Valley on the northernmost boundary of the Great Basin. Logan City, a university town with a population of 42,670, grew by 23.2% during the 1990s (U.S. Census, 2000). Research was conducted in connection with a city-sponsored water check program offered to households. The site-specific approach incorporated landscape water checks to inspect residential landscapes, historical ET₀ data to create irrigation water schedules, survey data to assess water conservation behavior and the effectiveness of a water check program as a conservation tool, remote sensing data to develop household water budgets, and city water billing records to evaluate water consumption during a six year period (2002 – 2007). In the current analysis, we report the results of the baseline characterization of the households that volunteered to participate in 2004 and the households that were recruited in 2005 because they exhibited higher than average water use. We interpret our results using a conceptual framework developed to better understand urban landscape water use efficiency as contextualized systems thinking.

\[^{1}\] This chapter was co-authored by Diana T. Glenn, Joanna Endter-Wada, Roger K. Kjelgren, Christopher M.U. Neale. Prepared for submission to Environment and Behavior.
Introduction

The arid Intermountain region of the western United States experienced a prolonged drought during 1999–2004, a period also characterized by some of the fastest population growth in the country. This region is also the most urbanized area of the country, with Utah having about 82% of its population living in urban areas and ranked the sixth most urbanized state in the nation (Utah Division of Water Resources [UDWR], 2001, p. 18). Urban water demand management is increasingly important to ensure adequate water supplies to accommodate regional population growth, particularly in areas where developing new municipal supply sources could seriously impact rural communities and natural environments. The greatest proportion of municipal water delivered to residential customers in the Intermountain West is used to irrigate outdoor landscapes, which are often overwatered.

Utah, where our research was conducted, is no exception to these general trends. Drought is a recurring feature of the Utah climate (UDWR, 2007). From 1990 to 2000, Utah’s population growth ranked fourth in the nation and grew by 29.6% (UDWR, 2001, p. 18; Western Resource Advocates [WRA], 2003, p. 8). Currently, 66% of publicly-supplied water in Utah is attributed to residential use. Two-thirds of this residential water is consumed outdoors, primarily for irrigating landscapes. On average, twice as much water is applied to landscapes than is required to meet plant needs (UDWR, 2003, p. 2; UDWR, 2004, p. 37).

Various factors have been found to contribute to landscape water consumption variability and trends. Drought cycles are clearly a contributing factor. The statewide
trend in Utah is lower water use in wet years (269 gpcd in 1995) and higher use during drought years (293 gpcd in 2000). The type of irrigation system influences landscape water consumption, and properties with underground automatic sprinkler systems are frequently overwatered (Endter-Wada, Kurtzman, Keenan, Kjelgren, & Neale, 2008; Kilgren, 2002; Kilgren, Endter-Wada, Kjelgren, & Johnson, in press; Klien 2005).

Landscape watering is also driven by people’s perceptions of summer weather conditions (Balling, Gober, & Jones, 2008; Trumbo, Markee, O’Keefe, & Park, 1999).

Our research objective was to better understand the influences of various factors contributing to urban landscape water use. We conducted our human behavior research in the context of delivering and analyzing the effectiveness of landscape water audits or water checks, which have been a popular water conservation tool in Utah. A well-designed landscape water check program has the potential to save cities significant amounts of water by providing residents with site-specific water conservation education that develops knowledge and skills, sprinkler system inspections that quantify a system’s efficiency, seasonally-adjusted watering schedules, and conservation recommendations that address soil, plant, and sprinkler system problems. Such programs generally enjoy popular support, because they are administered on a voluntary basis and their goal is to improve water efficiency on existing landscapes.

We found that the maintenance of residential landscapes is a surprisingly complex activity encompassing personal attitudes, social norms, ecological constraints, and technological challenges. The demand for water to maintain residential landscapes that conform to social norms and current water use regulations are key factors shaping urban
landscape water use. Human behavior, plant material, the particular site, and irrigation technology are embedded in urban ecosystems and define the situations in which people act. Taken together, these domains form the context and action arena informing a holistic understanding of how people maintain the landscapes on their urban properties (Endter-Wada et al. 2008; Honadle, 1999; Kilgren et al. in press; Ostrom, 2007; Wapner & Demick, 2002).

We will argue that choices and conditions in each of these four domains influence the effort required to achieve water use efficiency, but also that certain choices or conditions may doom a person to inefficient water use despite their best intentions to conserve. We demonstrate that not all water use is determined by the human behavioral aspects of applying water to the landscape. Sprinkler system design, site characteristics or plant types may make it difficult to use water efficiently. We investigated the interactions between the site characteristics, irrigation technology, plant material, and human behavior and created a framework for thinking systematically about how the pieces fit together. This framework can be used as a teaching tool and can guide creation of profiles of the common traits that characterize efficient water use or unnecessary water use. These profiles may identify potential indicator variables and their values that can provide benchmarks to guide a household’s efforts to use water efficiently. We contribute to conservation research by furthering a contextualized understanding of peoples’ landscape water use within their residential properties that are embedded in urban ecosystems.
Conceptual Framework

We created and here present a conceptual framework of water use efficiency as contextualized systems thinking that provides a heuristic tool for our analysis and illustrates our current understanding of the residential landscape system (Figure 2-1). We defined our urban ecosystem by the city boundaries of Logan, Utah, USA, while the residential lot defined the residential landscape system boundary and is our unit of analysis. We recognize that the residential landscape system and the urban ecosystem are embedded within and influenced by larger ecological and hydrologic systems, in this instance those defined by the Wasatch and Uinta mountain ranges and the Bear River Watershed, but these scaled system relationships were beyond the scope of this research.

Urban Ecosystem – Logan, Utah

Fig. 2-1 Conceptual framework of residential landscape water use in urban ecosystems, defined by the four domains of site characteristics, irrigation technology, human behavior, and plant material.
Residential Landscape System

The maintenance of residential landscapes is a problem-solving activity that occurs within a socioecological system that is embedded in a complex and dynamic urban ecosystem. Dörner (1996) used complexity to describe a system with many interdependent variables and argues that any problem and its context need to be considered equally. Allen, Tainter, & Hoekstra (1999) further clarify complexity as a system with many levels or a deep hierarchy. Scott (1998) cautioned against using simplified assumptions and singular measures of success. He observes that resilience is born of practical local knowledge of place and diverse approaches to issues people face. Holling (2001) characterizes system dynamism as an adaptive cycle that describes the systems’ potential for change, internal controllability, and resilience. In order to assess a system, we must first describe its components or domains, the relationships between them, and their spatial and temporal scales (Allen, et al., 1999; Cumming & Collier, 2005; Eakin & Luers, 2006; Holling, 2001; Pickett et al., 2001; Resilience Alliance, 2007; Tainter, 2006). Stave (2003) and her student, Cloud, developed a watershed system dynamics model of the Las Vegas, Nevada, USA water system and used model simulations in community workshops to demonstrate the likely outcomes of water conservation policies. They found that the use of system dynamics was an effective framework for aiding participants’ policy choices even though they had little experience in systems concepts.

Site characteristics domain. The lot size and location within the research city determine many of the residential landscape systems’ general physical attributes and the
microclimates they create. The west side of Logan City is located on the flat lower elevation of the wet valley floor, while the east side is on the dry foothills surrounding the mouths of Logan, Green, and Dry Canyons. The eastside neighborhoods experience morning and overnight canyon winds. Throughout the city, the variation in elevation and aspect along with urban heat island effects of the built environment influence interception of solar energy and net radiation gain (Strahler & Strahler, 2000).

Urbanization causes soil degradation by removing its natural vegetative cover and interrupting the physical, chemical, and biological processes of soil formation (Palm, Sanchez, Ahmed, & Awiti, 2007). Pickett and Cadenasso (2009) developed a framework for comparing urban and non-urban soils and described how the states of soil formation (climate, topography, organisms, time, and parent material) are influenced by urbanization to create novel and modified soils that have long-term effects on soil processes. For example, activities such as grading, digging, and planting can have lasting effects that alter the soil structure and function. Topographic alterations, such as changes in slope or installation of boulder walls, can effect hydrologic processes on a residential lot, changing soil moisture content and evapotranspiration (Xiao, McPherson, Simpson, & Ustin, 2006). The city’s southeast neighborhood has many steep lots with excessive cut and fill design features (Logan City, 1999). Consequently, minimizing runoff is a major issue in this area.

**Plant material domain.** Urban vegetation is a human created flora that reflects a region’s history as well as a neighborhood’s socioeconomic status. Landscape design and plant material can affect home values, while the cost of landscaping influences design
and plant selection (Behe et al., 2005; Helfand, Park, Nassauer, & Kosek, 2006; Keane, 1995; Martin, Warren, & Kinzig, 2004; Rupp & Kjelgren, 2006). The choice of plant types and varieties fixes the amount of water that will be needed by a landscape. Climate, topography, and soil type should be considered when selecting plants along with the plant’s water need, sun exposure, and space. Plants with similar needs should be grouped together. Plants that are adapted to the local environment generally are the most water efficient plant choices, which is the reason for promoting the use of native plants in urban landscape design (Ferguson, 1987; Hooper, Endter-Wada, & Johnson, 2008; Mee et al., 2002; Perry, 1995). Vegetation also influences microclimates on residential lots. Logan’s residential landscapes are dominated by traditional designs utilizing extensive Kentucky bluegrass lawns. The parking strips in Logan’s older central neighborhoods contain mature street trees, which lower temperatures, reduce wind speed, and increase humidity. Newer neighborhoods have more landscapes that are immature and do not enjoy these benefits (Bolund & Hunhammar, 1999; Keane, 1995; Logan City, 1999). Irrigated residential lawns substantially reduce surface temperatures around homes providing evaporative cooling (Bonan, 2000). Residential landscapes serve multiple purposes and make significant contributions to human quality of life.

**Irrigation technology domain.** The design of irrigation systems and the plants watered should be considered together in order to facilitate effective application of water and realize the timesaving benefits an automated in-ground system affords. The system zones should contain plants with similar water requirements. The Irrigation Association (2005, p. G-8) defines irrigation system efficiency as “the percent of water supplied
beneficially used by plants.” It is equally based on three elements: 1) plant water requirements, 2) distribution uniformity, and 3) how effectively water is managed to meet plant need. Distribution uniformity describes how evenly water is applied to the landscape and is a qualitative rating of its application effectiveness. Since the efficiency of water management is difficult to quantify, distribution uniformity is often used as a proxy measure of potential irrigation efficiency. Common problems associated with low distribution uniformity are poor irrigation system maintenance, mixed zones containing spray and rotor heads, variable pressure, and poor head-to-head coverage (Baum, Dukes, & Miller, 2005; Burt et al., 1997; Ferguson, 1987; Kjelgren, Rupp, & Kilgren, 2000).

The Seattle area Saving Water Partnership found that 55% of their water users surveyed (n=141) believed that their automated sprinkler system applied water with minimal waste. They found that high water use households were significantly more likely to use automated underground sprinkler systems (Saving Water Partnership, 2007). In a 2003 study of water efficient irrigation, the Saving Water Partnership found that none of the focus group participants could describe how they determined their water schedules. The Office of Water, United States Environmental Protection Agency (USEPA, 2003) cautions homeowners that irrigation controllers can be wasteful and must have certain minimum water saving features that allow flexible irrigation scheduling for diverse weather and site conditions. USEPA advises homeowners to “always be mindful that YOU are the ‘brains’ behind your irrigation system scheduling and YOU control the controller” (p. 3).
**Human behavior domain.** The maintenance of residential landscapes is an activity that is socially embedded and not simply a task (Kurz, 2002). Landscapes are maintained to meet neighborhood expectations, as a means of self-expression, to enhance a property’s value, and for their use values. People are guided by their psychological relationship with their landscape as well as their social relationships within the community (Kurz, Donaghue, & Walker, 2005). Kurz et al. brought together Hormuth’s (1999) ecopsychology approach, and Baron and Misovich’s (1993) social-ecological framework to gain a more holistic understanding of attitude and behavior change towards water conservation.

Hormuth’s (1999) ecopsychological approach views the individual as part of their environment and posits that use of objects mediate behavior that affects the environment and social experiences. Objects have instrumental, self-presentational, and symbolic functions. For example, a sprinkler system’s instrumental function is to water the landscape, its self-presentational function is to maintain a landscape that reflects who the owner is, and its symbolic function is to affirm (or not) the shared neighborhood aesthetic. Individuals can choose a xeriscape landscape to identify themselves as conservationists and to challenge the predominant “green grass” aesthetic. Often the instrumental function of an object has unintended environmental consequences. A sprinkler system’s purpose may be to water a landscape effectively, but it can also increase the likelihood of over watering a landscape when improperly used. Objects are usually perceived for their primary instrumental function rather than their environmental impact. Conserving water or saving time are often secondary complementary goals to the
sprinkler system’s primary instrumental function of watering the landscape (Endter-Wada et al., 2008; Hormuth, 1999; Kilgren et al., in press).

Baron and Misovich (1993) present three key principles that help illuminate interactions between physical and social environments – affordances, attunements, and effectivities. *Affordances* are the potential utility (positive and negative) of an object in meeting a goal; e.g., a sprinkler system may provide a more effective and time-saving watering tool, but it can also increase the likelihood of wasting water (Endter-Wada et al., 2008). *Attunements* are the array of perceptions one has toward an object; e.g. one may be attuned to the perception that a sprinkler system has improved the quality of their landscape, but not perceive the potential for water over-use and higher bills. *Effectivities* are the skills and knowledge required to utilize an object’s affordances once they are perceived. Does a person know how to program the sprinkler system controller, read ecological cues on the landscape, or recognize maintenance problems? Does that person have the knowledge necessary to appropriately water a landscape according to plant water requirements, soil type, sprinkler system precipitation rate, and distribution uniformity? Affordances, attunements, and effectivities work in concert to effect environmentally sustainable behavior and these principles can be used to evaluate and characterize a resident’s baseline landscape maintenance activities. Kurz (2002) has suggested that these perceptions are socially embedded. Individuals exchange ideas, information, and skills through conversation with their neighbors and observation of others’ practices.
Landscape water use is an activity that requires both technical and ecological knowledge. Klien (2004, p. 86) concluded that teaching the skills necessary “to recognize technical and ecological cues . . . would empower individuals” to achieve their conservation goals. The ability to effectively employ and demonstrate conservation skills results in what Corral-Verdugo (2002, p. 533) has termed “proenvironmental competency.” Competency is comprised of skill defined as the ability to carry out a conservation task and a requirement defined as a pressing need or conservation goal. Corral-Verdugo posited that “requirements are socially constructed (beliefs and norms) and individually grasped (motives, attitudes, perceptions)” (2002, p. 533). Requirement is the driving force in achieving competence. His study evaluated water conservation competence in two Mexican cities and found that participants in each city who had equal skills did not demonstrate equal competence because one city had abundant resources and a reliable municipal water system (no requirement) while the other experienced poor availability and frequent interruptions in service (requirement). In U.S. cities with a reliable water supply, goal setting can be a major motivation driving conservation behavior. Two home energy studies found that stating a conservation goal was critical to successful conservation (McCalley & Midden, 2002; van Houwelingen and van Raaij, 1989). A resident’s “proenvironmental competency” can be evaluated to describe their skill in maintaining their landscape in response to the need to do so efficiently.

Cognitive dissonance plays an important role in motivating an individual to change consumptive behavior and adopt conservation strategies. Dissonance is a disagreeable psychological state that occurs when a person holds inconsistent cognitions;
for example, a person believes that (s)he is conserving water but discovers (s)he are actually wasting water. When this occurs, a person acts to reduce dissonance by changing either their attitude or behavior (Festinger, 1957). This mental state involves a person’s self-concept and results in self-persuasion to reconcile the dissonant state, which tends to be a persistent and enduring change that leads to behavior more consistent with a person’s attitudes and beliefs (Aronson, 1980; Dickerson, Thibodeau, Aronson, & Miller, 1992; Thibodeau and Aronson, 1992). Dissonance may be experienced as feelings of guilt (for having wasted water), which then motivates a person to take action to correct the wasteful behavior (O’Keefe, 2002).

Methods

We utilized a quasi-experimental research design that tested the effectiveness of landscape water checks as a conservation tool and different participant recruitment methods. In 2004, Utah’s sixth year of drought, we offered free landscape water checks to all households in Logan, Utah. The free service was publicized in newspaper articles, radio programs, posters in public places, and flyers delivered to residents’ doorsteps. The water check included a detailed evaluation of households’ sprinkler systems and landscapes, site-specific seasonally-adjusted watering schedules, and conservation recommendations. Landscape water checks and interviews were completed for 148 self-selected volunteers. Generally, volunteers are those who are most interested in an issue and may already exhibit certain levels of knowledge and skill, so this delivery method contained an inherent self-selection bias (Brady & Collier 2004; Hartman, 1988).
During the summer of 2005, we selected a target sample of above-average water users and recruited them to participate in the water check program. The sample was selected from a preliminary analysis of Logan City water billing records, prior to construction of a water use index for more detailed analytic rankings and comparisons (more below). Above-average users were identified by normalizing water usage for lot size so that all lots could be compared. Then landscape water use was estimated by calculating the difference between winter and summer billing periods. The difference was assumed to be landscape water use. Households were characterized as above-average water users if they met both of the following thresholds for irrigation season water use in 2004 and in one or both of the two previous years (2002 and 2003): 1) 1150 or more gallons of water per day (gross); and 2) 5000 or more gallons per acre per day (normalized). The total sample included 420 households.

All households meeting these criteria received a letter identifying their property as having above-average water use and offering a free landscape water check. For people who believed they were conserving water or were striving to use water efficiently, the letter could have acted as a cognitive dissonance trigger. Households were given a phone number they could call to schedule the free service. Some people did call and volunteer to participate in response to the letter. In addition, researchers called households with listed phone numbers, asked if they had received the letter, and inquired as to whether they would be willing to participate in the water check program. At the time of the phone call, some information was obtained in a screening survey and, if the person chose not to
participate, they were asked to offer reasons for their decision. For the 2005 study year, 105 participants were recruited into the study and had water checks.

The two different approaches allow comparison of the effectiveness of different recruitment methods for conservation programs (volunteers vs. recruited households), as well as differing levels of intervention needed to secure participation in the program. The sampling method also allows us to compare participants that began the study with different levels of interest in water conservation that most likely represent the ends of the water use spectrum. We utilized within-case analysis of the survey data, as well as plant material, site, and irrigation technology metrics to make causal-process observations aimed at creating profiles of efficient water use and unnecessary water use and identifying key variables and their values distinguishing water use between the two groups at the time of the initial intervention (Brady & Collier, 2004).

The 2005 screening survey was used to ensure participants were single family households using municipal water on their landscape (as opposed to irrigation company water) and to identify the person responsible for watering the landscape. The services offered by the landscape water check were identical to 2004, as were the pre-intervention (at the time of the water check) and post-intervention (end of growing season) open-ended interviews except for a Likert scale question included in the 2005 survey to evaluate the acceptability of various water conservation approaches and an open-ended question investigating the household decision-making process regarding adoption of conservation practices (see Appendix A).
A landscape water check is essentially a water use “audit” for landscape irrigation systems that assesses system design, maintenance, and operational (time-clock) efficiency (given soil type and plant material) and then provides site-specific information to participants on how water use efficiency can be improved. The controller settings were noted and each zone of the sprinkler system was evaluated visually for operating or design malfunctions; e.g., leaks and zones similarly watering plants with different water requirements. A catch can test was conducted to determine the precipitation rate; which answers the question, “How long do I need to water my lawn?” The catch can test also measures distribution uniformity (lower quarter method) – how evenly the system applies water across the landscape. A soil feel test was also conducted to identify soil type and assess its water-holding capacity. Landscape plant type and quality was assessed visually and plant water requirements determined. The precipitation rate, soil type, and plant water needs were used to create a site-specific seasonally-adjusted irrigation schedule based on historical ET₀. Participants were also given a list of conservation recommendations that addressed soil and plant health, as well as sprinkler system maintenance and design issues (see Appendix B). The water checker reviewed the utility and function of each recommendation with the homeowner, answered their questions, and encouraged them to adopt the recommendations.

At the time of the water check, pre-intervention interviews were conducted with the persons responsible for watering the landscape. They were asked a set of open-ended questions and their voluntary responses were noted. The purpose of the interview was to establish baseline watering habits, conservation attitudes, conservation techniques already
adopted, and their understanding of water costs and billing information. At the end of the growing season, post-intervention interviews were conducted utilizing a set of open-ended questions and their voluntary responses were noted. The purpose of the post-interviews was to discover what recommendations people adopted, problems they encountered, how they dealt with challenges in adopting recommendations, and their assessment of the water check program in aiding them to conserve water (see Appendix A). The surveys were analyzed and categories of responses were created. Multiple response sets were created for some questions that evaluated level of knowledge or skill.

During subsequent analyses, remote sensing data were used to create water budgets for each participants’ landscape. Airborne multispectral images of the city were obtained in the summer of 2004 using the USU airborne multispectral system (Cai & Neale, 1999; Neale & Crowther, 1994) after trees had fully developed canopies. The spectral images were registered into 3-band images (green, red and near-infrared bands) and rectified to a orthophoto map base. The geo-rectified images formed a large multispectral mosaic covering the city. The imagery was calibrated for reflectance, using the system calibration and data from a standard reflectance panel and Exotech radiometer set out in a central location during the flight. The mosaic was classified using a supervised signature extraction and maximum likelihood method. In order to capture variability in the image resulting from bi-directional effects on trees as well as different urban surfaces, signatures for 140 classes were extracted. The resulting classified image was recoded into 9 final classes: grass, sparse grass, stressed grass, trees and shrubs, bare soil, concrete and roofs, asphalt and roofs, shadows, and water. A second flight in early
spring using the airborne system obtained imagery before leaf-out of the trees and shrubs and was used to characterize the amount of turf grass under the tree canopies by comparison with the summer imagery (Farag, 2003; Farag, Neale, Kjelgren, & Endter-Wada, 2010). The imagery was integrated with geographic information system data on parcel boundaries and building footprints obtained from Logan City. We recognize there is a trade-off between using parcel boundaries, which do not include parking strips that the city requires residents to maintain, and on-the-ground measurements, which can be less accurate than parcel boundaries and GIS data. Another limitation is that corner lots may be disadvantaged when compared to lots located within the block because they have parking strip on two sides and may have more landscaped area in the parking strip. A random sample (n=29) of all cases (N=249) was drawn and the parking strip area manually measured on the digital imagery in ArcGIS. The analysis revealed a similar range of landscaped area within the parking strip when comparing corner lots (0 - 13.6%, n=10) to inside the block lots (0.44 - 13.4%, n=19) and does not appear to disadvantage the correct indexing of corner lots. The width of parking strips varies throughout the city (.91 – 4.86 m).

Landscape water budgets, representing how much water landscapes needed given plant type, were created for each participants’ property for the years 2002 through 2007 based on the seasonal average ET₀ for each year and the proportion of the landscaped area represented by turf and trees and/or shrubs. The water budgets were compared with each household’s actual water consumption obtained from analysis of Logan City billing data. The watering season was defined as April 1 through October 31 for analytic
purposes. However, the water schedules given to participants discouraged use of a regular schedule during April and October. Instead, participants were encouraged to water on an “as needed” basis because spring and fall weather can be quite variable. Defining a longer watering season in the analysis allowed us to assess outdoor water use early and late in the season, when excess watering often occurs. Outdoor water use was estimated by summing water consumption April 1 through October 31 and subtracting indoor water use, which was assumed to be 70 gallons/person/day and calculated for the number of people in the household as determined through survey data (Mayer et al., 1999).

In order to compare participants’ individualized water use on a standardized scale, we created an index of landscape water use efficiency. The index is the ratio of outdoor water used (determined through the water billing data analysis) divided by plant water need (estimated by each locations’ landscape water budget). The advantage of the index is that it provides a method to evaluate the effectiveness of water management in comparison to an ecologically based standard – plant water need. An index value less than 1 indicates less water was used than the estimated plant need, a value of 2 indicates twice as much water was used compared to estimated plant need, a value of 3 indicates three times as much was used compared to estimated plant need, etc. The index was calculated for the two years prior to the landscape water check and the two years after the water check. The baseline urban landscape water index (baseline index) was calculated by averaging the annual index for the two years prior to the landscape water check. The index characterizes water use prior to the water check and establishes a baseline from which to measure post-water check water use. The index values produced a continuous
variable that was used for the descriptive statistics and correlations of continuous variables describing the site, irrigation technology, and plant material.

A categorical baseline index was created by comparing our range of index values with the Irrigation Association’s standards of appropriate water use measured in mm/day for climates characterized as warm-dry to cool-dry (Irrigation Association, 2005, p. 1-8). Logan experiences warm-to-hot days and cool nights during most of the irrigation season due to its location in a mountainous, semiarid environment at an elevation of 4,534 feet. Water use in mm/day for the majority of households in each of our index categories fell within the corresponding Irrigation Association’s standard ranges. Four water use categories defined for our study were (Table 2-1): “efficient” (ULWI ≤ 1); “acceptable” (1 < ULWI ≤ 2); “inefficient” (2 < ULWI ≤ 3); and, “unnecessary” (3 < ULWI). The mean baseline water use in mm for cases falling into these four categories is shown in the third column of Table 2-1 and can be compared to the 2004 baseline ET₀ of 4.56 mm/day and 2005 baseline ET₀ of 4.28 mm/day. The “efficient” and “acceptable” categories are considered justifiable water use while the “inefficient” and “unnecessary” water use categories are considered unjustifiable. The categorical baseline index was used for the contingency table analysis of categorical variables from the interview data.

**Results**

**Statistical Analyses**

The statistical analysis, profiles of efficient and unnecessary water use, and individual case studies illustrate the interplay of site, plant material, irrigation technology,
Table 2-1

*Categorical Baseline Urban Landscape Water Index (ULWI)*

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean Water Use</th>
<th>Distribution of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Index Value</td>
<td>2004</td>
</tr>
<tr>
<td>(Water Used/Water</td>
<td>(mm/day)</td>
<td></td>
</tr>
<tr>
<td>Needed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Justifiable Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficient</td>
<td>ULWI ≤ 1</td>
<td>2.01</td>
</tr>
<tr>
<td>Acceptable</td>
<td>1 &lt; ULWI ≤ 2</td>
<td>4.99</td>
</tr>
<tr>
<td>Unjustifiable Water Use:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inefficient</td>
<td>2 &lt; ULWI ≤ 3</td>
<td>7.72</td>
</tr>
<tr>
<td>Unnecessary</td>
<td>3 &lt; ULWI</td>
<td>12.20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>(148)</td>
</tr>
</tbody>
</table>

* Compared to the 2004 baseline ET<sub>o</sub> of 4.56 mm/day and 2005 baseline ET<sub>o</sub> of 4.28 mm/day.

* 2 outliers values ≥ 30 mm/day excluded, 1 case in each year

and behavior to reveal the complex systems thinking required to use water effectively in an a residential landscape system. The distribution of the 2004 Volunteers and the 2005 Recruits among the baseline index categories are depicted in Table 2-1. The majority (65%) of 2004 Volunteers (n=148) have justifiable water use prior to the water check, while the majority (76%) of 2005 Recruits (n=101) have unjustifiable water use (verification that the assumptions in our preliminary analysis of billing data were useful for identifying higher-use households). This distribution reveals that the two groups initially have differential capacities to conserve.
A summary of the significant relationships between the baseline urban landscape water index and the domain variables is presented in Table 2-2. When independently analyzing relationships of variables in each domain with the baseline index, different cases were omitted when the comparisons were not representative. For example, in the irrigation technology domain, the baseline index for cases with a sprinkler system less than two years old was calculated on 1 to 2 years of watering the landscape with a hose-end sprinkler and were omitted. Also in the behavior domain, cases with a different resident during the baseline period were omitted because we would be comparing the water use behavior of different residents. All cases were used in the site and plant domains because they were existing landscapes even if residents changed.

**Site and plant domains.** We explored the relationship between baseline index and lot size, corner lot, the proportion that is landscaped, and the proportion of trees and shrubs planted. We found that larger lots \((r = -0.249, p = 0.00)\) with greater percentage of landscaped area \((r = -0.436, p = 0.00)\) and more trees and shrubs \((r = -0.132, p = 0.037)\) had lower baseline index values. This reflects economy of scale in watering or inability to overwater large areas, and that trees and shrubs were likely watered less than turf in accordance with lower plant water need and reduced irrigation of turf areas due to increased shading by trees. We found that corner lots used significantly more water than lots in the middle of the block \((\chi^2 = 10.214, \text{Fisher’s exact test} = 0.002)\). Corner lots may have greater exposure to sun and wind increasing the real and/or perceived need for water. However, we did not collect data to be able to verify these possibilities. Residents
Table 2-2

Summary of Significant Relationships Between Baseline Urban Landscape Water Index and Domain Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>N&lt;sup&gt;a&lt;/sup&gt;</th>
<th>n&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Pearson's r</th>
<th>χ²</th>
<th>Eta</th>
<th>Independent samples t-test (2-tailed)</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site:</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lot size</td>
<td></td>
<td></td>
<td>-0.249**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corner Lot</td>
<td></td>
<td></td>
<td>10.214**</td>
<td>0.203*</td>
<td>-2.435*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of occupants</td>
<td></td>
<td></td>
<td>-0.129*</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants:</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaped area (% of lot)</td>
<td></td>
<td></td>
<td>-0.436**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turf area (% of landscaped area)</td>
<td></td>
<td></td>
<td>0.132*</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trees and shrubs (% of landscaped area)</td>
<td></td>
<td></td>
<td>-0.132*</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>N^a</td>
<td>n^b</td>
<td>Pearson’s r</td>
<td>χ^2</td>
<td>Eta</td>
<td>F-test samples t-test (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-------------</td>
<td>-------</td>
<td>-------</td>
<td>----------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Irrigation Technology:</strong> (no systems &lt; 2 yrs old)</td>
<td>232</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller type^c</td>
<td>148</td>
<td></td>
<td></td>
<td>16.215**</td>
<td>0.331**</td>
<td>4.692**</td>
<td></td>
</tr>
<tr>
<td>Proportion of malfunctions per sprinkler zone</td>
<td>203</td>
<td></td>
<td>0.303**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Behavior:</strong> (same resident)</td>
<td>202</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years using automated sprinkler system</td>
<td>162</td>
<td></td>
<td>0.327**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant’s schedule minutes/recommended</td>
<td>168</td>
<td></td>
<td>0.259**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minutes ≥ 2 times need</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practicing conservation^d</td>
<td>200</td>
<td>140</td>
<td></td>
<td>6.427*</td>
<td>0.179*</td>
<td>-2.479*</td>
<td></td>
</tr>
<tr>
<td>using soaker hose/drip^e</td>
<td>140</td>
<td>19</td>
<td></td>
<td>3.994*</td>
<td>0.169*</td>
<td>2.231*</td>
<td></td>
</tr>
<tr>
<td>using mulch, compost, mowing height^e</td>
<td>140</td>
<td>50</td>
<td></td>
<td>5.160*</td>
<td>0.192*</td>
<td>2.167*</td>
<td></td>
</tr>
<tr>
<td>Altruistic motivation to conserve^e</td>
<td>201</td>
<td>90</td>
<td></td>
<td>3.371*</td>
<td>0.130*</td>
<td>2.278*</td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>N&lt;sup&gt;a&lt;/sup&gt;</td>
<td>n&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Pearson’s r</td>
<td>$\chi^2$</td>
<td>$\eta$</td>
<td>Independent samples t-test (2-tailed)</td>
<td>F-test</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------</td>
<td>--------</td>
<td>-------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Knowledge of amount of water used&lt;sup&gt;f&lt;/sup&gt;</td>
<td>201</td>
<td>18</td>
<td>--</td>
<td>13.472**</td>
<td>0.259*</td>
<td>3.839*</td>
<td></td>
</tr>
<tr>
<td>Visual priority for yard to be well-kept&lt;sup&gt;e&lt;/sup&gt;</td>
<td>196</td>
<td>129</td>
<td>--</td>
<td>7.763*</td>
<td>0.148*</td>
<td>2.364*</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Between domains N changes due to missing data.  
<sup>b</sup> Within the Behavior domain, n changes due to multiple responses to open-ended questions.  
<sup>c</sup> Coded: 1 None, 2 Mechanical, 3 Combination, 4 Digital.  
<sup>d</sup> Coded: 1 Listed Item, 2 None Used.  
<sup>e</sup> Coded: 1 Mentioned, 2 Not Mentioned.  
<sup>f</sup> Coded: 1 Accurate Amount, 2 Some Idea, 3 No Idea.  

* $p \leq .05$. ** $p \leq .01$.  

* Knowledge of amount of water used, 201 observations, N changes due to missing data.  
* Visual priority for yard to be well-kept, 196 observations, N changes due to missing data.  
* Knowledge of amount of water used, 201 observations, N changes due to missing data.  
* Knowledge of amount of water used, 201 observations, N changes due to missing data.  
* Knowledge of amount of water used, 201 observations, N changes due to missing data.  
* Knowledge of amount of water used, 201 observations, N changes due to missing data.
may feel more neighborhood pressure to keep a nice yard since the house is located on a corner at an intersection. When asked what their visual priorities for their yard are, 74% of participants with corner lots (n=62) stated that they want it to be well-kept and weed free, while 62% of participants with interior lots (n=137) mentioned this concern. Landscapes with a greater proportion of turf ($r = 0.132, p = 0.037$) had higher baseline index values indicating turf was likely overwatered.

**Irrigation technology domain.** When exploring the relationship between baseline water use index and irrigation technology, the sprinkler system controller was found to be influential ($\chi^2 = 16.215, p = .001$). Table 2-3 further explores this relationship. Irrigation controllers have become increasingly sophisticated over time.

<table>
<thead>
<tr>
<th>Baseline Index Category</th>
<th>Manual</th>
<th>Mechanical</th>
<th>Combo</th>
<th>Digital</th>
<th>All Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justifiable ($\leq 2$)</td>
<td>100</td>
<td>37</td>
<td>47</td>
<td>63</td>
<td>53</td>
</tr>
<tr>
<td>Unjustifiable ($&gt; 2$)</td>
<td>0</td>
<td>63</td>
<td>53</td>
<td>37</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>N (13)</td>
<td>(24)</td>
<td>(79)</td>
<td>(32)</td>
<td>(148)</td>
<td></td>
</tr>
</tbody>
</table>

*Pearson’s $\chi^2 = 16.215***, *Cramer’s V = 0.331***, *Goodman & Kruskal’s tau 0.11***

*Note. Sprinkler systems < 2 years old omitted.*

*a Coded: 1 Manual, 2 Mechanical, 3 Combo, 4 Digital.*

*p ≤ .05, **p ≤ .01.*
The oldest sprinkler systems do not have controllers. These systems have valves for each zone that are manually turned on/off and the user monitors the run time. Mechanical controllers have a mechanical clock that on a set day of the week turns the system on/off and the zone run time is set with dials or slide switches with preset time increments; for example, each click of the dial equals 5 minutes. Digital controllers are electronic and are fully programmable. These controllers can store multiple programs, start zones on different days, run zones for different lengths of time, and use weekly or monthly schedules. Combination clocks combine a variety of mechanical and electronic features. Mechanical controllers have the least scheduling flexibility and digital controllers the greatest. Manual systems do not have a controller and consequently have no technological scheduling constraints.

All participants with manual sprinkler systems (n=13) meet justifiable water use, while 63% using mechanical controllers (n=15) and 53% using combination controllers (n=42) had water use that was unjustifiable. Scheffe post hoc test reveals that manual systems used significantly less water than both mechanical (mean dif. -1.53, p = .004) and combination controllers (mean dif. -.106, p =.038). Limitations of the mechanical and combination controllers for setting exact run times constrains users’ abilities to fine-tune their water schedules. The preset time increments force the user to choose between slightly underwatering or overwatering each scheduled day. We suspect that in most cases the choice was to overwater slightly. It appears that the cumulative effect of small, repeated overwatering over the course of the irrigation season adds up to a substantive amount of water. Participants using digital systems used more water than manual systems
(mean dif. was .96) but less water than mechanical (mean dif. was -.61) and combination (mean dif. was -0.13) systems, but this was not a statistically significant difference.

Poorly maintained sprinkler systems can exhibit a number of problems: leaking or broken pipes, valves, and/or sprinkler heads; heads that are tilted, clogged, or sunken into the turf; and improper spray patterns. Table 2-2 shows that systems exhibiting a high proportion of malfunctions per sprinkler zone utilized more water ($r = 0.303, p = 0.00$), probably to overcome these deficiencies. It is notable that of the people who said they were already practicing conservation ($N = 140$), less than 5% mentioned system maintenance ($n = 6$) as a measure they had adopted. Maintaining a system in optimal working condition is necessary to water efficiently as well as to achieve aesthetic goals. The common practice of nighttime watering can mask system problems (because people are not observing the irrigation system in operation) and can increase the difficulty of identifying maintenance issues in a timely manner.

**Human behavior domain.** When exploring the relationship between the baseline water use index and behavior, several variables were found to be significant and are presented in Table 2-2. We expected that participants who had more experience using automated irrigation systems would be more skilled and more likely to have justifiable water use. Responses ranged from no experience to 40 years of experience. However, we found that participants with more irrigation system experience had higher baseline index values ($r = 0.327, p = 0.00, n = 162$) and, at the time of the water check, 30% of the participants were using a water schedule that applied more than two times the water needed ($r = 0.259, p = 0.001, n = 168$). We expected that participants who were
comfortable programming their systems and adjusting their water schedules would be more likely to have acceptable water use. The majority of participants (85%) reported being comfortable programming their controllers and adjusting their schedule in response to weather, season, and/or their lawn’s condition (n = 165). But, these actions did not have a statistically significant relationship with the baseline water use index. However, the majority (58%) of participants who stated they were adjusting their water schedule as a conservation practice (n=33) were using water in the unjustifiable range.

Participants were also asked to describe their regular landscape watering routine. Responses were coded in categories that described their degree of active management; e.g., monitoring soil moisture, shutting off controller for rain, awareness of general watering recommendations such as time of day, varying zone run times by plant type, and, factors influencing their decisions regarding their water schedule, when to begin watering in the spring or finish watering in the fall. However, none of these responses had a statistically significant relationship with the baseline water use index.

We assumed participants who reported practicing conservation at the time of the water check (n = 140) would have justifiable water use and 53% fall within the justifiable range ($\chi^2 = 6.427$, Fisher’s exact test = 0.013). The majority of the participants who made a general effort to economize water use or who reduced/eliminated plants and/or planted drought tolerant varieties were using water justifiably, but these actions did not have a statistically significant relationship with the baseline water use index.

However, the only practice adopted that is statistically significant corresponds to unjustifiable water use. The majority (60%) of participants who were using mulch,
compost and/or adjusted their mowing height for longer turf (n = 50) were unjustifiably using water ($\chi^2 = 5.16$, Fisher’s exact test = 0.034). The majority of participants (68%) who were using soaker hoses or had installed drip zones on their irrigation system (n = 19) were unjustifiably using water ($\chi^2 = 3.994$ Fisher’s exact test = 0.052). The majority (54%) of participants who reported altruistic motivations to conserve (n = 90) meet justifiable water use standards ($\chi^2 = 3.371$, Fisher’s exact test = 0.088). We expect that participants who reported altruistic motivations but did not meet justifiable water use standards experienced some level of cognitive dissonance that would influence their adoption of water check recommendations.

Participant’s knowledge of the amount of water used and what they paid for water was minimal. We expected participants who had some knowledge of how much water they used or what they paid for water would use less of it. Less than 10% of all participants (n = 201) had any idea how much water they used (n = 18) and, of those, 15 (83%) met justifiable water use on their landscapes ($\chi^2 = 13.472$, $p = .001$). Scheffe post hoc test reveals that participants who had some idea of the amount of water they consumed used significantly less water than participants who didn’t know (mean dif. - 0.94, $p = 0.025$). In contrast, 40% of all participants (n = 201) had at least some idea of their monthly water costs (n = 81) but this knowledge did not have a statistically significant relationship with the baseline water use index.

Our interviews explored how participants used their yards and their visual priorities for their yards. We found that use of a yard as a recreation area did not have a statistically significant relationship with the baseline index. The majority (57%) of
participants who were concerned that their yards be well-kept, weed free, and look nice (n=129) were using water in the unjustifiable range ($\chi^2 = 7.763, p = .051$).

**System interrelationships in residential urban landscapes.** Table 2-4 presents a summary of significant relationships between the domain variables. Relationships within and between domains illustrate the full spectrum of interactions that characterize the context of water use and illustrate the system dynamics involved in utilizing water to maintain urban residential landscapes.

<table>
<thead>
<tr>
<th>Table 2-4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary of Significant Relationships Between Domain Variables</strong></td>
</tr>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td><strong>Site:</strong></td>
</tr>
<tr>
<td>Lot size and Year home built</td>
</tr>
<tr>
<td>No. of occupants and Year home built</td>
</tr>
<tr>
<td><strong>Site and Plants:</strong></td>
</tr>
<tr>
<td>Year home built and percent of turf</td>
</tr>
<tr>
<td>No. of occupants and percent of turf</td>
</tr>
<tr>
<td><strong>Site and Irrigation Technology:</strong></td>
</tr>
<tr>
<td>Lot size and Rotor distribution uniformity (%)</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Lot size and Precipitation rate (in/hr)</td>
</tr>
</tbody>
</table>

**Site and Behavior:**

- No. of occupants and Years using automated system
  - N: 150
  - Pearson's: -0.227**
  - Cramer's: --
  - Goodman and Kruskall's: --

**Irrigation Technology:**

- Fixed head - Precipitation rate and Distribution uniformity
  - N: 126
  - Pearson's: 0.452**
  - Cramer's: --
  - Goodman and Kruskall's: --

- Number of zones and Pressure
  - N: 94
  - Pearson's: -0.289**
  - Cramer's: --
  - Goodman and Kruskall's: --

**Irrigation Technology and Plants:**

- Rotor distribution uniformity (%) and sq. ft. of trees/shrubs
  - N: 57
  - Pearson's: -0.427**
  - Cramer's: --
  - Goodman and Kruskall's: --

- Fixed head - pressure and sq. ft. of turf
  - N: 77
  - Pearson's: -0.306**
  - Cramer's: --
  - Goodman and Kruskall's: --

**Irrigation Technology and Behavior:**

- Controller type\(^a\) by Use of automatic setting\(^b\)
  - N: 112
  - Pearson's: --
  - Cramer's: 12.344*
  - Goodman and Kruskall's: 0.235* 0.062*
Controller type\(^a\) by Adjustment of frequency or run time settings\(^c\)

Plants:
Turf root depth and average quality

Plants and Behavior:
Average turf quality and Proportion of old/new schedule

Behavior:
Adopted conservation practices\(^c\) by Motivation to conserve – drought/scarcity\(^d\)
Knowledge of cost of water\(^d\) by Motivation to conserve – cost\(^d\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>(r)</th>
<th>(\chi^2)</th>
<th>(V)</th>
<th>(\tau)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controller type(^a) by Adjustment of frequency or run time settings(^c)</td>
<td>117</td>
<td>--</td>
<td>25.099**</td>
<td>-0.463**</td>
<td>0.215**</td>
</tr>
<tr>
<td>Turf root depth and average quality</td>
<td>152</td>
<td>0.291**</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Average turf quality and Proportion of old/new schedule</td>
<td>153</td>
<td>0.326**</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Adopted conservation practices(^c) by Motivation to conserve – drought/scarcity(^d)</td>
<td>141</td>
<td>--</td>
<td>5.40*</td>
<td>0.164*</td>
<td>0.027*</td>
</tr>
<tr>
<td>Knowledge of cost of water(^d) by Motivation to conserve – cost(^d)</td>
<td>104</td>
<td>--</td>
<td>10.969**</td>
<td>0.232**</td>
<td>0.054**</td>
</tr>
</tbody>
</table>

Note. Between domains, N = same resident, no systems < 2 yrs old. Within the Behavior domain N = same resident.

\(^a\)Coded: 1 Manual, 2 Mechanical, 3 Combo, 4 Digital. \(^b\)Coded: 1 No, 2 Seasonally, 3 Yes. \(^c\)Coded: 1 Yes, 2 No.

\(^d\)Coded: 1 Mentioned, 2 Not Mentioned. \(^e\)Coded: 1 Accurate Amount, 2 Some Idea, 3 No Idea.

\(p \leq .05. \quad \** p \leq .01.\)
**Site interrelationships.** Exploring these relationships, we found small positive correlations among the site variables and between site and plant variables. Newer homes tended to have larger lots \((r = 0.256, p = 0.000)\), more occupants \((r = 0.313, p = 0.000)\) and a greater percentage of their landscaping devoted to turf \((r = 0.345, p = 0.000)\). Also, the landscapes of homes with more occupants had a greater portion planted in turf \((r = 0.265, p = 0.000)\). In their interviews, participants with children often expressed the importance of having lawns for children and pets to play on.

We found small negative correlations between some site and irrigation technology or site and behavior variables. Large lots had lower distribution uniformity on rotor zones \((r = -0.264, p = 0.045)\) and lower precipitation rates on all zone types \((r = -0.190, p = 0.010)\). Sites with more occupants had fewer years of experience using automated sprinkler systems \((r = -0.227, p = 0.005)\).

**Irrigation technology interrelationships.** We found a moderate positive correlation between the precipitation rate of fixed head zones and distribution uniformity of fixed head zones \((r = 0.452, p = 0.000)\). In a further exploration of size influences, we found stronger negative correlations between plant and irrigation technology variables than we did between the site and irrigation technology variables. Lots with more square feet of trees and shrubs had lower distribution uniformity on rotor zones \((r = -0.427, p = 0.001)\) and lots with more square feet of turf had lower pressure on fixed head zones \((r = -0.306, p = 0.007)\). Distribution uniformity and pressure are affected by the number and size of the systems’ zones. Sprinkler systems with a greater number of zones had lower pressure \((r = -0.289, p = 0.005)\). Some zones may have inappropriate sprinkler head
spacing, poorly adjusted heads, or inappropriate operating pressure, which also contribute to poor distribution uniformity. The sprinkler system controller is the primary irrigation tool at the intersection of technology and behavior. We found that participants used digital controllers on the automatic start setting throughout the season more often than participants with mechanical controllers who tended to start their systems manually ($\chi^2 = 12.344, p = .015$). Participants with digital or combination controllers also adjusted their water schedule settings more often than participants using mechanical controllers or than participants using manual systems varied their zone run times ($\chi^2 = 25.099, p = .000$).

Since digital and combination controllers provide more options for fine-tuning water schedule settings in contrast to mechanical controllers, this result can be seen to confirm the effect of the greater scheduling flexibility newer controllers provide.

**Behavior interrelationships.** We explored the relationships among the behavior variables and found that of the 141 participants who reported they were practicing conservation, 36% (n=51) stated that the drought or water scarcity had motivated them to try to use less water ($\chi^2 = 5.40$, Fisher’s exact test = .021). In contrast, for the 104 participants who reported they were motivated by the cost of water or motivated by altruistic interests, we did not find a statistically significant relationship with the adoption of conservation practices. However, 51% of participants (n=104) who reported they were motivated by the cost of water had at least some idea what they were paying for water (n=53) and this relationship was statistically significant ($\chi^2 = 10.969, p = .004$). Generally, participants who are concerned about water costs know what they are paying for water.
Water Use Profiles

The relationships among and between the domain variables indicate that various interactions between site, plants, irrigation technology and human behavior can enhance or constrain acceptable water use. Each site has a unique profile of characteristics that makes water use a contextualized activity. We are particularly interested in identifying what characteristics locations with efficient water use have in common and how those are distinguished from the common characteristics of locations with unnecessary water use (the ends of our categorized spectrum). We identified cases with the same resident throughout the study period and conducted within-case analysis of the survey (behavior) data along with the water check data (plant material, site, and irrigation technology metrics). We identified characteristics that were common to the majority of cases in each water use category to create the profiles depicted in Table 2-5. It is likely that the domain interactions will elucidate a causal process that differentiates efficient water use from unnecessary water use. Due to the small number of cases, we do not consider these profiles to be definitive, rather they should only be considered illustrative.

Efficient water users were located throughout the city and tended to have larger lots ($Mdn = .13 \text{ ha}$) with more landscaped area and a greater portion planted in trees and shrubs. Their sprinkler systems had lower precipitation rates and at least a third of their system was comprised of rotor sprinkler head zones. Distribution uniformity varied
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Efficient Water Use (n=24)</th>
<th>Unnecessary Water Use (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Hillcrest Neighborhood 33%</td>
<td>Hillcrest Neighborhood 64%</td>
</tr>
<tr>
<td></td>
<td>Cliffside Neighborhood 21</td>
<td>Cliffside Neighborhood 21</td>
</tr>
<tr>
<td></td>
<td>Island Neighborhood 21</td>
<td>Island Neighborhood 7</td>
</tr>
<tr>
<td></td>
<td>Adams Neighborhood 4</td>
<td>Adams Neighborhood 7</td>
</tr>
<tr>
<td></td>
<td>West of Main Street 21</td>
<td></td>
</tr>
<tr>
<td>Lot size a</td>
<td>.13 ha (.06-.69)</td>
<td>.11 ha (.06-.14)</td>
</tr>
<tr>
<td><strong>Plants:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaped area (% of lot) a</td>
<td>69% (21-91)</td>
<td>55% (31-65)</td>
</tr>
<tr>
<td>Trees and shrubs (% of landscaped area) a</td>
<td>31% (8-57)</td>
<td>26% (10-57)</td>
</tr>
<tr>
<td><strong>Irrigation Technology:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation rate a</td>
<td>2.51 cm/hr (1.12-5.13)</td>
<td>4.39 cm/hr (3.18-5.70)</td>
</tr>
<tr>
<td>Sprinkler zones head type</td>
<td>≥ 33% of system Rotors</td>
<td>≥ 57% of system Fixed sprays</td>
</tr>
<tr>
<td>Distribution uniformity b</td>
<td>Varies – 29-86%</td>
<td>Varies – 40-79%</td>
</tr>
<tr>
<td></td>
<td>26% of cases rated ≥ Good</td>
<td>57% of cases rated ≥ Good</td>
</tr>
<tr>
<td>Pressure ac</td>
<td>317 kPa (103-841)</td>
<td>241 kPa (138-482)</td>
</tr>
<tr>
<td>Sprinkler system leaks</td>
<td>No leaks – 88% of cases</td>
<td>Leaks – 71% of cases</td>
</tr>
<tr>
<td>Sprinkler system maintenance</td>
<td>Good ≤ 1 Malfunction/Zone</td>
<td>Poor ≥ 1.8 Malfunction/Zone</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Efficient Water Use (n=24)</td>
<td>Unnecessary Water Use (n=14)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Sprinkler zones water both turf and shrubs</td>
<td>Yes, 58% of cases</td>
<td>Yes, 86% of cases</td>
</tr>
<tr>
<td>Controller type&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Manual or Digital</td>
<td>Mechanical or Combo</td>
</tr>
</tbody>
</table>

**Behavior:**

- Motivations to conserve<sup>e</sup>
  - Altruism: 67% Efficient Water Use, 50% Unnecessary Water Use
  - Cost: 42 Efficient Water Use, 57 Unnecessary Water Use

- Use controller on automatic start<sup>f</sup>
  - No: 19% Efficient Water Use, 9% Unnecessary Water Use
  - Seasonally: 11% Efficient Water Use, 18% Unnecessary Water Use
  - Yes: 70% Efficient Water Use, 73% Unnecessary Water Use

- Participant has adopted general conservation recommendations and believe they are conserving
  - Yes, 67% of cases Efficient Water Use, 71% of cases Unnecessary Water Use

*Note.* Cases profiled are locations with the same resident throughout the study period 2002-2006.

<sup>a</sup>Median value and range are reported. <sup>b</sup>Good or better rating ≥ 65% for rotors and ≥ 55% for fixed spray heads. <sup>c</sup>Functional operating pressure for rotors ranges from 345 to 550kPa (n=15) and for fixed spray heads 140 to 205 kPa (n=9). <sup>d</sup>All cases analyzed due to missing data (n=51). See Table 2-3 for statistics. <sup>e</sup>More than one response possible. <sup>f</sup>All cases analyzed due to missing data (n=60).

widely, but only 26% of cases (n=23) were rated *good* or better (DU ≥ 55%). Fewer of their systems, than of those locations with unnecessary water use, water both turf and shrub beds, i.e., more of their systems were designed to water these zones separately. Systems were generally well maintained and leak free. All locations with manual systems
(no controller) in the study population fell within the justifiable water use category and, of those, 21% fell within the efficient water use category. In addition, 59% of all locations with digital controllers fell within the justifiable water use category and, of those, 11% fell within the efficient water use category. More participants with controllers who chose not to use the automatic start setting were also in the efficient category. Fewer of the efficient water users reported they had adopted conservation practices but, of those who did, altruistic motivations were cited most often.

Unnecessary water users were located primarily in the Hillcrest and Cliffside neighborhoods. The city identified these areas as having the highest water use in the city (M. Nielson, personal communication, September 21, 2006). These cases had smaller lots ($Mdn = .11$ ha) with less landscaped area and fewer trees and shrubs. Their sprinkler systems had high precipitation rates and nearly all of their systems were comprised of fixed spray head zones. Distribution uniformity varied widely, but 57% of all cases ($n=16$) were rated good or better ($DU \geq 65\%$). Most of their zones watered both turf and shrub beds. Systems were poorly maintained and most cases had undetected leaks for some length of time. In terms of controller type, 63% of all locations with mechanical controllers fell within the unjustifiable water use category and, of those, 27% fell in the unnecessary water use category (not reported in table). In addition, 53% of all combination controllers fell within the unjustifiable water use category and, of those, 64% fell in the unnecessary water use category. Most participants in the unnecessary water use category used their controller on the automatic start setting throughout the watering season. Interestingly, most of the unnecessary water users reported they had
adopted conservation practices and cited the cost of water as their main motivation. Another factor that influenced the categorization of one site as unnecessary was a long-term indoor leak.

**Water Use Case Studies**

Table 2-6 presents a summary of selected case studies based on within-case observations and illustrates how domain relationships work together as a system to enhance or constrain participants’ ability to use water efficiently.

Case 1 (efficient) is located on the western edge of town, which has a higher water table than other areas of the city. The lot is large (0.28 ha) with 78% of the area landscaped and 27% of the landscaped area planted in trees and shrubs. The sprinkler system has a low precipitation rate (1.5 cm/hr) and distribution uniformity (43%), and 6 zones have rotor heads and 3 have fixed spray heads. The zones are designed to water turf and shrub beds separately. The system is well maintained and leak free. The participant is actively working to reduce his water consumption. He has taken out plants and converted that area to a mulched non-water use space and plans to plant trees in another area that will be watered with bubbler heads. He had conducted his own catch-cup test and based his water schedule on the results. During the baseline period, the participant used about half the estimated water needed by the plants in the landscape (baseline index = 0.45). This case represents efficiency gained from large lot size, use of trees and shrubs, and good sprinkler system design combined with active management, maintenance, and effort to reduce water use. This participant is attuned to the natural site characteristics, the potential to overwater if the sprinkler system precipitation rate is not
used to create his water schedule, and the higher water need of turf. He has effectively employed his knowledge and skills.

Case 2 (efficient) is located in the northeast section of town between Green and Logan Canyons. The area experiences morning and afternoon canyon winds. This lot is moderately sized (0.09 ha) with 65% of the lot landscaped and 35% of the landscaped area planted in trees and shrubs. The sprinkler system has a moderate precipitation rate (2.51 cm/hr) and high distribution uniformity (70%). The system is very well maintained and leak free. The zones are designed to water turf and shrub beds separately. Five zones are fixed spray heads watering shrubs with moderate to low water need and 2 zones are rotor heads watering the turf. The participant set a goal of watering no more than 2 times a week throughout the watering season. He accomplishes this goal through supplementing the system by spot watering stressed turf with a hose. During the baseline period, the participant used 59% of the estimated water needed by the plants in the landscape according to our generalized procedures for determining the water use index and was therefore ranked as being very efficient. This case represents careful plant selection and good sprinkler system design initially combined with subsequent maintenance and behavioral goal setting that drives efforts to conserve water. This participant is fully attuned to the affordances of his landscape and has demonstrated his knowledge and skills by optimizing the positive utility of his landscape.

The two efficient cases studies presented above characterize two versions of best case scenarios. We also discovered an alternate path to efficient water use that is counter-intuitive.
### Table 2-6

**Profiles of Water Use Case Studies**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Efficient</th>
<th></th>
<th></th>
<th>Unnecessary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 3</td>
<td>Case 4</td>
<td>Case 5</td>
</tr>
<tr>
<td><strong>Baseline Index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>West of Main St.</td>
<td>Hillcrest</td>
<td>Hillcrest</td>
<td>Hillcrest</td>
<td>Cliffside</td>
</tr>
<tr>
<td>Lot size (ha)</td>
<td>.28</td>
<td>.09</td>
<td>.09</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Plants:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscaped area (% of lot)</td>
<td>78%</td>
<td>65%</td>
<td>56%</td>
<td>62%</td>
<td>54%</td>
</tr>
<tr>
<td>Trees &amp; shrubs (% of landscaped area)</td>
<td>27%</td>
<td>35%</td>
<td>40%</td>
<td>16%</td>
<td>25%</td>
</tr>
<tr>
<td>Irrigation Technology:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation rate (cm/hr)</td>
<td>1.5</td>
<td>2.51</td>
<td>--</td>
<td>5.33</td>
<td>3.51</td>
</tr>
<tr>
<td>Sprinkler zones head type</td>
<td>6 Rotor 3 Fixed</td>
<td>2 Rotor 6 Fixed</td>
<td>5 Fixed 3 Mixed</td>
<td>10 Fixed 1 Rotor</td>
<td>5 Fixed</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Efficient</td>
<td>Unnecessary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----------</td>
<td>-------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 3</td>
<td>Case 4</td>
<td>Case 5</td>
</tr>
<tr>
<td>Distribution uniformity</td>
<td>43%</td>
<td>70%</td>
<td>--</td>
<td>66%</td>
<td>77%</td>
</tr>
<tr>
<td>Pressure operating range for head type</td>
<td>High</td>
<td>OK</td>
<td>High</td>
<td>High</td>
<td>--</td>
</tr>
<tr>
<td>Sprinkler system leaks</td>
<td>None</td>
<td>None</td>
<td>2 Leaks &amp; many missing heads</td>
<td>1 Leak</td>
<td>4 Leaks</td>
</tr>
<tr>
<td>Sprinkler system maintenance -</td>
<td>0.7</td>
<td>0.38</td>
<td>1.75</td>
<td>1.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Malfunctions/Zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinkler zones water both turf &amp;</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>shrubs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller type</td>
<td>Unknown</td>
<td>Combo</td>
<td>Combo</td>
<td>Combo</td>
<td>Combo</td>
</tr>
</tbody>
</table>

**Behavior:**

- Uses controller on automatic start: Yes, Yes, goal water, No, Yes
- 2x/week or less: Yes, No, Yes, Yes
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Efficient</th>
<th>Unnecessary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
<tr>
<td>Participant has adopted general conservation recommendations &amp; believe they are conserving</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Main motivation to conserve</td>
<td>Cost &amp; lack of water</td>
<td>Limited resource, setting good example</td>
</tr>
</tbody>
</table>

*a*Catch can test conducted on first listed head type. *b*Missing data. *c*Not applicable to zones with mixed head types.
Case 3 (efficient) is located in the northeast section of town. This lot is moderately sized (0.09 ha) with 56% of the lot landscaped and 40% of the landscaped area planted in trees and shrubs. The sprinkler system was in such poor repair we were unable to conduct a catch-cup test. The participant was forced to start her sprinkler system manually, because the runoff from leaks required careful observation to prevent damage; e.g. flooding a window well. This participant was able to achieve a low baseline index value because personal time constraints and sprinkler system condition forced her to manually start her system, water fewer days per week for shorter periods of time, and visually monitor the system as it ran.

Case 4 (unnecessary) is located in the northeast section of town (Hillcrest neighborhood). This lot is moderately sized (0.12 ha) with 62% of the lot landscaped and 16% of the landscaped area planted in trees and shrubs. The landscape is dominated by turf. The sprinkler system has a high precipitation rate (5.33 cm/hr) and high distribution uniformity (66%). The system is poorly maintained and leaky. In several zones, a few sprinkler heads are tilted, blocked by foliage, and/or clogged. One of five shrub zones waters both turf and shrubs; however, the 4 exclusive shrub zones are watered the same as the lawn. The participant reports he wanted to “have a nice yard in the most cost effective way” but also wanted to be a “good citizen” in his resources use. However, his baseline water use index is nearly 3.5 times the water needed by the landscape. The water schedule was adopted through trial and error, the condition of the lawn, and the desire to have a nice yard. This case represents overwatering due to a poorly maintained system and improper water management. The high precipitation rate and distribution uniformity
enables the uniform rapid application of water. In addition, the incorrect water schedule (too long run time) results in gross overwatering. This participant has incorrectly evaluated the lawn’s water need and does not know or perceive the differing water need for the shrub beds.

Case 5 (unnecessary) is located in the Cliffside neighborhood. The area is a bench at the mouth of Dry Canyon that was created by alluvial deposits in the ancient Lake Bonneville. The shallow top soil is layered upon a gravelly base that quickly drains. This lot is moderately sized (0.12 ha) with 54% of the lot landscaped and 25% of the landscaped area planted in trees and shrubs. Eight of the 13 sprinkler zones are comprised of both rotors and fixed spray heads creating double coverage. These mixed head zones have a lower precipitation rate (1.85 cm/hr) and distribution uniformity (57%), while the fixed spray head zones have a moderate precipitation rate (3.51 cm/hr) and high distribution uniformity (77%). All zones water both turf and shrub beds. The system is poorly maintained and has several leaks. In many zones, the sprinkler heads are tilted, blocked by foliage, and/or clogged. In several places, the sprinkler head spray patterns do not match the area watered resulting in overspray throughout the yard. The participants report they are concerned about water costs and want to “do their part” (to conserve water) due to the drought. However, their baseline water use index is nearly 3 times the water needed by their landscape. The participants installed their own landscaping and sprinkler system. They continue to spend a lot of time in their yard creating a “homey” outdoor atmosphere that is green and colorful. They are always working on a yard project; for example, creating nooks with folk statuary, installing paver paths and a patio.
Their trees have matured, the backyard has become shady, and the landscaping has changed since building their home and originally installing the sprinkler system. The participants reported several watering issues such as dry areas they cannot adequately water and other areas growing mushrooms and moss in the shady backyard. As a result, they are constantly rearranging the sprinkler system and adding fixed spray heads to rotor zones to cover dry spots. During the hottest part of the summer, they water every day. This case represents overwatering due to the participants’ incorrect assessment of watering issues and inappropriate actions to address them. They water at night and were unaware of 4 leaks in their system causing the mushroom and moss growth at the location of the leaks while reducing pressure elsewhere in the sprinkler zone causing the dry spots. Repairing the leaks would alleviate the dry spots. By adding fixed spray heads to the rotor zones, the participant is compounding distribution uniformity and pressure regulation problems. Each head type has a unique pressure operating range and consequently neither head type pressure is calibrated properly. The participants also watered too frequently for short periods. These participants did not have the knowledge and skills necessary to correctly assess technical and ecological cues on their landscape.

Discussion

Based on our findings, we developed our conceptual framework for better understanding the complex contextualized systems thinking required to use water efficiently in maintaining a residential landscape. Urban landscape water use efficiency results from contextualized system thinking that connects decisions and actions in the
four domains of a landscape system: landscape design appropriate to site characteristics; plant selection based on water need appropriate to local climatic conditions; irrigation system design, maintenance, and operation appropriate to the needs of different types of plant material; and active and perceptive water management on the part of individuals.

The objective of landscape water checks and water budgets is to provide the individualized, site-specific information necessary to assess the interactions of site characteristics, plant material, irrigation technology, and behavioral choices to empower people to achieve water conservation goals.

When comparing the general profile in Table 2-5 to the individual case studies in Table 2-6, it is clear that a single variable does not ensure efficiency. There are multiple paths to achieve efficiency and the choices and conditions in each domain influences the effort required to achieve water use efficiency. It is relatively easy to water efficiently when site characteristics guide plant selection, plants are hydro-zoned and sprinkler systems are designed and correctly scheduled to water different plant types. The only on-going effort required is routine sprinkler system maintenance and adhering to landscape hydro-zones when additional plants are incorporated. However, when plant material is not grouped according to water requirements and sprinkler systems do not use optimal design principles, then the on-going level of the household’s effort required to use water efficiently increases. In order to be efficient under these conditions, the household would need to hand water plants with different water needs, schedule sprinkler zones that water both turf and shrub beds for the lower water requirement of shrubs, and use supplemental hand watering on turf areas in mixed sprinkler zones. Poorly designed sprinkler systems
may save installation costs but, over the long-term, they require the water user to invest additional time continually and consistently to achieve water use efficiency. This defeats the sprinkler system’s secondary affordance to save time. For water users who are more concerned with the value of their time than water costs, efficiency in their consumption of low-priced water may be a negligible consideration. In contrast, water users who self-identify as conservationists experience cognitive dissonance when they are not striving to use water efficiently. They are more likely to invest the time and/or expense necessary to become more efficient. Given the impact well-designed sprinkler systems and landscapes have on a cities’ future water demand, cities should consider adopting ordinances requiring minimum standards for automated irrigation systems and water-wise landscaping ordinances.

Water schedules are based on irrigation system measurements, seasonal weather variation, soil type, and plant water requirements. Each site has unique combinations of characteristics that constrain or enhance water conservation efforts. Participants were generally comfortable programming their controllers, but did not know their system’s precipitation rate or what an appropriate water schedule would be. They were attempting to respond to the correct cues (weather and landscape assessments) and adjusted their water schedule accordingly. The mechanical scheduling constraints of older controllers also limited the user’s ability to fine-tune their water schedule. The majority (70%) of all participants (n=202) had adopted a conservation practice and believed they were conserving. But of those, 33% of the participants were applying twice as much water as was needed and another 13% were applying more than three times what was needed by
their landscape. Since the participant water schedules were grossly incorrect, the adjustments made were inconsequential. Participants were motivated and had attempted to implement their goals, but their lack of information or skill thwarted their efforts and resulted in unintentional overwatering.

The statistical analysis, profiles of efficient and unnecessary water use, and individual case studies illustrate the interplay of site, plant material, irrigation technology, and behavior to reveal the complex systems thinking required to use water effectively in an a residential landscape system. We propose these characteristics are likely candidates for system indicators and their values could be used to evaluate and adjust landscape maintenance practices. The conceptual framework provides a means for teaching participant’s to think “systematically” about how the pieces fit together. In Table 2-6, the variable values are suggestive and efficient water use values could be used to create benchmark goals to aid homeowners’ efforts to achieve efficient water use. In contrast, the variable values of unnecessary water use could be used to diagnose problems and focus homeowners’ conservation efforts on those items that will create the greatest water savings. In this baseline characterization of our participants water use and their landscapes, we were not able to determine how many efficiency benchmarks need to be met in order to achieve efficient water use or how many unnecessary variable values need to be exceeded to create the greatest water overuse. Further research is needed using a stratified, random sample research design in order to generalize these results.

The design of landscape water conservation programs to convey relevant and useful technical information is critical. General conservation guidelines do not address
site specific issues. Cities should design conservation programs to address variation within the residential landscape system to provide residents with the information and problem-solving skills necessary to water efficiently.

Landscape water checks promote water use efficiency and have the potential to save cities significant amounts of water. A landscape water check takes into account an individual’s water use context and can provide specific information regarding how the site characteristics, plant material, irrigation technology, and watering practices function together as a system. This understanding can help the water user to realize the importance of their up-front investments and appreciate what it means in terms of water use over time. The best conservation programs teach water users the long-term skills necessary to assess the technical and ecological cues of the system domains that enable them to achieve water conservation goals under varying conditions over time. Landscape water conservation is not a one-time endeavor; rather it is an on-going practice and process of contextualized systems thinking applied to urban landscapes.

References


http://ecologyandsociety.org/bol10/iss1/art29/


CHAPTER 3
EFFECTIVENESS OF AN URBAN LANDSCAPE WATER CHECK PROGRAM

Abstract

We utilized a quasi-experimental research design to test the effectiveness of landscape water checks as a conservation tool. Our overall objective is to help find better ways to evaluate landscape water use and more effectively target water conservation programs to locations with capacity to conserve. We report on research conducted in connection with delivery of a city-sponsored but university-delivered landscape water check program. We report on several assessment and monitoring tools we developed. In analyzing change in participants’ water use and working to eliminate explanations other than the water check intervention, we found that the factors influencing landscape water use tend to be highly contextualized and that the water conservation intervention itself needed to be analyzed. We found that the majority of participants who adopted the water check recommendations successfully reduced their water use and that water check program design needs to accommodate participants’ differing knowledge and skill levels. We conclude that landscape water checks have the potential to provide people with the information and problem-solving skills necessary to appropriately maintain residential landscapes.

2 This chapter was co-authored by Diana T. Glenn, Joanna Endter-Wada, Roger Kjelgren, and Christopher Neale. Prepared for submission to the Journal of Environmental Management.
1. Introduction

One of the greatest challenges in conducting water conservation research is determining how to assess the effectiveness of a water conservation program. The water conservation field does not have common assessment tools, making it difficult to compare results from programs in different cities (e.g. Jorgensen et al., 2009; Syme et al., 2000; USEPA, 2002). The field has relied on comparisons using measures like gallons per capita per day (gpcd), which fails to fully capture the context and conservation challenges unique to urban residential landscapes that affect water use (Endter-Wada et al., 2008; Gregory and DiLeo, 2003). For cities, these challenges include aging infrastructure (leak control), differing billing methods/periods, mobile and growing populations, and the level of public support for conservation. With cities’ limited conservation budgets, it is important to understand when and where to focus conservation efforts (Kilgren et al., 2010; Lappe' and Lappe', 2002 pp. 280-281). For residents, these challenges include maintaining and effectively using static sprinkler systems in dynamic, evolving residential landscapes (see Chapter 2), developing conservation competency and problem solving skills (Baron and Misovich, 1993; Coral-Verdugo, 2002; Hormuth, 1999; Kurz, 2002; Kurz et al., 2005) that enable residents to assess what to do and how to do it, and assessing the effectiveness of conservation actions. For instance, poor billing information can impede the timeliness of information feedback on residents’ water use, while their own time and financial constraints can limit their best intentions.

Cities need to meet municipal water demand and plan for the future in a socially equitable manner that assures residents their water use is assessed fairly, and they need
good tools to help them identify and address inefficient water use. What constitutes appropriate water use? What constitutes water conservation success? How do we describe and measure these two phenomena?

The purpose of this chapter is to report on research conducted in connection with delivery of a city-sponsored but university-delivered landscape water conservation program. We utilized a quasi-experimental research design to test both the effectiveness of landscape water checks as a conservation tool and different participant household recruitment methods. We developed several assessment and monitoring tools to help us analyze our results. In analyzing change in participants’ water use and working to eliminate explanations other than the water check intervention, we found that the factors influencing landscape water use tend to be highly contextualized (see Chapter 2), which confirmed previous findings (Endter-Wada et al., 2008; Kilgren et al., 2010), and that the water conservation intervention itself needed to be analyzed. We report on the analytic tools we developed and our research findings. Our overall objective is to help find better ways to evaluate landscape water use and more effectively target water conservation programs to locations with capacity to conserve.

2. Methodologies

This section describes our data gathering methodologies and our development of several assessment and monitoring methodologies.
2.1. Data Gathering Methodologies

We created a unique data set that integrates information from residential landscapes, water billing data, climate, and survey data.

2.1.1. Sample of Participant Households

In 2004, Utah’s sixth year of drought, we offered free landscape water checks to all households in Logan, Utah. The free service was publicized in newspaper articles, radio programs, posters in public places, and flyers delivered to residents’ doorsteps. Our advertising material stated "landscape specialists and USU researchers" would conduct the water check. The water check included a detailed evaluation of households’ sprinkler systems and landscapes, site-specific seasonally adjusted watering schedules, and conservation recommendations. Landscape water checks and interviews were completed for 148 self-selected volunteers. Generally, volunteers are those people who are most interested in an issue and may already exhibit certain levels of knowledge and skill, so this delivery method contained an inherent self-selection bias (Brady and Collier, 2004; Hartman, 1988).

During the summer of 2005, we selected a target sample of above-average water users and recruited them to participate in the water check program. We selected the sample from a preliminary analysis of Logan City water billing records, prior to construction of a water use index for more detailed analytic rankings and comparisons (more below). Above-average water users were identified by normalizing water usage for lot size so that all lots could be compared. Then landscape water use was estimated by calculating the difference between winter and summer billing periods. The difference was
assumed to be landscape water use. Households were characterized as above-average water users if they met both of the following thresholds for irrigation season water use in 2004 and in one or both of the two previous years (2002 and 2003): 1) 1150 or more gallons of water per day (gross); and, 2) 5000 or more gallons per acre per day (normalized). The total sample included 420 households.

All households meeting these criteria received a letter identifying their property as having above-average water use and offering a free landscape water check. For people who believed they were conserving water or were striving to use water efficiently, the letter could have acted as a cognitive dissonance trigger (Dickerson et al., 1992; Festinger 1957; O'Keefe, 2002). Households were given a phone number they could call to schedule the free service. Some people did call and volunteer to participate in response to the letter. In addition, households with listed phone numbers were called, asked if they had received the letter and if they would be willing to participate in the water check program. At the time of the phone call, some information was obtained in a screening survey and, if the person chose not to participate, they were asked to offer reasons for their decision (see Appendix A). The 2005 screening survey was used to ensure participants were single family households using municipal metered water on their landscape (as opposed to irrigation company water) and to identify the person responsible for watering the landscape. For the 2005 study year, 105 participants were recruited into the study and had water checks performed.
2.1.2. Landscape Water Check

A landscape water check is essentially a water use “audit” for landscape irrigation systems that assesses system design, maintenance, and operational (time-clock) efficiency (given soil type and plant material) and then provides site-specific information to participants on how water use efficiency can be improved. The services offered by the landscape water check in 2004 and 2005 were identical, although the water check staff changed.

The water check started with program staff taking on-the-ground measurements. The controller settings were noted and each zone of the sprinkler system was evaluated visually for operating or design malfunctions; e.g., leaks and zones similarly watering plants with different water requirements. A catch can test was conducted on a zone or zones with the best maintenance and function to determine the precipitation rate, which helps determine the amount of watering time needed. The catch cup test also measures distribution uniformity (lower quarter method) – how evenly the system applies water across the landscape (Irrigation Association, 2005). The dynamic water pressure of the system was tested using a pressure gauge attached to an individual sprinkler head. A soil feel test was conducted to identify soil type and assess its water-holding capacity. Landscape plant type and quality was assessed visually and classified by plant water requirements.

Using the information gathered on irrigation system precipitation rate, soil type, and plant water need, water check staff created a site-specific seasonally-adjusted irrigation schedule based on local historical evapotranspiration (ET$_o$, 2.99 mm/day).
Participants were given this schedule, along with a list of general conservation recommendations that addressed soil and plant health and a list of sprinkler system maintenance and design issues where specific problems the water check staff identified were check marked. The water checker reviewed the utility and function of each recommendation with the homeowners, answered their questions, and encouraged them to adopt the recommendations and the irrigation schedule. The emphasis of the water check was to convince participants to adopt the irrigation schedule and recommendations suggested by the water check personnel (see Appendix B). The water check was a one-time intervention.

2.1.3. Interview and Survey Data

At the time of the water check, pre-intervention interviews were conducted with the persons responsible for watering the landscape to establish baseline watering habits, conservation attitudes, conservation techniques already adopted, and their understanding of water costs and billing information. The interviews were conducted while the water check personnel inspected the landscape. At the end of the growing season, post-intervention interviews were conducted utilizing a set of open-ended questions. The purpose of the post-interviews was to discover what recommendations people adopted, problems they encountered, how they dealt with challenges in adopting recommendations, and their assessment of the water check program in aiding them to conserve water. The interviews were identical in 2004 and 2005 except for a Likert-scale question included in the 2005 interview to evaluate the acceptability of various water
conservation approaches and an open-ended question investigating the household decision-making process regarding adoption of conservation practices.

2.1.4. Remote Sensing/Geographic Information Data

During subsequent analyses, remote sensing data were used to create water budgets for each participants’ landscape. Airborne multispectral images of the city were obtained using the Utah State University airborne digital system (modified from Neale and Crowther, 1994) in the spring of 2002 before trees had leafed out and later in the summer after trees had fully developed canopies. An additional summer flight in 2004 over the entire city of Logan provided more recent imagery for this study. The spectral band images were registered into 3-band images with a pixel resolution of 1 m and rectified to an ortho-photo map base.

The geo-rectified image forms a large mosaic covering the city. The imagery was calibrated for reflectance. The mosaic was classified using a supervised signature extraction and maximum likelihood method. In order to capture variability, 140 classes were obtained and recoded into 9 final classes: grass, sparse grass, stressed grass, trees and shrubs, bare soil, concrete and roofs, asphalt and roofs, shadows, and water. The comparison of the spring images with the summer images enabled greater accuracy in estimating the amount of turf under the tree canopy (Farag, 2003; Farag et al., Unpublished results). The imagery was integrated with geographic information system data on parcel boundaries and building footprints obtained from Logan City. We recognize the trade-off between using parcel boundaries, which do not include parking
strips that the city requires residents to maintain, and on the ground measurements, which proved to be less accurate than parcel boundaries and GIS data. Corner lots have parking strip on two sides and may have more landscaped area in the parking strip. A 10% random sample of all cases (N=249) was drawn and the parking strip area manually measured on the digital imagery in ArcGIS. The analysis revealed a similar percentage of landscaped area within the parking strip when comparing corner lots (0 - 13.6%, n=10) to inside the block lots (0.44 - 13.4%, n=19) and did not affect the categorical indexing of these properties except in one instance. The width of parking strips varies throughout the city (.91 – 4.86 m). We also discovered that the 1 m resolution is quite coarse when looking at small residential lots (< .20 acres or .08 hectares) and resulted in less accurate cover classifications due to edge effects created by the greater proportion of edges to total area.

2.1.5. Landscape Water Budgets

Landscape water budgets, representing how much water landscapes needed given plant type, were created for each participant’s property for the years 2002 through 2007 based on the seasonal average ET\textsubscript{o} for each year and the proportion of the landscaped area represented by turf, trees and/or shrubs, and turf under trees. The water budgets were compared with each household’s actual water consumption obtained from analysis of Logan City billing data. The watering season was defined as April 1 through October 31 for analytic purposes. However, in providing water schedules to participants, water check staff discouraged use of a regular schedule during April and October, and encouraged adjustments over the course of the season in recognition of changes in plant
water needs over the growing season. For the beginning and end of the irrigation season, participants were encouraged to water on an “as needed” basis because spring and fall weather can be quite variable. Defining a longer watering season in the analysis allowed us to assess outdoor water use early and late in the season, when excess watering may occur.

It should be noted that the recommended water schedule is based upon local historical ET₀ for a 20-year period (2.99 mm/day), while the water budget is based upon actual seasonal ET₀ for each study year (3.75 – 4.64 mm/day). Thus, the water schedule recommended participants use less water than the water budget used to calculate the index values. Our evaluation of participants’ water use is more generous than the recommended water schedule, which means our analysis of water use patterns is conservative to the benefit of water users.

Outdoor water use was estimated by summing water consumption April 1 through October 31 and subtracting indoor water use, which was estimated at 70 gal/person/day (Mayer et al., 1999) and calculated for the number of people in the household at the time of the water check as determined through survey data.

2.2. Assessment and Monitoring Methodologies

We developed several analytic tools that we suggest can provide the water conservation field with common measures for assessing landscape water use and monitoring conservation program effectiveness. These tools include: 1) the Urban Landscape Water Index, designed to evaluate water use and more effectively target conservation programs to locations with capacity to conserve; 2) the Participant
Conservation Outcomes Assessment Tool, designed to evaluate participant response to a water conservation program; and 3) the Conservation Intervention Evaluation Tool, designed to assess the quality of the intervention response and identify participants who may need more assistance. The creation of the Participant Conservation Outcomes Assessment Tool and Conservation Intervention Evaluation Tool involved creating an outcome scoring scheme, characterizations of a household’s baseline and post-water-check landscape water use, and evaluations of the water check’s effectiveness.

2.2.1. Urban Landscape Water Index

The Urban Landscape Water Index (ULWI) is based on a standard of ecologically appropriate water use - plant water need. The index is the ratio of outdoor water used (determined through the water billing data analysis) divided by plant water need (estimated by each locations’ landscape water budget). The index provides an easily understandable metric of the amount of landscape water applied relative to plant water need; e.g., an index of 2.5 means a household is using 2.5 times the water needed by the plants on their landscape. The index was conceived by Endter-Wada and grew out of past research by Endter-Wada, Kjelgren and Neale (Endter-Wada et al., 2008) and Endter-Wada and Kjelgren (Kilgren et al., 2010) where they utilized a threshold approach.

The ULWI establishes a site-specific benchmark of landscape water use and allows us to assess landscape water conservation potential by quantifying (in)efficiency of a particular household regardless of lot size. The index is a broadly useful tool for initial evaluation of household water use citywide and allows cities to set goals for their water conservation programs and target them appropriately. The index also allows
residents to evaluate their own water use and informs their decisions regarding modification of their residential landscape system (site, plants, irrigation technology, and behavior; see Chapter 2).

For our analyses here, a baseline index was calculated by averaging the annual index for the two years prior to the water check, and a response index was calculated by averaging the annual index for two years after the water check. The baseline index characterizes water use prior to the water check and establishes a baseline from which to measure post-water check water use characterized by the response index. The index values produced continuous variables that were used for descriptive statistics and are the basis of two monitoring tools: Participant Conservation Outcomes Assessment Tool and a Conservation Intervention Evaluation Tool.

We also created categorical baseline and response indices by comparing our range of baseline index values with the Irrigation Association’s standards of appropriate water use measured in mm/day for climates characterized as warm-dry to cool-dry (Irrigation Association, 2005, p 1-8). Logan experiences warm-to-hot days and cool nights during most of the irrigation season due to its location in a mountainous, semiarid environment at an elevation of 4,534 feet. Water use in mm/day for the majority of households in each of our index categories fell within the corresponding Irrigation Association’s standard ranges. Four water use categories defined for our study were (Table 3-1): “efficient” (ULWI ≤ 1); “acceptable” (1 < ULWI ≤ 2); “inefficient” (2 < ULWI ≤ 3); and, “unnecessary” (3 < ULWI). The mean baseline water use in mm for cases falling into
Table 3-1

Category Definitions for Baseline\textsuperscript{a} Urban Landscape Water Index (UWLI)

<table>
<thead>
<tr>
<th>Index Category</th>
<th>Mean Water Use\textsuperscript{b} (mm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Water Used/Water Needed)</td>
<td></td>
</tr>
<tr>
<td>Justifiable Water Use:</td>
<td></td>
</tr>
<tr>
<td>Efficient</td>
<td>ULWI ≤ 1</td>
</tr>
<tr>
<td>Acceptable</td>
<td>1 &lt; ULWI ≤ 2</td>
</tr>
<tr>
<td>Unjustifiable Water Use:</td>
<td></td>
</tr>
<tr>
<td>Inefficient</td>
<td>2 &lt; ULWI ≤ 3</td>
</tr>
<tr>
<td>Unnecessary</td>
<td>3 &lt; ULWI</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Baseline values are the average of 2 years prior to the water check
\textsuperscript{b} Compared to 2004 baseline ET\textsubscript{o} of 4.56 mm/day and 2005 baseline ET\textsubscript{o} of 4.28 mm/day
\textsuperscript{c} 2 outlier values ≥ 30 mm/day excluded

these four categories is shown in the third column of Table 3-1 and can be compared to the 2004 baseline ET\textsubscript{o} of 4.56 mm/day and 2005 baseline ET\textsubscript{o} of 4.28 mm/day. The “efficient” and “acceptable” categories are considered justifiable water use while the “inefficient” and “unnecessary” water use categories are considered unjustifiable.

2.2.2. Participant Conservation Outcomes Assessment Tool

The Participant Conservation Outcomes Assessment Tool is based upon plotting the baseline index against the response index and the outcome score is used to categorize the results. We created the outcome-scoring variable by establishing 12 definitions that
characterize a household's water use and the direction and extent of the changes in their water use after the water check (Table 3-2). The outcome score consists of a letter indicating the type of change (or no change) and two digits indicating the extent of change. For each case, we compared the baseline index to the response index and assigned a score. A case with a baseline index of 5 and a response index of 2.5 would be

**Table 3-2**

Outcome Scoring Definitions. Each case assigned score by comparing baseline index to response index.

<table>
<thead>
<tr>
<th>Score&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Response Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Start and remain Unnecessary &gt; 3</td>
</tr>
<tr>
<td>C4</td>
<td>Increase and become Unnecessary &gt; 3</td>
</tr>
<tr>
<td>C31</td>
<td>Increase and become Inefficient &gt; 2 ≤ 3</td>
</tr>
<tr>
<td>C30</td>
<td>Increase but remain Inefficient &gt; 2 ≤ 3</td>
</tr>
<tr>
<td>C21</td>
<td>Increase and become Acceptable &gt;1 ≤ 2</td>
</tr>
<tr>
<td>C20</td>
<td>Increase but remain Acceptable &gt;1 ≤ 2</td>
</tr>
<tr>
<td>B31</td>
<td>Reduce and become Inefficient &gt; 2 ≤ 3</td>
</tr>
<tr>
<td>B30</td>
<td>Reduce but remain Inefficient &gt; 2 ≤ 3</td>
</tr>
<tr>
<td>B21</td>
<td>Reduce and become Acceptable &gt;1 ≤ 2</td>
</tr>
<tr>
<td>B20</td>
<td>Reduce but remain Acceptable &gt;1 ≤ 2</td>
</tr>
<tr>
<td>B1</td>
<td>Reduce and become Efficient ≤ 1</td>
</tr>
<tr>
<td>A</td>
<td>Start and remain Efficient ≤ 1</td>
</tr>
</tbody>
</table>

<sup>a</sup> Second digit: 0 = did not change categories, 1 = changed categories
scored B31 - B means a household reduced its water use, 3 means to an index less than 3, and 1 means the reduction was enough to change categories (See Table 3-2 for complete definitions).

In order to better depict the scoring scheme graphically, the 12 scores were re-coded into the 4 categories of the letter definitions: A - the case started and remained in the Efficient category, B - the case reduced its index, C - the case increased its index, and D - the case started and remained in the Unnecessary water use category (Fig. 3-1). The water check was deemed successful if a household reduced its index or remained in the Efficient water use category, while it was deemed unsuccessful if a household increased its index or remained in the Unnecessary water use category. It should be noted, that some cases in the D category may have saved a large amount of water, but use was still beyond what could be characterized as "justifiable" based on plant water need of their landscape. The outcome score focuses on the appropriateness of the household’s water use (its measure of efficiency) and its direction of change (whether it conserved or used more landscape water subsequent to the water check).

2.2.3. Conservation Intervention Evaluation Tool

The Conservation Intervention Evaluation Tool takes another perspective (Fig. 3-2). Its focus is on the effectiveness of the water check intervention and what additional action may be necessary to help participants achieve appropriate water use. This tool is based upon plotting the baseline index against the response index and then, depending on the nature of the change in someone’s index relative to the appropriateness of their
resulting water use, the need for additional intervention is characterized. We created this categorization scheme by defining five categories describing what further action, if any, needs to be taken by the conservation program administrator. Households that decreased their index below 2 were judged to need no further intervention, while households that increased their index were deemed to need further intervention. For those participants who increased from the acceptable to unacceptable range and/or for those who start and remain in the acceptable range, a different intervention approach is likely needed. A

**Fig. 3-1** Participant Conservation Outcomes Assessment Tool
follow-up intervention is recommended to reinforce the water check for those who reduced their index but remain in the inefficient range or to refine the water check for those who increased but remain in the acceptable range. Monitoring of billing records is recommended for those who start in the unjustifiable range (baseline index > 2) but end up in the acceptable range (response index between 1 and 2). No further intervention is deemed necessary for those who reduced their index to end up in the efficient range (response index ≤ 1). For those participants who start and remain in the efficient range, no initial intervention was needed (see Fig. 3-2 for complete definitions).

**Fig. 3-2 Conservation Intervention Evaluation Tool**
3. Results and Discussion

Our goal was to evaluate the effectiveness of the landscape water check based on our participant households’ changes in water use post-water check. The difficulty of attributing this change to the water checks became apparent during the analysis, which was confounded by infrastructure problems, errors made by the field team during the water check, and mobility of the population (Table 3-3). After the water check, a few locations developed water leaks that increased their index and obscured the households’ behavioral efforts (n = 4). During the 2005 season, the field team made several mistakes and provided water schedules with incorrect run times and/or watering frequency (n=38). We eliminated these 42 cases from further analysis. While we recognize that errors in the delivery of water checks are an indication of program ineffectiveness, we aim to analyze the effectiveness of accurately delivered water checks from the participant point of view.

Table 3-3

Study Participant Attrition – Cases for Final Analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>2004 Volunteers</th>
<th>2005 Recruits</th>
<th>All Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Participants</td>
<td>149</td>
<td>101</td>
<td>250</td>
</tr>
<tr>
<td>Leaks</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Incorrect or No Water Schedule</td>
<td>0</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Residential Mobility</td>
<td>44</td>
<td>19</td>
<td>63</td>
</tr>
<tr>
<td>Total Cases Final Analysis (N)</td>
<td>102</td>
<td>43</td>
<td>145</td>
</tr>
</tbody>
</table>
and to further our understanding of human conservation behavior. We choose to be transparent about this issue because we doubt there is sufficient attention to internal errors in assessments of behavior change related to conservation program delivery.

Our temporal analysis includes data from 2002 through 2007 for the 208 remaining cases. During this period, Logan City’s population grew by 12% and was accompanied by the housing boom (US Census Bureau, 2008). We discovered that 63 (30%) of the remaining 208 property locations changed resident households one or more times. The subsequent analysis is split into two parts: 1) observations on the effect of residential mobility on water use; and 2) assessment of water check effectiveness for the remaining 145 cases, which we shall refer to as “good cases,” meaning those with consistent data and no residential mobility where we can fairly assess the water check as a conservation tool.

3.1. Effect of Residential Mobility on Water Use

Further analysis of residential mobility (n=63) revealed some interesting insights into the influence of site characteristics and human behavior. We utilized the Participant Conservation Outcomes Assessment Tool to conceptually interpret and describe differences in water use between prior residents and new residents (Fig. 3-3). It should be noted that our water budget assumes the same number of occupants based on occupancy at the time of the water check. New residents at locations that fell within the “A” category were able to maintain efficiency practices of the prior resident. They likely were not confronted with new structural problems and may have followed the irrigation scheduling of the former resident. New residents at locations that fell within the “B”
category were more efficient than the prior resident. The new resident may have implemented better watering practices, repaired a leak, converted landscaped area to a non-water use purpose such as a patio, or abandoned or fixed a dilapidated sprinkler system. However, for the “A” and “B” categories, the new household may have fewer occupants and we may have incorrectly assigned outdoor water use to indoor use making the household appear more efficient than it actually is. New residents at locations that fell within the “C” category were less efficient than the prior resident. These residents may have had less efficient watering practices, installed new landscaping that required establishment watering, installed a sprinkler system, or developed a water leak. New residents at locations that fell within the “D” category were just as inefficient as the prior resident. These locations may have undetected leaks, poorly designed sprinkler systems, old controllers, or challenging site characteristics; e.g. wind, sun exposure, poor soil that makes efficient water use difficult to achieve. Again, for the “C” and “D” categories, the water budget assumes the same number of occupants. The new household may have had more occupants and we may have incorrectly assigned indoor water use to outdoor use making the household appear more inefficient than it actually is.

Locations that remain in the “A” group may reflect favorable site and/or technology characteristics improving the residents' ability to be efficient, while those who remain in the “D” group may reflect site constraints that impede their efforts. In contrast, locations in the “B” and “C” categories may reflect differential behavior of the new resident and demonstrate that there are not likely to be site and/or technology constraints
at these locations. The lack of household information for new residents prevents us from investigating these possibilities and determining the results factually.

**Fig. 3-3** Residential Mobility Assessment. We utilized the Participant Conservation Outcomes Assessment Tool to interpret and describe differences in water use between prior resident and new resident.
During the course of the study (2002-2007), 70% of our study locations were occupied by the same resident, 15% had different residents during the baseline period (2 years prior to water check), 11% had new residents during the response period (2 years after the water check), and 5% of the locations had different residents both before and after the water check (N = 208). Table 3-4 reports the distribution of mobility categories by response index. The baseline index for these cases did not differ significantly. However, we found a statistically significant relationship between mobility type and response index ($F$-test $5.119$, $p = 0.002$) and found that locations with the same resident had a mean average response index 0.60 higher than locations with a new resident at the time of the water check (Scheffe post test). This indicates that during the two years’ post-

Table 3-4

Distribution of mobility categories (%) by response index.

<table>
<thead>
<tr>
<th>Response Index</th>
<th>Efficient $\leq 1$</th>
<th>Acceptable $&gt;1 \leq 2$</th>
<th>Inefficient $&gt; 2 \leq 3$</th>
<th>Unnecessary $&gt; 3$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Resident</td>
<td>19</td>
<td>23</td>
<td>35</td>
<td>14</td>
<td>100%</td>
</tr>
<tr>
<td>Index Prior</td>
<td>32</td>
<td>45</td>
<td>19</td>
<td>3</td>
<td>100%</td>
</tr>
<tr>
<td>Index New</td>
<td>41</td>
<td>46</td>
<td>5</td>
<td>9</td>
<td>100%</td>
</tr>
<tr>
<td>Response Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Different</td>
<td>30</td>
<td>60</td>
<td>10</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>All Cases</td>
<td>24</td>
<td>37</td>
<td>28</td>
<td>11</td>
<td>100%</td>
</tr>
</tbody>
</table>

| N              | (145)             | (31)                    | (22)                    | (10)             | (208) |

Note: Cases without leaks who received correct water schedule.
water check, locations with stable residency applied 60% more water than locations with new residents at the time of the water check. These locations had a different resident during the baseline period (2 years prior to water check), but the water use of the resident who received the water check is reflected in the response index. The locations with the same resident and a new resident at the time of the water check are the only mobility categories that compare the same people who received the water check.

Figure 3-4 depicts the Participant Conservation Outcomes Assessment Tool applied to each of the mobility categories. This figure shows 43% of the same resident group reduced their index post-water check (top panel, Fig. 3-4). Residents who remain in their homes may have a greater investment in their landscape (money, time, emotion) and could have been more resistant to the water check recommendations.

Figure 3-4 also shows that 58% of the new residents at the time of the water check reduced the response index to less than the baseline index of the prior resident (second panel, Fig. 3-4). We asked participants why they were interested in participating in the water check program. New residents mentioned that they wanted to “start off right,” “learn how to use their sprinkler system,” or “get the right water schedule.” Other participants who had moved to Logan from another state mentioned the challenges they faced trying to figure out how to care for their landscapes appropriately in a different climate with new pests and different soils, and some wished the water check had been available at that time. New residents may be more willing to adopt conservation practices and new residency could provide an entry point and the opportunity for conservation program managers to intervene more effectively.
Fig. 3-4 Effect of Mobility on Water Use. Sites with the same resident have mean average response index 0.60 higher than new residents at the time of the water check (BLI prior resident).

3.2. Assessment of Water Check Effectiveness

We now turn to analysis of water check effectiveness at the locations without known leaks, incorrect water check information, and residential mobility (n=145).
3.2.1. Adoption of Water Check Recommendations

We expected that households who adopted the recommended water schedule and implemented the plant, soil, or sprinkler system recommendations would reduce their water use. However, we did not find a significant relationship between any particular recommendation and outcome scores, which were re-coded into two categories describing households’ responses to the water check – successful or unsuccessful. Table 3-5 reports the distribution of recommendations adopted by water check category for the “good cases.” The greater percentage of cases was successful for all recommendations they could adopt. This reveals the interconnected nature of site characteristics, irrigation technology, plant material, and human behavior in achieving successful water conservation. It is likely that several things are working together to achieve savings, so no single recommendation brings about significant reductions in water use. Success appears to be site-specific and relies on a suite of recommendations addressing conditions of the residential landscape system, which includes the household's conservation competency. However, the water check did not focus on problem-solving skills or conservation competency nor was a second catch can test conducted to adjust the irrigation schedule after the irrigation system recommendations were adopted.

3.2.2. Household's Water Check Response

We utilized the Participant Conservation Outcomes Assessment Tool to conceptually interpret and describe differences in water use after the water check. The participant's baseline index for the "good cases" is plotted against the response index and
Table 3-5
Distribution of Recommendations Adopted

<table>
<thead>
<tr>
<th>Water Check Category</th>
<th>Plants</th>
<th>Soil</th>
<th>Schedule</th>
<th>Adjusted</th>
<th>Repaired</th>
<th>Altered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful (index &lt; 2)</td>
<td>59</td>
<td>69</td>
<td>56</td>
<td>56</td>
<td>63</td>
<td>57</td>
</tr>
<tr>
<td>Unsuccessful (index &gt; 2)</td>
<td>41</td>
<td>31</td>
<td>44</td>
<td>44</td>
<td>37</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>N^a</td>
<td>(69)</td>
<td>(45)</td>
<td>(120)</td>
<td>(87)</td>
<td>(84)</td>
<td>(28)</td>
</tr>
</tbody>
</table>

*Note. Cases without leaks who received correct water schedule and are the same resident 2002-2007.

^a N changes because more than 1 recommendation is possible.

categorized by the outcome score (Fig. 3-5). Households in the “A” group (15%) were efficient to begin with and remained so after the water check. These households had a low capacity to conserve on their existing landscape, yet some still managed to reduce their water use even further. For most households in this group, achieving even more water savings would require transitioning to more drought tolerant plant material or reducing their landscaped area. Water managers should evaluate landscaping and plant material at these locations and target conservation landscaping programs to these households.

Households in the “B” group (43%) had a good behavioral response to the water check and reduced their water use. However, not all of them have achieved justifiable water use and some households in this group continue to use more than their landscape
Fig. 3-5 Water Check Response. The participant's baseline index is plotted against the response index and categorized by the outcome score to interpret and describe differences in water use after the water check.

needs with indices ranging between 2 and 3. These households had a high capacity to conserve and need to continue to work on reducing their water use. Some households were watering on a daily basis for short time periods and their turf had very poorly developed root systems. This required that the lawn be weaned from the over-application of water and the recommended watering schedule be phased in over a couple watering
seasons, which may have limited these participants’ reductions in water use (either because of initial negative results or insufficient time to see the results of the weaning). Other households had poorly designed sprinkler systems and/or older controllers that limited their ability to reduce water use. If a sprinkler system zone waters both turf and shrubs, the household needs to choose which plant water need to schedule. The water checker encouraged participants to separate their zones by plant material, but also offered alternative ways to deal with poor design short of digging up the zone. Choices included watering for turf and overwatering shrubs, which saved participants time, or, alternatively, watering for shrubs and under watering the turf, which would require supplemental hand-watering and more of the households’ time. Another suggestion was to adjust the sprinkler heads in the shrub bed to restrict the water flow. Water managers should target conservation programs that improve irrigation technology to these locations.

Households in the “C” group (34%) had a poor behavioral response to the water check and increased their water use. We could not determine any one cause but, generally, participants were changing how they had done things in the past and may have incorrectly assessed the effect of their actions. However, 9 of the 49 (18%) households were already watering efficiently at the time of the water check and we gave them a water schedule that called for increased water use. When conducting a water check, the water checker should always calculate the weekly total run time for both the current schedule in use and the recommended schedule and use the lesser of the two. The water checker could make recommendations that adjust how water is applied to improve turf health; e.g.
longer run times less frequently or applying in repeated cycles to gain better infiltration.

Households in the “D” group (8%) were in the unnecessary water use category and remained so after the water check. However, cases below the diagonal did reduce their water use and achieved some relative success. However, their index remains greater than 3, indicating that they unnecessarily used 3 times the water needed by their landscape. We suspect some cases in the “D” group may have slow undetected leaks, or challenging site characteristics; such as windy locations, high sun exposure, or very poor rocky soil. These site characteristics are not fully accounted for in the water budget and/or the recommended water schedule. These locations warrant further investigation because they have a high capacity to conserve.

3.2.3. Water Check Intervention Assessment

We utilized the Conservation Intervention Evaluation Tool to identify participants who may need more assistance and to assess the quality of the intervention. The participant's baseline index for the “good cases” is plotted against the response index and categorized by the intervention characterization to identify participants who may need more assistance and to assess the quality of the intervention (Fig. 3-6).

Group 1 households (15%) were efficiently using water prior to the water check and never needed the intervention to begin with. Interestingly, all households in this group are 2004 volunteers who generally were interested in water conservation already and had previously implemented conservation measures on their own. Water managers could tap this groups' accomplishments by recruiting them as neighborhood water conservation resource persons from whom other water users could learn and seek help.
The baseline index is plotted against the response index and categorized by the intervention assessment to identify participants who may need more assistance and assess the quality of the intervention.

Group 2 households (5%) successfully reduced their response index below 1 and are using water efficiently. This group does not need any further intervention by water conservation managers.

Group 3 households (21%) have successfully reduced their response index below 2 and are using water acceptably. Water conservation managers should monitor this groups' billing records to assure the durability of their water use reductions.
Group 4 households (28%) are comprised of two groups who need follow-up visits but for different reasons. The first group, above the diagonal and below 2, was efficient to begin with but increased their index to greater than 1 after the water check. This group needs a follow-up visit to evaluate why their water use increased and fine-tune their actions as appropriate. The second group, below the diagonal and above 2, reduced their response index to less than 3, but is still inefficiently using water. This group needs a follow-up visit to reinforce their efforts and determine what else could be done.

Group 5 households (31%) were using water more than 3 times plant water need prior to the water check and remained in the unnecessary water use category after the water check. We recruited the 2005 participants because these households were identified as having above-average water use. When comparing distributions of each year, a greater proportion 42% of all 2005 Recruits (n = 43) are in this group, while only 27% of all 2004 Volunteers (n = 102) are in the unnecessary water use category. The water check was completely ineffective for this group and they need an entirely different approach. While the water check did provide basic conservation recommendations, it did not provide much "how-to" information or any technical assistance in adopting the recommendations.

Groups 4 and 5 also may have needed more time with the water check personnel than other participants did. We interviewed the participant while the water check personnel completed the walk through site assessment in order to reduce our imposition on the participants’ time. The water check personnel would have preferred that the
participant accompany them so they could complete the walk through assessment together. The water checker is able to deliver the assessment in the context of hands on participatory evaluation and the participant has more opportunities to ask questions and discuss landscape issues. The way that we conducted the research may have impeded the effectiveness of the water check especially for these groups who needed more help.

3.2.4. Assessing Water Check Program Delivery

In conducting the water checks, we made several general observations regarding the delivery of the water check program. We discovered volunteers and recruits have different motivations, information needs, and skill levels. Conservation programs should be designed to account for participants’ differing needs based on their own past efforts and experience with conservation. Generally, volunteers desired detailed information about specific issues that would allow them to achieve even greater water savings than they had on their own. They are often “do-it-yourselfers” with practical skills that enabled them to strive towards their conservation goals. In contrast, recruits were just beginning to address water conservation issues. Generally, they needed basic information on conservation as well as technical “how-to” information to get them started and may have needed on-going assistance to correctly implement recommendations.

The water check was delivered as a one-stop intervention, which may not have been the most effective mode of delivery. Water conservation is a continual process involving change, monitoring, adjustment, and reinforcement. It is iterative by its nature. Participants need time to properly absorb information they are given. They need the opportunity to experiment to see what works best in a particular context. On the ground
circumstances vary – landscapes mature, sprinkler systems become worn – so the key to effective water conservation appears to be an ability to understand which tools work best under what circumstances. Household circumstances also change and people may have periods where they do not have the time and/or money to devote to water conservation.

How program administrators interact with the household unit also appears to be important. In 2004, we noted that in some cases participants had volunteered for the water check to resolve a household dispute over landscape water use. We only met with the person who scheduled the appointment and discovered in the post-water check interview that the water schedule and recommendations mostly were rejected by the person who did not participate. We learned that we needed to work with both heads of household. Household decision makers need the opportunity to participate in the water check, ask questions, and synthesize information on their own – instead of having it passed to them by another household head.

Participants need support over longer time horizons than most programs plan. Participants often commented to us, “I wish you would come back . . .” for a variety of reasons ranging from a general desire for more help to specific requests for certain technical information; better billing information or understanding their water bills; lists of local resources for plants, irrigation contractors, or service people. This led us to understand that people desire program administrators to act as a partner and engage with them in more of a problem-solving or consultancy approach. Participants had busy lives and often did not have the time or possibly the inclination to do the research necessary to
achieve their goals. Program administrators could act as that knowledge resource and help smooth the path for people to act on their best water conservation intentions.

Water conservation managers need to adopt the participant's point of view rather than that of an outside expert dispensing advice and recommendations. Participants experience constraints on their time, availability of money, varying interest, and conflicting behaviors and goals within the household that may impede their conservation efforts. Water conservation programs should take into account the participant's objectives, what they need to know to achieve them, what their choices are, and what constraints or opportunity costs they face in order to make fully informed conservation decisions. Participants are also interested in how their conservation efforts contribute to their own longer-term needs, as well as community values or the greater good of society as a whole.

4. Conclusions

In order to assess the effectiveness of water check programs, we need a common set of assessment tools. We developed the Urban Landscape Water Index so that we could equitably compare and evaluate participants' individualized water use based on an ecologically based standard – plant water need. The index can be used to evaluate landscape water use efficiency and identify locations that could possibly benefit from participation in a water conservation program. Locations with high indexes warrant further investigation to determine if there are any water leaks, if household size is significantly larger than average, or if there is any identifiable circumstance that could account for the water use. Once it is determined that none of these issues are present, a
landscape water check can identify structural and behavioral issues that contribute to excessive water use.

We created an outcome scoring scheme and developed the Participant Conservation Outcomes Assessment Tool and Conservation Intervention Evaluation Tool based on the score in order to systematically characterize change and the effectiveness of the water check intervention. While we did not find a statistically significant relationship between the water check recommendations and the outcome score, it does appear that successful water conservation relies on a suite of site-specific actions. The assessment and evaluation tools provided a framework for conceptually interpreting our results and identifying cases for further assistance.

Successful water conservation is also influenced by knowing when people are most receptive to adopting changes. New residency appears to be an opportune moment to undertake water conservation actions. This suggests that it could be advantageous for program managers to forge relationships with area realtors. Realtors could provide a venue for delivering programs to new residents, especially people new to the area who may have a steeper learning curve due to differing climate and soil types from their former homes.

Conservation programs designed to meet the needs and goals of the people who use them are likely to be the most successful. Achieving conservation goals is a process that occurs over a longer time from than most programs plan. For cities, conservation provides some of the most cost-effective water for meeting demand and it is in everyone's best interest to work together.
References


Irrigation Association, 2005. Landscape Irrigation Scheduling and Water Management, Irrigation Association, Falls Church, VA.


CHAPTER 4
CONCLUSION

One of the greatest challenges in conducting water conservation research is determining how to characterize water use that is a fair and equitable comparison of residential landscapes and then to assess the effectiveness of a water conservation program. This project utilized an interdisciplinary technique developed by Endter-Wada, Kjelgren and Neale, that incorporated landscape water checks to inspect residential landscapes, historical ET$_o$ data to create irrigation water schedules, survey data to assess water conservation behavior and the effectiveness of a water check program as a conservation tool, remote sensing data to develop household water budgets, and city water billing records to evaluate water consumption.

This study illustrates the complex contextualized systems thinking required to use water efficiently in maintaining a residential landscape. Efficient water use on urban landscapes is more likely when water users engage in contextualized system thinking that connects decisions and actions in the four domains of a landscape system: landscape design appropriate to site characteristics; plant selection based on water need appropriate to local climatic conditions; irrigation system design, maintenance, and operation appropriate to the needs of different types of plant material; and active and perceptive water management on the part of individuals. The study documented significant relationships between baseline water use and variables in each landscape system domain. The type of sprinkler system controller appears to be especially influential in mediating
the appropriateness of water use on a landscape. However, the case studies revealed that water users can overcome constraints to efficient water use if they adopt habits that consistently commit personal time to address the limitations of their landscape system. This has important implications for the design of landscape water conservation programs. Programs need to provide relevant and useful technical information that addresses the variation within the residential landscape system and empowers residents with the information and problem-solving skills necessary to maintain their landscapes and use water efficiently. Landscape water checks have the potential to provide this education and save cities significant amounts of water.

In order to characterize water use and assess the effectiveness of the water check program, we developed the Urban Landscape Water Index so that we could equitably compare and evaluate participants' individualized water use on an ecologically based standard – plant water need. The index provided a method to evaluate landscape water use and identify locations that could possibly benefit from participation in a water conservation program. The index proved to be an effective and reliable tool for an initial assessment. Cities could use the index to identify locations with high indexes that warrant further investigation to determine if there are any water leaks, if household size is significantly larger than average, or if there is any identifiable circumstance that could account for high water use. Once it is determined that none of these issues are present, a landscape water check can identify behavioral issues that contribute to excessive water use.
We created an outcome scoring scheme and developed the Participant Conservation Outcomes Assessment Tool and Conservation Intervention Evaluation Tool based on the score in order to systematically characterize change and the effectiveness of the water check intervention. These tools were very helpful in the conceptual interpretation of the post-water check response. While we did not find a statistically significant relationship between the water check recommendations and the outcome score, it does appear that successful water conservation relies on a suite of site-specific actions. The assessment and evaluation tools provided a framework for conceptually interpreting our results and identifying cases for further assistance.

Successful water conservation is also influenced by knowing when people are most receptive to adopting changes. New residency appears to be an opportune moment to undertake water conservation actions. This suggests that it could be advantageous for program managers to forge relationships with area realtors. Realtors could provide a venue for delivering programs to new residents, especially people new to the area who may have a steeper learning curve due to differing climate and soil types from their former homes.

Landscape water conservation is not a one-time endeavor; rather it is an on-going practice and process of contextualized systems thinking applied to urban landscapes. Conservation programs designed to meet the needs and goals of the people who use them are likely to be the most successful. We conclude that landscape water checks have the potential to provide people with the information and problem-solving skills necessary to appropriately maintain residential landscapes.
APPENDICES
Appendix A. Survey Instruments
Hi, I’m with the Natural Resource and Environmental Policy Program at Utah State University. We are partnering with USU’s Center for Water Efficient Landscaping and the City of Logan this summer to conduct research in connection with the Water Check program. Water checks are being offered as a free service to Logan water customers in return for their participation in research designed to evaluate and increase the effectiveness of this program. The research consists of a short pre-survey and a post-season survey in September or October.

Right now, we would like to ask you a few questions as part of the pre-survey. This should only take about 15 minutes of your time. All of the information you give us will be kept completely confidential.

**PARTICIPATION IN WATER CHECK PROGRAM**

1. How did you learn about the Water Check program?
2. Why are you interested in participating in the Water Check program?

**PAST WATERING PRACTICES**

3. In the past, what has been your regular landscape watering routine?
   
   Prompts (only ask if not already covered in response to question 3):
   
   *How do you decide when in the spring to turn on your sprinkler system?*
   *
   How do you decide when in the fall to turn off your sprinkler system?*
   *
   Do you hand-water any portion of your lawn?*

4. Why did you adopt this watering routine?
   
   Prompt: *How did you decide your current watering schedule was appropriate for your landscape?*

5. Are there any other outdoor water uses that may significantly affect your overall water consumption?

**SPRINKLER SYSTEM**

6. Who designed and who installed your sprinkler system?
7. How long have you been using an automated sprinkler system?
8. Who maintains (repairs/fixes) your sprinkler system?
9. Is your sprinkler system applying water on a fairly even basis across the landscape? If Yes, How do you know this?

10. Are you comfortable programming your sprinkler system?

11. Do you adjust or change the setting on your sprinkler system any time during the watering season (April to October)? If Yes, Why/When?

CONSERVATION MEASURES

12. What landscape water conservation measures are you currently using, if any?
   
   If the respondent gives examples of conservation measures ask: *What has motivated you to conserve water?*

   If the respondent does not give examples of conservation measures ask: *What would motivate you to conserve water?*

WATER BILLING

13. How much water does your household use on a monthly basis?

14. How much do you pay for water?

15. What information on your monthly water bill is the most useful to you and why?

OTHER

16. What are the main uses for your yard?

17. What are your visual priorities for your yard?

Thank you for your time today. We truly appreciate it. As I mentioned earlier, we will come back and do a similar type of survey with you again in a couple of months. Again, thank you for your help with this study.
Logan City Water Conservation Research Project
Summer 2004 Post-Survey

We would like to thank you for participating in the Water Check Program this summer, we hope you found it useful, and we hope it helped you to water your landscape more efficiently. Now that the watering season is near the end, we would like to ask you a few question about whether or not you felt you were able to effectively conserve water this summer, and how beneficial the information your received from us earlier was in your efforts to conserve water. This should take no more than 15 minutes of your time, and like the first interview you participated in, your responses will be kept completely confidential. Our analysis of this information will only examine group data, and no individual response will be identified in any of our research reports.

1. Did you use the watering schedule we provided you? Why or Why not?
2. Reviewing this list (Water Conservation Measures), what water conservation measures have you adopted this summer because of your participation in the Logan Water Check Program and why have you used them?
   (If participant has completed the form, review it and ask: Why did you choose to implement the measures you have checked?)
3. Which of the conservation measure you adopted were most effective in helping you to conserve water?
4. I’d like you to tell me if there are any conservation measure you remember that (Jenny/Mark) specifically recommended to you that you did not use this summer?
5. Do you plan to implement any additional water conservation measures in the future? If so, which ones, and why?
6. On a scale of 1 to 10, with 10 meaning very helpful and 1 meaning not at all helpful, how effect would you rate the overal Logan Water Check Program in helping you to conserve water? [Record comments they may choose to make.]
7. Do you have any suggestions for improving the usefulness of the water check program?
8. If the drought should end next year, will you continue to use these water conservation methods? Why of Why not?
9. What do you feel would motivate others in Cache Valley to conserve water?
Water Conservation Measures
Schedule of Use and Comments

Below you will find a list of water conservation measures that reflects the list given to you by the specialist that completed your water check. On the original list the specialist recommended some of these measures to help you in your water conservation efforts. We are interested in knowing how many of these conservation measures you actually implemented this summer. Please put a check mark next to those that apply. We would also like to know when you implemented them (approximate date), if you stopped using them (approximate date), whether or not you felt they were effective, and any other information you think would be helpful to us. We will pick up this form when we visit with you at the end of the summer. We truly appreciate your help in our research efforts, and thank you in advance for taking the time to complete this checklist.

Plants

☐ Adjusted system (or hand watered) to cover dry spots
  Date Began: ____________  Date Ended: ____________
  Comments: ______________________________________

☐ Used mulch on non-turf planting areas
  Date Completed: ____________
  Comments: ______________________________________

☐ Followed watering schedule received from USU specialist
  Date Began: ____________  Date Ended: ____________
  Comments: ______________________________________

☐ Utilized the “repeat cycling” recommendation – allowing more time for water to absorb into the soil
  Date Began: ____________  Date Ended: ____________
  Comments: ______________________________________

☐ Aerated soil
  Date Completed: ____________
  Comments: ______________________________________
☐ Treated thatch (excess grass) problem (please explain what you did)
Date Began:_________________________ Date Ended:_________________________
Comments:________________________________________________________________

☐ Separated valves according to various plant water requirements
Date Completed:_____________________
Comments:________________________________________________________________

☐ Separated valves for varying sun exposure
Date Completed:_____________________
Comments:________________________________________________________________

Sprinkler Systems

☐ Repaired broken or clogged heads
Date Completed:_____________________
Comments:________________________________________________________________

☐ Repaired broken/leaking valve or pipe
Date Completed:_____________________
Comments:________________________________________________________________

☐ Took measures to correct high pressure causing misting
Date Began:_______________________ Date Ended:_______________________
Comments:________________________________________________________________

☐ Took measures to correct low pressure problems
Date Began:_______________________ Date Ended:_______________________
Comments:________________________________________________________________
☐ Adjusted/corrected for spray arc problems
Date Completed: ____________________________

Comments: ____________________________

☐ Installed check valves or replaced existing heads to address low head drainage
Date Completed: ____________________________

Comments: ____________________________

☐ Replaced mismatched heads on valve systems
Date Completed: ____________________________

Comments: ____________________________

☐ Adjusted or changed spray patterns to address over-spraying problem
Date Completed: ____________________________

Comments: ____________________________

☐ Moved or raised sprinkler heads or removed obstruction to address spray pattern problem
Date Completed: ____________________________

Comments: ____________________________

☐ Raised or replaced sprinkler heads to address problem of sunken heads/short pop-ups
Date Completed: ____________________________

Comments: ____________________________

☐ Realigned tilted heads to address ponding and uneven coverage problems
Date Completed: ____________________________

Comments: ____________________________
☐ Addressed uneven or extended head spacing
Date Completed: 
Comments: 

☐ Drip Systems

☐ Replaced clogged emitters/missing filter
Date Completed: 
Comments: 

☐ Moved emitters as recommended so they are not too close/far from plant
Date Completed: 
Comments: 

☐ Installed a pressure regulator
Date Completed: 
Comments: 

☐ Repaired or replaced missing/broken emitter
Date Completed: 
Comments: 

☐ Straightened or replaced pinched/broken tubing
Date Completed: 
Comments: 

☐ Reattached or replaced tubing pulled/blown off single/multiple outlet emitters
Date Completed: 
Comments: 

Water Check #
July 2005

Dear Logan City Water Customer,

We are conducting research to better understand landscape watering practices and to evaluate and increase the effectiveness of a city water check program. This research is being conducted by the Department of Environment and Society and the Center for Water-Efficient Landscaping at Utah State University, in partnership with the City of Logan. It is part of a broader research effort to determine how water can be managed to best meet future needs in Utah.

As you may know, Utah is an arid state that has experienced drought in recent years, and likely will experience water shortages over the longer term as its population and economy continue to grow. The greatest potential for future residential water savings is in the area of landscape watering (lawns and gardens). We recently conducted an analysis of landscape water use patterns for the City of Logan, incorporating actual water use records with aerial photography of landscaped areas. Your property has been identified as one with above average landscape water use, when compared to similarly sized and landscaped lots. Oftentimes, above average landscape water use is related to irrigation system inefficiencies or use of a watering schedule that does not fully take into account how much water plants really need given the climate, soil type, and other characteristics of a particular landscape. Sometimes there could be a problem with the water meter or with billing information.

We would like to offer you a free water check to help you identify what may be contributing to higher than average water use. A landscape specialist and university researchers will conduct the water check. The water check includes a detailed evaluation of your sprinkler system that may take up to 2 hours, depending upon the size of your sprinkler system, the results of which will be given to you along with recommendations on how to conserve water on your particular landscape. The water check also includes a short pre-survey to ask you a few questions regarding your current watering practices, your thoughts on conservation approaches, and your knowledge of water consumption and prices. In the fall, we will return to conduct a short post-survey.

Participation in the water check program and accompanying research is voluntary, and all information regarding your property as well as your responses and comments to the surveys will be kept completely confidential. In conducting this research, code numbers will be used in
place of your name, the code list will be kept separate from survey forms, and the code list will be destroyed once data analysis is complete in about one year. There are minimal risks involved in this study.

In order to schedule a water check, please contact Diana Glenn, USU Graduate Research Associate, by phone at 797-3237 or by e-mail at diana.glenn@usu.edu and include "water check" in the subject line of the email.

We appreciate your time and want to thank you in advance for your participation. The results of this research will help Logan City officials, as well as other State officials, consider the needs and preferences of their water customers and the effectiveness of various water conservation methods. Our goal is to provide information that can help city and state officials manage water resources efficiently and equitably.

If you have any questions about this project, or if we can be of any assistance, please feel free to contact us. Our telephone numbers and email addresses are listed below.

Respectfully,

Joanna Endter-Wada, Ph.D.
Associate Professor
Department of Environment and Society
College of Natural Resources
435-797-2487
Joanna.Endter-Wada@usu.edu

Roger Kjelgren, Ph.D.
Director, Center for Water Efficient Landscaping
Department of Plants, Soils, and Biometeorology
College of Agriculture
435-797-2972
rkjel@mendel.usu.edu

Christopher Neale, Ph.D.
Professor
Dept. of Biological and Irrigation Engineering
College of Engineering
435-797-3689
cneale@cc.usu.edu
Logan City Water Check Program - 2005
SCREENING SURVEY

If they call us:

Thank you for contacting us about the water check program. The letter explained the program, but I would be glad to answer any questions you might have. [Answer their questions.] We mentioned this in the letter, but we want to remind you that your participation in the water check program is voluntary. Also, all information we gather from you will be kept completely confidential.

If we call them and get a message machine:

Hi. My name is _____ and I am a graduate student from Utah State University. I am calling to follow-up on a letter that was recently sent to you offering a free water check. This program is being offered by Utah State University in partnership with the City of Logan. My university office number is 797-3237 in case you want to call back, but I will also try to get in touch with you again.

If we call them and someone answers:

Hi. My name is _____ and I am a graduate student from Utah State University. I am calling to follow-up on a letter that was recently sent to you offering a free water check. Did you receive this letter? [If they do not recall the contents of the letter, offer to read it to them.] As noted in that letter, this program is being offered by Utah State University in partnership with the City of Logan. Also, your participation in the water check program and accompanying survey research is voluntary. All information we gather from you will be kept completely confidential.

1. Are you interested in participating in the Logan City Water Check Program?
   Yes (ask screening questions 2-9 and schedule an appointment)
   No (ask why)

2. Let me start by getting your name and contact information:
   Date Contacted: ________________ ☐ Volunteer - Group: ____ ☐ Solicited - Group: ____
   Name: ____________________________
   Phone #: __________________________
   Address: __________________________

3. How many people live at this address? ________

4. Is your residence a rental or condominium?
   a. Do you share a common water meter with other residents?
b. Does someone who is not a member of your household pay the water bill?
5. How many years have you resided at this address?
6. Does this property have an in-ground sprinkler system?
7. How many zones does the sprinkler system have?
8. Do you use secondary water from an irrigation canal or well to water any part of the landscape?
9. In order to schedule the water check and make it most effective, we would like to know:
   a. Who is responsible for watering the lawn and programming the sprinkler timer?
   b. Who maintains the lawn, flowerbeds, and shrubs?

Appointment Scheduling:
[If the answers to 9a and 9b identify the same person, ask to meet with that person.]
[If the answers to 9a and 9b identify different people, ask if there is a time when both are available.]
Appointment Date: ___________________ Time: ______________ _M.
Appointment with (name): ___________________
Logan City Water Conservation Research Project

Summer 2005 Pre-Survey

Hi, I’m with the College of Natural Resource at Utah State University. We are partnering with USU’s Center for Water Efficient Landscaping and the City of Logan this summer to conduct research in connection with the Water Check program. Water checks are being offered as a free service to Logan water customers in return for their participation in research designed to evaluate and increase the effectiveness of this program. The research consists of a short pre-survey and a post-season survey in September or October.

Right now, we would like to ask you a few questions as part of the pre-survey. This should only take about 15 minutes of your time. All of the information you give us will be kept completely confidential.

PARTICIPATION IN WATER CHECK PROGRAM

1. Why are you interested in participating in the Water Check program?
   Prompt: Were you surprised to learn that this property location was identified as having above-average water use?

PAST WATERING PRACTICES

2. In the past, what has been your regular landscape watering routine at this location?
   Prompts (only ask if not already covered in response to question 2):
   How do you decide when in the spring to turn on your sprinkler system?
   How do you decide when in the fall to turn off your sprinkler system?
   Do you hand-water any portion of your lawn?

3. Why did you adopt this watering routine?

4. Have you made any changes to your watering routine this year?
   ___ Yes (ask what/why) ___ No (ask why)

5. Are there any other outdoor water uses that may significantly affect your overall water consumption?

SPRINKLER SYSTEM

6. Who designed and who installed your sprinkler system?

7. What year was this sprinkler system installed?

8. How long have you been using an automated sprinkler system?
9. Who maintains (repairs/fixes) your sprinkler system?

10. Is your sprinkler system applying water on a fairly even basis across the landscape? If Yes, How do you know this?

11. Are you comfortable programming your sprinkler system?

12. Do you adjust or change the setting on your sprinkler system any time during the watering season (April to October)? If Yes, Why/When?

**CONSERVATION MEASURES**

13. What landscape water conservation measures are you currently using, if any?  
   (If the respondent gives examples of conservation measures ask: 13a and b  
   If the respondent does not give examples of conservation measures ask: 13c)  
   a. What has motivated you to conserve water?  
   b. What would motivate you to further conserve water?  
   c. What would motivate you to conserve water?

14. Can you tell me about your household’s decision-making process in relation to landscape water use?  
   a. Who is involved?  
   b. How do you decide?  
   c. Does everyone participate and agree?

**WATER BILLING**

15. How much water does your household use on a monthly basis?

16. How much do you pay for water?

17. What information on your monthly water bill is the most useful to you and why?

18. What information would you like to see on your water bill?

19. Who usually pays the water bill?

**OTHER**

20. What are the main uses for your yard?

21. What are your visual priorities for your yard?

Thank you for your time today. We truly appreciate it. As I mentioned earlier, we will come back and do a similar type of survey with you again in a couple of months. Again, thank you for your help with this study.
Water Check Number

Logan City Water Check Program - 2005
POST-SURVEY

On behalf of the USU water check team and Logan City, I would first like to thank you for participating in the Water Check Program this summer. The main objective of this post-survey is to have you help evaluate the water check program. Now, I would like to ask you a few questions about whether or not you feel you can effectively conserve water, and how beneficial the information we gave you earlier is to your water conservation efforts.

These questions should take no more than 45 minutes of your time and, like the interview you participated in earlier, your responses will be kept completely confidential. Our analysis of this information will only examine group data, and no individual responses will be identified in any of our reports. I want to remind you that this was a pilot water check program and your participation and feedback is valuable for helping us to assess and improve its effectiveness.

1. Generally, what was useful to you from the water check program?
2. Did you use the watering schedule we provided you?
3. What month did you finish watering this season?
4. How did the watering schedule we recommend differ from your old watering schedule?
5. Do you have your copy of the Walk-Through Site Evaluation recommendations that were given to you when the water check was conducted?

As we review this together, I want you to tell me which recommendations you have adopted or intend to adopt and which you have not adopted or do not intend to adopt, and then feel free to comment on your reasons. (Record responses on Question 5 Addendum at end)

6. We left a packet of information with you earlier. What part of that information packet was most helpful to you?
7. Can you tell me about your household's decision-making process in relation to the conservation recommendations that you adopted?
   a. Who was involved?
   b. How did you decide?
   c. Did everyone in the household participate and agree?
8. Which of the conservation measures you adopted were most effective in helping you to conserve water?
9. Do you plan to implement any additional water conservation measures in the future? Can you explain?

10. On a scale of 1 to 10, with 1 meaning not at all helpful and 10 meaning very helpful, how effective would you rate the overall Logan Water Check Program in helping you to conserve water?

[Record comments they may choose to make]:

11. Do you have any suggestions for improving the usefulness of the water check program?

12. Will you continue to use the water conservation methods that you have adopted? Can you explain?

13. Water checks are just one means to help people conserve water. Cities and water purveyors use a variety of conservation programs. I am going to read a list of other approaches to water conservation and, for each approach, I want you to rate how helpful you think it would be in aiding your efforts to conserve water [CARD].

Please rate each approach on a scale of 0 to 10, with 0 meaning not at all helpful and 10 meaning very helpful.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Not at all helpful</th>
<th>Very helpful</th>
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<tbody>
<tr>
<td>a. A water bill with an annual comparison of your household's usage by month . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<td>b. A water bill comparing your household to average water use for households with similarly sized lots . . . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<td>c. An increase in your water bill of 25% . . . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<tr>
<td>d. An increase in your water bill of 100% . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<td>e. Landscape watering restrictions with fines for violations . . . . . .</td>
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<td>f. A rebate offer to help offset the cost of retrofitting your sprinkler system . . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<td>g. A rebate offer for replacing your landscape with a water-wise landscape . . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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<tr>
<td>h. A city landscape ordinance that specified landscape design criteria for new construction; e.g., % efficiency standard or a water-wise plant list . . . .</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
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</table>
1. A reduced connection fee for new residential customers who put less than 50% of their yard in lawn

2. A 30% increase in water rates during the summer season

[Record comments they may choose to make]

14. What do you feel would motivate other people in Cache Valley to conserve water?

Thank you for your time today and your participation in our research project. We truly appreciate it!

Water Conservation Measures
Post-Survey Question 5 Addendum

Plants

☐ Dry Spots: Adjusted system (or hand watered) to cover dry spots
   ☐ Adopted  ☐ Not Adopted

☐ Mulch needed in areas: Used mulch on non-turf planting areas
   ☐ Adopted  ☐ Not Adopted

☐ Over-watered area: Followed watering schedule received from USU specialist
   ☐ Adopted  ☐ Not Adopted

☐ Ponding near plants: Followed watering schedule received from USU specialist
   ☐ Adopted  ☐ Not Adopted

☐ Run-off/sloped area: Utilized the “repeat cycling” recommendation – allowing more time for water to absorb into the soil
   ☐ Adopted  ☐ Not Adopted

☐ Soil Compaction: Aerated soil
   ☐ Adopted  ☐ Not Adopted
☐ Thatch (excess grass): Treated problem (please explain what you did)
  ☐ Adopted  ☐ Not Adopted

☐ Valves separated by plant water requirements
  ☐ Adopted  ☐ Not Adopted

☐ Valves separated for varying sun exposure
  ☐ Adopted  ☐ Not Adopted

**Sprinkler Systems**

☐ Broken or clogged heads repaired
  ☐ Adopted  ☐ Not Adopted

☐ Broken/leaking valve or pipe repaired
  ☐ Adopted  ☐ Not Adopted

☐ High pressure causing misting corrected
  ☐ Adopted  ☐ Not Adopted

☐ Low pressure decreasing efficiency corrected
  ☐ Adopted  ☐ Not Adopted

☐ Spray arc problems corrected
  ☐ Adopted  ☐ Not Adopted

☐ Low head drainage: □Installed check valves □Replaced existing heads
  ☐ Adopted  ☐ Not Adopted

☐ Mismatched heads replaced
  ☐ Adopted  ☐ Not Adopted

☐ Over-spray: □Adjusted  □Changed spray patterns
  ☐ Adopted  ☐ Not Adopted

☐ Spray pattern blocked or misdirected
  ☐ Adopted  ☐ Not Adopted

☐ Sunken heads/short pop-ups
  ☐ Adopted  ☐ Not Adopted

☐ Tilted heads realigned to address ponding and uneven coverage problems
  ☐ Adopted  ☐ Not Adopted
☐ Uneven or extended head spacing addressed
  ☐ Adopted  ☐ Not Adopted

**Drip Systems**

☐ Clogged emitters/missing filter replaced
  ☐ Adopted  ☐ Not Adopted

☐ Emitters too close/far from plant repositioned
  ☐ Adopted  ☐ Not Adopted

☐ High pressure/Missing pressure regulator installed/replaced
  ☐ Adopted  ☐ Not Adopted

☐ Missing/broken emitter repaired or replaced
  ☐ Adopted  ☐ Not Adopted

☐ Pinched or broken tubing
  ☐ Adopted  ☐ Not Adopted

☐ Tubing pulled/blown off single/multiple emitters reattached/replaced
  ☐ Adopted  ☐ Not Adopted
Appendix B. Irrigation Schedule and Water Check Recommendations
Do not irrigate October through April. Use this irrigation schedule as a guide. The weather during the Spring and Fall varies considerably. If the weather is extra hot, adjust your controller by adding a watering day. If it is cloudy or cool, adjust you controller by deleting a day. Turn off your timer in the rain. If you need additional help please call (435) 232-5128.

<table>
<thead>
<tr>
<th>Station #</th>
<th>Program</th>
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| Month: | | | | | | | | | | | | | | | | | |
|--------|--------------|--------------|--------------|--------------|
| May    | | | | |
| June   | | | | |
| July   | | | | |
| August | | | | |
| September | | | | |

- Controller Programmed
Logan City and USU Water Check
Thank you for participating in this Water Check program. This is a free service offered to the citizens of the City of Logan. It is sponsored by the City of Logan, Utah State University, and the Center for Water-Efficient Landscaping.

A series of evaluations and tests have been performed on your irrigation system. We have determined how much water your irrigation system emits in a given amount of time (precipitation rate), the soil absorption rate (infiltration rate), and the uniformity of water distribution through an area (distribution uniformity).

Root Depth
Healthy lawn roots should have a depth of 8 to 12 inches or more. Through deeper, infrequent watering, your lawn will be more able to tolerate extreme temperatures and decreased amounts of water.

Your lawn's root system is about ______ inches deep.

Water Infiltration Rate
If water is applied faster than the soil is able to absorb it, irrigation turns into run-off. Clay soils absorb water very slowly, whereas sand can absorb it very quickly. By knowing your soil type, a watering schedule can be adjusted to maximize the amount of water absorbed by your lawn, instead of losing it to run-off.

Your soil type is ____________________________.

Precipitation Rate
Sprinkler precipitation rate, as with rainfall, is a measure of how many inches of water per hour are emitted, in this case, from your sprinklers. Different systems and different sprinkler heads will also have different precipitation rates. This rate will determine how long you need to run your sprinklers.

Fixed sprinkler heads apply about 50% more water (1.5 inches/hour) than rotor heads (0.75 inches/hour). This means that rotor heads will usually need to run about twice as long as fixed spray heads. Remember that while fixed heads don't move and all the water they emit is applied to the same area, rotor heads oscillate and cover a greater area. The water emitted must be distributed accordingly.

Your precipitation rate is _______ inches/hour (fixed), _______ inches/hour (rotor).

Distribution Uniformity (DU)
This measures a sprinkler system's ability to apply water evenly over the surface of a landscape. If the amount of water put out by irrigation systems is not completely uniform (100%), some areas of the landscape will receive more water than others. This measurement can be improved through proper maintenance, adjustments and repair to your system. Please refer to the "Walk-Through Site Evaluation: Explanation and Suggestions" for items that can be attended to in your landscape.

Your Distribution Uniformity (efficiency) is _______% (fixed), _______% (rotor).

Water Pressure
Operating pressure is the water pressure located at the base of the sprinkler head. Each model of sprinkler head has a specific range of pressures at which optimum performance is achieved. In general, fixed pop-up (plastic) spray heads work best between 20 to 30 pounds per square inch (psi). Water pressure for rotor (oscillating) heads should be between 50 to 80 psi. Refer to the "Walk-Through Site Evaluation: Explanation and Suggestions" for recommendations on your system’s pressure.

Your Water Pressure is ______ psi (fixed), ______ psi (rotor).
Walk-Through Site Evaluation:
Explanation and Suggestions

Plants

☐ Dry spots
There are dry spots in the landscape that are not getting water. Adjust or modify the irrigation system to cover the area instead of increasing the watering time for this irrigation station. If unable to adjust or modify the system, supplement irrigation with hand watering or hose and sprinkler watering.

☐ Mulch needed in areas
We recommend the use of organic mulch at least 2 inches deep in all non-turf planting areas. This will reduce evaporation, moderate soil temperatures, add nutrients to soil, and discourage weeds. Keep mulch at least 6 inches away from the base of the trunk (crown) of plants to discourage disease.

☐ Over-watered area
The area was checked with a soil probe and the soil was saturated. Following the accompanying irrigation schedule will allow the soil to dry out partially between watering, allowing air into the soil. This will result in a healthier appearance and more vigorous plants.

☐ Ponding near plants
Ponding can indicate over-watering or applying water at a rate that is too high for your type of soil to absorb. Following the accompanying irrigation schedule will allow the soil to dry out partially between watering. Ponding can also be an indication that the spray is being block by plant foliage.

☐ Run-off/sloped area
Lawn or shrub areas in clay soil/sloped areas require a special irrigation schedule called repeat cycling. This means taking the estimated daily runtime and dividing it into two, three, or more separate run times. There should be enough time for water to soak into the soil before the next cycle begins. Instead of losing water to run-off, it is absorbed into the soil.

☐ Soil compaction: Need to aerate
The turf areas require periodic aeration, which is the removal of cores or plugs from the lawn. Aerating increases air and water transfer to the root zone, which is vital for a healthy lawn. Aerating is especially necessary in clay soils and in turf areas where there is heavy foot traffic. It is recommended that you add compost to the area that was aerated to improve soil quality.

☐ Thatch – excess grass
In cool season lawn, thatch build-up could be a problem of over-fertilization, or the lawn may be mowed too low, or over a third of the leaf blade is being cut at the time of mowing. Consult with a local extension or nursery lawn care specialist to diagnose your specific problem.

☐ Valves not separated by plant water requirements
The station(s) water both turf and shrubs together. Shrub generally use less water than turf. For optimum water efficiency, these should be separated. Shrubs and groundcover generally require less water, less frequent water, and deeper watering that turf.

☐ Valves not separated for sun exposure
The station(s) has heads in both sunny (hot) and shady (cool) areas. Turf in the shade will use considerably less water than turf in sun. Individual stations should be limited to only one of these areas (exposures). If this is not possible, heads in the shady areas should have a lower precipitation rate than the sunny areas.
Sprinkler Systems

- **Broken or clogged heads**
  Broken heads need to be fixed to save irrigate and efficiently water the landscape. Clogged heads need to be cleaned to ensure proper coverage. Consider installing irrigation heads that have screens to prevent debris (grass, soil, or bugs) from clogging the sprinkler heads.

- **Broken/leaking valve or pipe**
  These problems need to be fixed to save water and efficiently irrigate the landscape. One sign of a leaking valve is the lowest head on the station is leaking and algae or moss is growing in the area.

- **High pressure causing misting**
  High pressure results in a very fine spray, which drifts downwind and creates high evaporation losses. High pressure can be corrected with a pressure regulator placed after the meter, pressure regulating sprinkler heads, or added devices on the individual sprinkler heads. Visit your local irrigation supply store for needed materials.

- **Low pressure decreases efficiency**
  If pressure is too low, sprinklers cannot cover the desired area. This is often caused by having too many sprinkler heads installed on one valve, or sometimes by watering at a time when too many others in the area are watering. Low pressure causes a heavy application of water in limited areas, which increases run-off. If your pressure is too low, try watering at a different time or modify your system so there are fewer sprinklers on each valve. Consult with a qualified professional or the possibility of redesigning the irrigation system.

- **Incorrect spray arc**
  The spray arc is too wide/narrow for the area being watered. Consider adjusting the spray pattern if possible, or replace the spray head(s) with the correct spray pattern.

- **Low head drainage**
  Install check valves where appropriate, or replace existing heads with heads that contain built-in check valves to prevent drainage of water from pipes through the lower heads when the system is shut off. This will save a significant amount of water (the water needed to fill and pressurize the system), especially when using repeat cycles. Visit your local irrigation supply store for needed materials.

- **Mismatched heads**
  Some turf areas are being irrigated with a variety of sprinkler types, causing low uniformity, i.e. rotors and spray heads. Make adjustments so that each head on a valve has the same kind of heads. Nozzles should also be correlated for match precipitation rates. Visit your local irrigation supply store for needed materials.

- **Over-spray**
  Water is being lost due to the sprinklers over-spraying the planting area. The sprinklers' spray patterns should either be adjusted or changed to a pattern that will stay within the planting area. Another alternative would be to redesign the sprinkler system to spray only the planting areas for each station.

- **Spray pattern blocked or misdirected**
  Spray pattern of irrigation head(s) is being blocked. The irrigation head(s) need to be moved/raised to where they can spray as intended or the obstruction needs to be moved.
☐ Sunken heads/short pop-ups
There are sunken heads causing the spray pattern to be partially blocked due to the stream being intercepted by grass near the head. This results in over-saturated areas near the head. To correct the problem, raise the sunken head to grade (level with the soil) or replace existing short pop-up heads in the lawn with 4 inch or taller pop-ups, as necessary. You can also trim around existing heads to avoid blocking the spray but you will have to do this on a continual basis. Visit your local irrigation supply store for needed materials.

☐ Tilted heads
Heads should be aligned vertically, except when on a sloped area. If on a sloped area, heads should be aligned perpendicular to the slope to achieve proper coverage. Tilted heads can cause ponding and uneven coverage decreasing the efficiency of the system.

☐ Uneven or extended head spacing
To ensure even water distribution, irrigation heads need to have head-to-head spacing (the water from one sprinkler should reach the sprinkler heads around it). Consult with a qualified professional to design a system with head-to-head spacing. There is no specific pattern to the placement of the sprinkler heads.

Drip Systems

☐ Clogged emitters/Missing filter
Clogged emitters need to be replaced. If the system does not have a water filter, one needs to be installed. The clogging could be caused from bugs, dirt or plants growing into the emitters. Visit your local irrigation supply store for needed materials.

☐ Emitters too close/far from plant
Emitters need to be at the edge of the root-ball on new plantings and moved out to the drip line (edge of foliage) of established plants.

☐ High pressure/Missing pressure regulator
There is not a pressure regulator on the system, which is causing compression fittings and emitter to pop off the line. Install a pressure regulator on the valve for all drip stations. Visit your local irrigation supply store for needed materials.

☐ Missing/Broken emitter
Missing and broken emitters need to be replaced to keep your system running efficiently. Visit your local irrigation supply store for needed materials.

☐ Pinched or broken tubing
Pinched tubing needs to be straightened or replaced. Broken tubing needs to be fixed to save water and efficiently irrigate the landscape.

☐ Tubing pulled/blown off single/multiple outlet emitters
Tubing needs to be reattached to emitters or replaced. If the system does not have a pressure regulator, one needs to be installed or the condition will continue to happen. Visit your local irrigation supply store for needed materials.