SITUATIONAL WASTE IN LANDSCAPE WATERING: RESIDENTIAL AND BUSINESS WATER USE IN AN URBAN UTAH COMMUNITY[1]

Joanna Endter-Wada, Judith Kurtzman, Sean P. Keenan, Roger K. Kjelgren, and Christopher M.U. Neale[2]

ABSTRACT: Landscape water conservation is an important issue for municipalities throughout the Western United States, and especially in Utah as rapid growth strains existing water supplies. We conducted interdisciplinary research in Layton, Utah, that aimed at understanding patterns of landscape water use among households and businesses. The research project involved three basic tasks. First, a landscape "water budget" was developed by producing a calibrated and classified mosaic of landscape type and area from airborne multispectral digital imagery, integrating this information with Layton City parcel boundary data to determine landscape vegetated areas per lot, and estimating irrigation needs derived from reference evapotranspiration (ETo) obtained using weather data for the Salt Lake City metropolitan region. Second, utilizing Layton water billing data, water use for each household and business was identified and categorized as "conserving," "acceptable" or "wasteful" by determining how much the water applied varied from actual landscape plant need. Third, surveys were administered to a random stratified sample of households and businesses in the study area to investigate various factors that were hypothesized to be predictive of wasteful watering practices. This paper primarily focuses on analysis of the household and business survey data, which explores factors affecting urban landscape water use from a human behavioral perspective. We found that the most significant factors predicting actual water use were the type of irrigation system and whether the location was a household or business. Attitudinal and motivational characteristics were not consistently associated with water use. We found that wasteful watering is the result of many factors embedded in the complex context of urban landscapes. This implies that water conservation programs should identify potential wasteful users through analyses of water billing data and direct water conservation measures at these users by focusing on site-specific evaluations and recommendations. Water audits or water checks are one such tool that some communities have employed to help people understand and assess the quantity of water needed by and applied to their landscapes. This approach provides an opportunity to evaluate situational constraints at particular locations and design appropriate strategies for reducing water waste.

(KEY TERMS: water conservation; sociology; remote sensing; drought; water budget; urban landscape irrigation; environmental behavior; interdisciplinary research.)

---

[2]Respectively, (Endter-Wada, Kurtzman, and Keenan) Associate Professor, Senior Lecturer, and Senior Researcher, Department of Environment and Society, Utah State University, Logan, Utah 84322-5215; (Kjelgren) Professor, Department of Plants, Soils and Biometeorology, Utah State University, Logan, Utah 84322-5215; and (Neale) Professor, Department of Biological and Irrigation Engineering, Utah State University, Logan, Utah 84322-5215 (E-mail/Endter-Wada: Joanna.Endter-Wada@usu.edu.)

INTRODUCTION

Water conservation is an important issue for municipalities throughout the Western United States (U.S.) as they are challenged to supply enough water to meet growing urban demands. Utah is one of the fastest growing and most highly urbanized states in the nation, and the current population of 2.3 million people is expected to more than double to 5 million by the year 2050. In addition, Utah is the second most arid state in the U.S. and is subject to periodic droughts. Many communities along Utah's rapidly expanding Wasatch Front face serious water shortages within the next decade, and are encountering political, legal, and economic difficulties in pursuing water supply augmentation options (Utah Division of Water Resources, 2001, 2007).

The State of Utah is increasingly emphasizing demand management strategies to stretch limited water supplies (Utah Division of Water Resources, 2003). In 1998 and 1999, the Utah Legislature passed and revised the Water Conservation Plan Act requiring retail water providers to develop and submit a water conservation plan, and in 2004 this act was amended to require retail water providers to conserve water (Utah Code Annotated 73-10-32). Residential and commercial landscape watering is estimated to be one of the largest sources of potential urban water conservation. Water shortages are most critical during the summer months, and it is estimated that household and business landscapes consume roughly 50-70% of overall municipal water (Kjelgren et al., 2000). Assessments by plant and turfgrass experts indicate that water savings generally can be achieved with minimal loss in amenity characteristics of existing landscapes because people often overwater urban lawns and gardens (Kjelgren et al., 2002).

Most research on water conservation has focused on identifying sources of water waste, developing water efficiency measures, and administering and evaluating water conservation programs (e.g., Ferguson, 1987; Planning and Management Consultants, Ltd, 1993; Pacific Institute, 1999; Kilgren, 2001; Vickers, 2001; Green Associations Water Conservation Council, 2006). Municipal water conservation programs have concentrated, for the most part, on increasing the efficiency of indoor water use through retrofitting plumbing fixtures (faucets, shower heads, toilets), promoting use of low-water appliances (e.g., washing machines), and encouraging people not to let water run when it is not being used. However, increasing attention is being focused on landscape water use, as demographic change and suburbanization trends in arid regions of the U.S. fuel increasing water demand.

Much of the research on urban landscape water conservation has been conducted by irrigation engineers, plant scientists, landscape designers, and some cultural observers. Irrigation engineers emphasize evaluating the application efficiency of various types of irrigation technologies and developing guidelines for their efficient use (e.g., Bennett and Hazinski, 1993; Irrigation Association, 2005a,b). Plant scientists have focused on determining the actual water needs of various types of plant material and promoting transitions to xeric, water-wise, and native plant landscapes (e.g., Knopf, 1991; Ellefson et al., 1992; Costello and Jones, 1994; Denver Water and Rob Proctor, 1996; Mee et al., 2002). The interest of landscape designers and cultural observers has largely been to understand people's aesthetic preferences for and obsessions with certain types of landscape designs and trends (e.g., Jenkins, 1994; Teyssot, 1999; Bormann et al., 2001; Hooper, 2003; Nielson and Smith, 2005; Guenter, 2006; Larsen and Harlan, 2006; Steinberg, 2006).

Water conservation literature from a human behavioral perspective is embedded in a larger body of research that has focused on trying to identify the key factors that either encourage or constrain people from engaging in resource conservation efforts and environmentally sustainable behaviors. Most environmental behavior research has emerged from various psychology subdisciplines and focused on the influence of attitudes, motivations, social orientations, decision-making processes, prior experiences, and demographics on the environmental behaviors of individuals (e.g., Hines et al., 1987; Ajzen, 1991; Cameron et al., 1998; Kaiser et al., 1999; Werner, 1999; DeYoung, 2000; Kaplan, 2000; Stern, 2000a,b; Kurz, 2002; Vining and Ebreo, 2002; Gregory and Di Leo, 2003; Saunders, 2003; Dietz et al., 2005). Findings have not been definitive as to factors shaping environmental behavior because of the difficulties in measuring these concepts at the right level of specificity and the influences of multiple contextual factors on behaviors. Generalizing across various domains of environmental behavior (e.g., recycling, energy conservation, water conservation) also has proven problematic because of variations in the nature of different resources and the ways they are obtained, used, and disposed. Some researchers have emphasized the importance of proenvironmental knowledge and skills for putting into effect proenvironmental attitudes (e.g., Hines et al., 1987; DeYoung, 1988/89; Corral-Verdugo, 2002; Monroe, 2003). Others have stressed the need to consider the social and ecological contexts within which behaviors take place and the ways in which people interact with things that cause them to have an environmental impact (Altman and Rogoff, 1987;

Baron and Misovich, 1993; Hormuth, 1999; Stern, 2000a,b; Kurz, 2002; Kurz et al., 2005).

Drawing upon this body of literature, Gregory and Di Leo (2003) developed an environmental behavior model that looks at the effect on water consumption of stimuli (or awareness, such as environmental concerns, knowledge, opportunities to conserve), reasoned influences (attitudes, intentions, normative components), unreasoned influences (habits, routines), and situational influences (income, education, household characteristics, and environmental influences). The model advances our understanding of environmental behavior by explicitly recognizing the role of unreasoned influences that traditional attitudinal models fail to take into account. In their model, various physical environment variables that other studies found to be correlated with residential water consumption are considered situational influences, such as climatic conditions (temperature and precipitation), household and lot size, number of water-using appliances, and assessed value of the residence.

Gregory and Di Leo's model of residential water conservation is conceptually consistent with one developed by Bruvold and Smith (1988) in which they posit that the immediate determinants of residential water consumption consist of two sets of locational factors, behavioral responses and structural responses, and a set of external or exogenous variables (temperature, rainfall, household income, and household size). Bruvold and Smith hypothesized that various residential water conservation program interventions impacted residential water use either indirectly through mediating cognitive processes or directly, thereby influencing changes in behavioral and structural responses.

Both of these models draw attention to the roles of situational or structural factors and of outdoor water use in water consumption patterns. Other findings point to the importance of these factors. Syme et al. (1991) found that the contribution of a garden to the resale value of a house and a garden as a source of recreation were the strongest predictors of water use. Property value was also an important predictor of water use in other studies, as was income which may be a proxy for property value (see Aitken et al., 1994, and Gregory and Di Leo, 2003, for reviews). In their insightful and close examination of the dynamics of water's flow and control, Chappells et al. (2001:169) noted that "patterns of consumption are strongly determined by infrastructural arrangements and by the habits, expectations, and practices they engender and sustain…infrastructures and systems of water supply actively create and structure demand [and] do not simply meet it."

Few researches on water consumption and conservation have focused specifically on landscape water use, social and behavorial aspects of how people interact with their landscapes, the performance of irrigation technologies in everyday settings, or integrating perspectives from different disciplines. The research reported on in this paper used an innovative interdisciplinary and cooperative approach to analyze factors affecting water use on residential and business landscapes in the urban community of Layton, Utah. The interdisciplinary team consisted of researchers from the fields of plant science, engineering, social science, and policy. The basic conceptual approach was to utilize a water budget to determine the amount and location of urban landscape water that could potentially be saved by reducing irrigation in excess of plant needs, and to survey households and businesses in the study area to identify factors that affect urban landscape water use patterns. The research was facilitated by cooperation between Utah State University (USU) and the City of Layton. City officials shared water utility billing information upon which much of the research and data analysis depended. The research findings provided by USU could, in turn, contribute to designing more targeted and cost-effective municipal water conservation strategies.

Layton is a rapidly growing community located on the Wasatch Front approximately 30 miles north of Salt Lake City. Its population at the 2000 U.S. Census was 58,474. The economic base of the community is highly dependent on Hill Air Force Base, which is located on its northern border, and otherwise consists of a mix of other government and private sector activities. The majority of the city's water supply comes from the Weber River, which flows west out of the Wasatch Mountains toward the Great Salt Lake, but neighboring communities that are also growing rapidly depend upon this same water source. Urban expansion in the area is contributing to agricultural land conversion and corresponding transfers of water from agricultural use to municipal and industrial use. However, long-term growth scenarios have prompted water officials to seek additional supply sources from more distant rural areas, particularly the Bear River Basin to the northeast. In this context, urban water use efficiency and conservation efforts are particularly important as cities attempt to accommodate growing populations and urban landscaping while reducing impacts to the agricultural sector.

The research took place in the context of drought. The residential population was surveyed in July and August of 1999 and the commercial properties were surveyed during the summer of 2001. Utah experienced its first year of a drought cycle in 1998. By 2001, most of Utah's municipalities and state officials were urging people to conserve water. All five water

conservancy districts in Utah were participating in the "Slow the Flow: Save H20" campaign, which was designed to educate the public on water conservation measures. Television and radio advertisements were run to remind residents of the importance of conserving water and provide tips on how to save water. The primary emphasis was placed on reducing outdoor water use. A number of cities and counties placed a moratorium on watering lawns between the hours of 10:00 AM and 06:00 PM. Although one major Utah city, Sandy, did increase its water rates during this time, most municipalities used voluntary measures to reduce residents' water use. Residents were encouraged to adjust or repair their sprinkler systems to avoid overwatering, accommodate seasonal weather changes and precipitation, and not spray sidewalks and streets. At the end of the 2001 season, state water managers found that water use had dropped by almost 9% during peak demand times, and overall use during the months of June and July also decreased.

In the Methods section of this paper, we describe the interdisciplinary approach to our research, including methods used by each of the disciplines involved. However, in the Findings section, we focus on analysis of the household and business survey data, which explores factors affecting urban landscape water use from a human behavioral perspective. An overview of the entire project is important because the interdisciplinary collaboration provided an independent measure of people's landscape water use in relation to the amount of water their landscape plant material needed to remain healthy. This measure was used to categorize each household or business in terms of the appropriateness of its landscape water use relative to an ecologically-based standard of waste and efficiency. This categorization became the key dependent variable in the social analysis of water use behaviors.

METHODS

The research was originally conceptualized based upon several operating hypotheses. The first hypothesis was that urban landscapes are generally overwatered, by businesses even more so than households, and that this is primarily a human behavior issue, especially in relation to how people operate their irrigation systems. In the case of businesses located in the study area, we thought that many of them might be owned and/or operated by nonlocal entities and this management structure, as well as the nature, size, and shape of business landscapes, might be

factors influencing their greater water use. Secondly, in addition to the American lawn tradition (Jenkins, 1994; Teyssot, 1999; Bormann *et al.*, 2001; Steinberg, 2006), Utah has a deeply rooted cultural tradition of trying to "make the desert bloom" (McCool, 1995), and we thought it might be hard to change this landscape preference through promoting the use of predominantly native and water-wise plant material. Thus, we hypothesized that people can conserve water used outdoors even while maintaining existing landscapes in good condition by employing more efficient watering practices (Ferguson, 1987). This hypothesis assumes that water savings can occur without requiring xeriscaping or transitions in plant material, so existing landscape preferences are granted to users. Third, consistent with most environment behavior research, we had hypothesized that water conservation is the result of conscious and intentional actions, generally resulting from people's motivations, knowledge, and experiences in relation to conservation.

The research site consisted of a 5-mile square area (2.5 miles by 2 miles) within the Layton City limits bisected by Interstate 15 with the Layton Hills Mall approximately in the center. This area was chosen because it included households and businesses on metered city water with little or no access to older secondary water systems (mostly converted agricultural water delivery systems). Within this area, there were 3,083 households and 197 commercial properties. Institutions such as schools, churches, and government facilities were excluded, as were multifamily complexes such as apartments and condominiums.

The research project involved the following three basic tasks: (1) applying a "water budget" by determining the amount of water that existing urban landscapes actually needed based on local climate, (2) categorizing water use by determining how much the water actually applied varied from what the landscapes needed (locations were categorized as having conserving, acceptable, or wasteful watering practices), and (3) explaining variations in water use based upon surveys administered to a sample of households and businesses in the study area.

The first task was applying a "water budget," the estimated water needs of the landscape derived from reference evapotranspiration (ETo) obtained using weather data for the Salt Lake City metropolitan region. Our "water budget" was a modification of an approach pioneered by the Irvine Ranch Water District in Southern California for establishing water rate structures (Wong, 1999; Irvine Ranch Water District, 2007). This led to estimates of the amount of irrigation water that these landscaped areas required to be kept in good condition. Equation (1) was used to

estimate the amount of irrigation water needed to replace that used by the landscape:

$$I = ((ETo_p * Kc) - R_p)/DU, \tag{1}$$

where I is estimated irrigation need in depth units (inches or mm), ETo is reference evapotranspiration, a standardized measure of water loss from a large, uniform, well-watered cool-season turf (Allen et al., 1994), Kc is the "crop" or vegetation water use coefficient that varies with plant type, ranging from 0.7 to 0.9 for cool season turf (Kneebone et al., 1992; Ervin and Koski, 1998) and from 0.2 to 1.0 for woody plants (Montague et al., 2004), and R_p is rainfall and DU is the distribution uniformity of the irrigation system, or how uniformly water is applied, which is critical for maintaining acceptable turfgrass appearance and is measured by a fraction between 0 and 1, 1 being completely uniform application (Burt et al., 1997). In practice, most urban landscape irrigation systems are somewhat nonuniform, with DUs in the range of 0.6-0.7, the upper number being an acceptable standard (Kjelgren et al., 2000).

The second task involved devising a categorization scheme to represent how much actual landscape water use deviated from the appropriate amount of irrigation to meet plant needs. Actual landscape water use of households and businesses was derived from a separate water billing database obtained from Layton City and calculated as the amount of water applied monthly over the growing season minus baseline (indoor) water use during winter months when there is no landscape irrigation in this snow-covered area. The approach assumes that indoor water use is constant throughout the year.

Actual landscape water use was divided by irrigated landscape area derived from remote sensing. Airborne multispectral digital images for the Layton urban area were collected in 1998 and processed to produce a calibrated mosaic, which was then classified to obtain landscape type and area. This information was then integrated with the Layton City parcel boundary data in a geographic information systems (GIS) database to determine urban landscape vegetated areas per lot (Farag et al., 2001; Farag, 2003). Figure 1 provides an example of the original false color images and the subsequent classified image used in this analysis. The landscape area information was verified by manual ground measurements (using a wheel measure) of vegetated areas and regressing on GIS-derived areas. The relationship between GIS-derived areas and ground truth measurements was significant for residential landscapes (Farag, 2003). The commercial parcel boundary database had not been updated in a number of years and thus was unusable, so landscaped areas of all surveyed properties used in this study were measured manually. Estimated volume of landscape irrigation was then normalized to depth units (measured in inches and converted to mm) by dividing by the remotely sensed, and ground measured, landscape areas, thus factoring out differences in water use due to size of landscaped area.

Because we did not measure distribution uniformity of the irrigation systems used by households and businesses in this study, and given the inherent variability in turfgrass and woody plant Kc values, categorizing deviation of actual water use from estimated needs tailored to each property was not possible. Instead, two water "thresholds" were identified based upon different assumptions about watering practices: (1) the "floor," defined using Equation (1) as the amount used if irrigation water is applied from May 1 through September 30 (a conservative but sufficient estimate of the length of the irrigation season) at a rate that meets plant evapotranspiration needs but with rainfall subtracted (assumes sprinklers are turned off during rain); and (2) the "ceiling," defined again using Equation (1) as the amount used if irrigation water is applied from April 1 through October 30 (a liberal estimate of the length of the irrigation season) at a rate that meets plant evapotranspiration needs without subtracting rainfall (assumes sprinklers are not turned off during rain). Table 1, which provides threshold calculations for 1997-2001, illustrates how the thresholds vary from year to year in response to changes in ETo and rainfall, thus allowing us to control for climate variability. The lowest thresholds were in 1997, a relative cool and wet year, but progressively increase (the upper threshold by 28% and the lower threshold by 67%) over four years through 2001, which was much hotter and drier. Implicit in the use of Equation (1) to calculate the floor and ceiling are two simplifying assumptions. First, we assume that Kc and DU are both 0.7, albeit at the lower and upper end of their ranges. Second, we assume that the entire landscape is turfgrass, which occupies the majority of landscape area for Layton (Farag, 2003).

Three water use categories were then defined in relation to these thresholds: (1) "conserving" water use is watering at or below the "floor", (2) "acceptable" water use is watering between the "floor" and "ceiling," and (3) "wasteful" water use is watering above the "ceiling." The conserving category means that water use is less than that needed to keep turfgrass in acceptable appearance, either because of deficit irrigation or use of lower water use nonturf
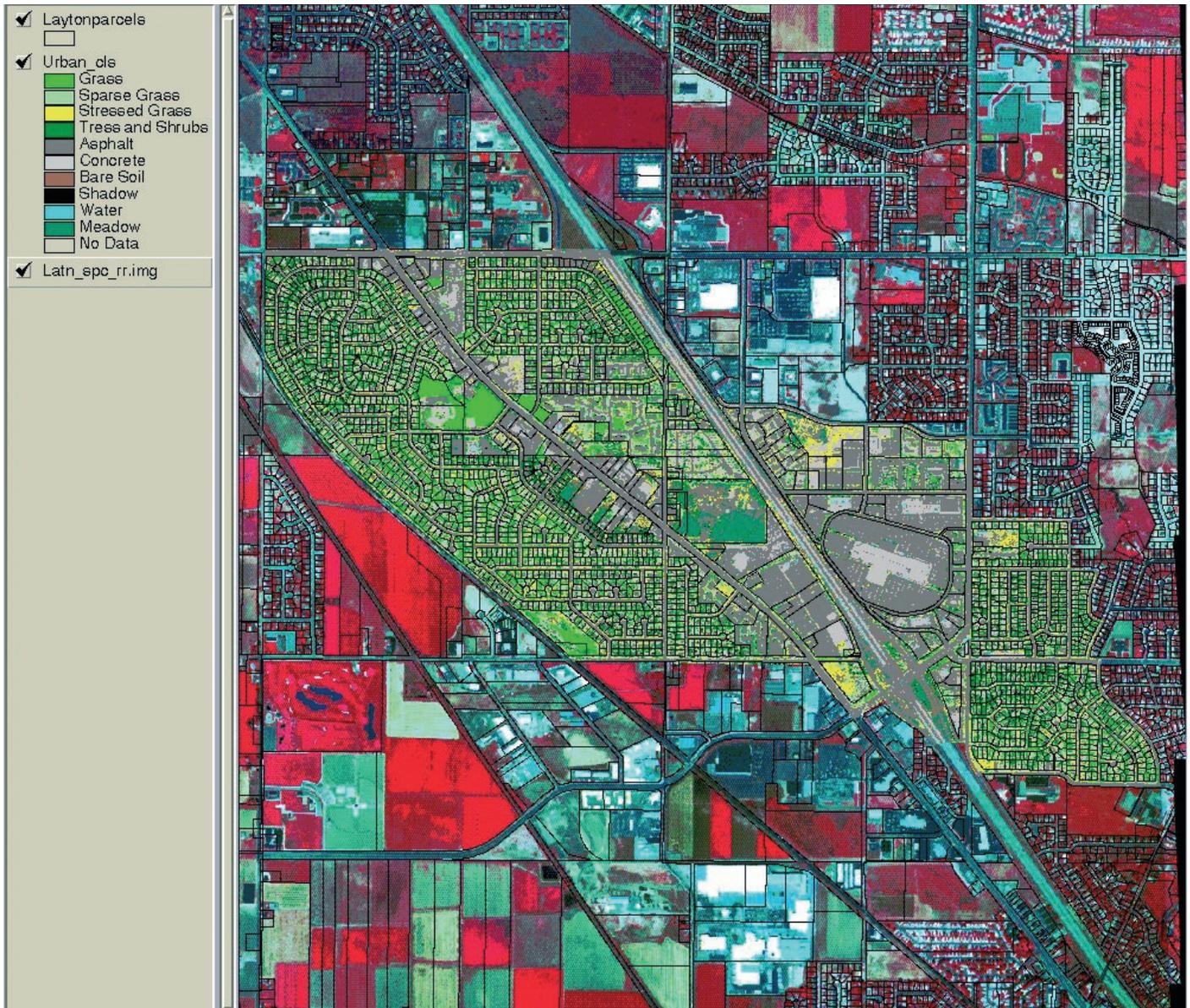
FIGURE 1. Classified Image of a Layton Neighborhood Imbedded Over a False Color
Composite Digital Multispectral Image Mosaic Obtained With the USU Airborne System.

TABLE 1. Water Use Thresholds Used in Categorizing
Household and Business Water Use, 1997-2001.

	1997	1998	1999	2000	2001
	Millimeters				
Upper Threshold					
ETo, April-October	843	904	912	1062	1080
ETo, May-September	678	719	737	886	904
Rainfall, May-September	183	221	140	152	74
Lower Threshold					
ETo – rain, May-September	495	500	594	734	828

plants. The acceptable water use category represents consumption that can be justified by Equation (1) under most circumstances, although certainly at the upper end there is room for conservation. The wasteful water use category represents excessive use that cannot be justified using Equation (1) and thus the end user has capacity to conserve.

The third task involved administering surveys to households and businesses in the study area to gather data that would help explain variations between units placed in different water use categories. Both the household and business surveys were

designed primarily to gather information specific to landscape water use and conservation. Questions focused on landscape perceptions, responsibilities for the landscape and paying water bills, watering practices, irrigation system characteristics and maintenance, presence of other outdoor water-using devices (pools, hot tubs, water features, etc.), motivations and attempts to conserve water, installation and use of indoor water saving devices (assumed to be a corresponding water conservation behavior), general knowledge about local and state water issues, opinions about drought and various approaches to water conservation, and background information on the household or business as well as the person(s) responsible for landscape oversight and maintenance. Household and business survey information was coded and then entered and analyzed using the Statistical Package for the Social Sciences (SPSS for Windows, 2006).

Households were surveyed in 1999 using a self-completion questionnaire that was dropped off and picked up at households randomly selected from a list of all households in the study area that had been stratified according to average water use during the two previous summers (1997 and 1998). The person responsible for watering the lawn was asked to complete the household questionnaire. Of the 322 households that were contacted (approximately 10% of the total of 3,083 households), 296 completed the questionnaire for a response rate of 92%.

Businesses were surveyed in 2001 using face-to-face administration of a survey instrument because of challenges involved in identifying the person that needed to complete the survey. The on-site business manager was initially contacted to obtain information about business and property ownership and management, and then two different sections of the survey were administered, one to the person responsible for overseeing maintenance of the business' landscape and another to the person who actually maintained and watered the landscape (with provisions for survey administration if this was the same person). Although we had water billing data for the businesses, we did not stratify the businesses by the amount of water used on their landscapes (as was done with residential properties), but instead decided to survey 100 businesses, or approximately 50% of the 197 total. A total of 98 businesses participated in the survey, for a response rate of 98%. For the current analysis, we eliminated 10 of the 98 businesses because two did not have accurate water billing data, one did no landscape watering, and seven had irregular patterns of water use that could not clearly be attributed to landscape watering.

FINDINGS

The basic characteristics of the sample populations are depicted in Table 2 (households) and Table 3 (businesses). These tables reveal several important points about the diverse contexts within which landscape watering occurs. In terms of households, there is wide variability in the age of the housing structures, how long survey participants have occupied them, and basic demographic characteristics of the occupants. However, most of the households surveyed were owner occupied (88.5%) and all of the occupants (including renters) maintained their own landscapes (no households hired a professional landscaper). In terms of businesses, various types of commercial establishments were represented in the sample. The most significant factor that distinguishes businesses from each other (and from the household group) is the wide variety of combinations of property and business ownership and management, and of responsibilities for overseeing and doing the landscape work.

A basic profile of water use in Layton is presented in Table 4. Of the 376 cases included in water use analyses (households and businesses) and represented in the "all cases" column, almost 37% of all households and businesses were "conserving" in landscape water use (below the "floor" threshold in the year prior to the one in which they were surveyed). About 24% were within the acceptable range (between "floor" and "ceiling" thresholds) and 39% exhibited wasteful water use (above the "ceiling" threshold). Landscape watering was done with different irrigation methods. About 41% of cases primarily watered landscapes manually with a sprinkler or spray nozzle and hose (i.e., above-ground irrigation system that is manually moved, started, and stopped), 9% primarily watered with an underground manually started sprinkler system, and about 50% primarily watered with a programmed sprinkler irrigation system (i.e., underground, fixed system that is started and stopped with a time clock).

In interpreting this relationship, it is useful to think of the three categories of landscape watering systems as increasing levels of automation (i.e., increased convenience of landscape watering). Manual watering with a hose typically requires the most manual labor to water landscapes, while a programmed underground system typically requires the least. Using this conceptualization, Table 4 illustrates a moderately strong and positive correlation between range of water use and automation of watering system (Gamma correlation coefficient = 0.63, chi-square = 89.05, $p < 0.001$). This relationship is also evident in the percentages in each water use range

TABLE 2. Characteristics of Layton Household Sample, 1999.

Household Characteristics

Year house was built (259 responses)	
Mean	1968
Median	1970
Mode	1960
Percentage of houses built since 1950	85%
Percentage of houses built since 1930	96%
Year occupants moved into residence (287 responses)	
Mean	1986
Median	1991
Mode	1997
Percentage there less than five years	31%
The occupants of the house (295 responses)	
Own the house	88.5%
Rent the house	9.8%
Other	1.7%
Number of people in household (284 responses)	
Mean	3.5
Median	3.0
Mode	2.0
Total household income before taxes (260 responses)	
Under $8,000	2.3%
$8,000 to $19,999	6.2%
$20,000 to $39,999	34.2%
$40,000 to $59,999	32.3%
$60,000 to $79,999	19.2%
$80,000 to $99,999	3.1%
$100,000 to $120,000	1.9%
over $120,000	.8%

Respondent Characteristics

Age of respondents (282 responses)	
Mean age	44 years
Median	42 years
Mode	30 years
Gender of respondents (288 responses)	
Male	54.5%
Female	45.5%
How long have you lived in Layton? (287 responses)	
Mean	18 years
Median	13 years
Mode	2-3 years
How long have you lived in Utah? (281 responses)	
Mean	29 years
Median	28 years
Mode	30 years
Were you born in Utah? (291 responses)	
Yes	48.1%
No	51.9%
Residence outside Utah (289 responses)	
Have lived in other states	66.8%
Have lived in other countries	25.6%
Education (285 responses)	
Did not complete high school	2.8%
Graduated from high school	22.5%
Attended some college/trade school	33.7%
Graduated from college/trade school	32.3%
Attended graduate school	2.8%
Completed graduate school	6.0%
Racial or ethnic background (283 responses)	
American Indian/Native American	1.1%
Asian	3.2%
Black/African American	2.8%
Hispanic/Mexican American/Latino	4.9%
White/Caucasian	86.9%
Other	1.1%

TABLE 2. Continued

Political affiliation (247 responses)	
Democrat	23.1%
Independent	13.8%
Libertarian	1.6%
Reform	1.2%
Republican	49.8%
Other	10.5%
Religious affiliation (274 responses)	
Latter Day Saints	57.3%
Protestant	11.7%
Catholic	11.7%
Other	5.1%
No religious affiliation	14.2%
Self-rating of social views (282 responses)	
More socially conservative	31.9%
More middle of the road	58.2%
More socially liberal	9.9%

by type of system. Almost 63% of cases that primarily watered with a hose were conserving compared to about 17% of cases with a programmed sprinkler system. Conversely, about 14% that primarily watered with a hose were in the wasteful range compared to about 57% with a programmed system. Among cases with an underground but manually-started sprinkler system, about 29% were in the conserving use range while about 53% were in the wasteful use range.

Table 5 explores this relationship between water use and increasing levels of automation separately for households and businesses. Among households, 63.7% of those who primarily watered with a hose were conserving compared to 41.7% of those with a manually started sprinkler system and 18.6% of those with a programmed system. On the other end of the water use range, 50.8% of households with programmed systems watered in the wasteful range, compared to 41.7% with manually started sprinklers and 13.7% with manual hose watering. The gamma correlation coefficient for this statistical relationship, 0.63, is the same as the overall sample.

The same tendency is observed for businesses but the correlation is not statistically significant and the gamma coefficient is much smaller, 0.18. This is due to prevalence of programmed systems among businesses and a stronger tendency for businesses to be in the high water use category. Almost 81% of businesses primarily watered with a programmed system (71 of 88 businesses in the sample). Only seven businesses primarily watered with a hose (8%) and only 10 businesses (11.4%) primarily watered with a manually started sprinkler. Also, a larger proportion of all businesses (64.8%) were in the high water use category compared to all households (31.3%). However, it is also important to note that while automation of watering systems appears to promote overwatering,

TABLE 3. Characteristics of Layton Business Sample, 2001.

Business Characteristics	
Business Characteristics	
Type of business (95 cases)	
Restaurants, fast foods, salons	21.1%
Offices, medical, insurance, realtors	16.8%
Retail sales	45.3%
Laundry services	2.1%
Hotels, motels	3.2%
Car wash	1.1%
Warehouses, construction, manufacturing.	5.3%
Malls, strip malls	5.3%
Landscape Responsibilities	
Person who oversees landscape work (95 cases)	
Business manager (in one case an employee)	46.4%
Business owner	31.6%
Property manager	11.6%
Property owner	7.4%
Other	3.2%
Person who does landscape work (95 cases)	
Business manager	15.8%
Business employee	8.4%
Business owner	22.1%
Property manager	1.1%
Property owner	5.3%
Landscape service	44.2%
Other	3.2%
Person who pays landscaping services bill (43 cases)	
Business manager	32.6%
Business owner	4.7%
Property manager	18.6%
Corporate office	34.9%
Accounting/secretary	9.3%
Primary Interviewee *(95 interviewees) ~ characteristics of overseers of landscape work, some of whom also do landscaping*	
Age of person who oversees landscape (95 responses)	
Mean number of years	42 years
Standard deviation	11.3
Range of number of years old	22-82
Gender of person who oversees landscape (95 responses)	
Male	76.8%
Female	23.2%
Length of time living in Utah (95 responses)	
Mean number of years	32 years
Standard deviation	15.7
Range of number of years in Utah	1-68
Time overseeing this landscape (94 responses)	
Mean number of years	6 years
Standard deviation	6.6
Range on # years for this landscape..	1-45
% Responsible for three years or less	51.1%
Time in business/property management (65 responses)	
mean number of years	11 years
standard deviation	9.6
range of number of years	1 to 45
percentage in it for 3 years or less	27.7%
Degree/discipline in higher education (93 responses)	
Landscaping	1.1%
Business management	40.9%
Engineering	6.5%
College degree unrelated	9.7%
Some college/training	16.1%
On-the-job training	8.6%
None	17.2%

TABLE 3. Continued

Secondary Interviewee	
Secondary Interviewee *(n = 35) ~ characteristics of hired landscapers and employees who do landscape work*	
Age of landscaper (28 responses)	
Mean number of years	39 years
Standard deviation	8.3
Range of number of years old	22-55
Gender of landscaper (28 responses)	
Male	93.0%
Female	7.0%
Length of time living in Utah (28 responses)	
Mean number of years	29 years
Standard deviation	13.6
Range of number of years in Utah	3-51
Time in the landscaping business (28 responses)	
Mean number of years	12.6 years
Standard deviation	10.5
Range of number of years	<1 to 40
% In business five years or less	32.0%
Type of training in landscaping (28 responses)	
Self-trained, on- the-job	60.7%
USU degree or master gardener	17.9%
Workshops, seminars	10.7%
None	10.7%

this effect is not deterministic; among both households and businesses, some cases exhibited wasteful water use with manual watering while others were conserving with programmed and manually started sprinkler systems.

The prevalence of overwatering among businesses suggests there may be differences between households and businesses besides the watering system that influence the amount of water used on landscapes. One difference between residential and commercial landscapes involved the size and shape of landscaped areas. As illustrated in Figure 2, commercial landscapes exhibited much greater variability in size than household landscapes, which tended to occur mostly on standard quarter-acre residential lots (about 1,012 m^2). Many commercial landscapes were smaller in size than residential landscapes, generally consisting of planter areas surrounding buildings. The effect of this difference is also illustrated in Figure 2 because, for both households and businesses, overwatering tended to occur on smaller landscapes, where there was also much larger variability between units of similar size. A second difference between water use on residential and business landscapes relates to the years in which these units were studied. Households were studied in 1998 as Utah entered a drought period (1997 was used as their baseline), while commercial landscapes were studied in 2001 after several years of drought (2000 was used as their baseline). While the thresholds used in categorizing households and businesses took ETo and rainfall into account and allowed for greater water

TABLE 4. Range of Water Use by Automation of Watering System, All Cases.

Water Use Range Relative To Plant Need	Level of Automation of Watering System* (percentages within each category)			All Cases
	Low (manual hose watering)	Medium (manual start sprinkler)	High (programmed sprinkler)	
Low (conserving use)	62.7	29.4	17.5	37.0
Medium (acceptable use)	22.9	17.6	25.9	23.9
High (wasteful use)	14.4	52.9	56.6	39.1
Column percentage totals	100.0	99.9	100.0	100.0
Number of total cases	153	34	189	376
Percentage of total cases	40.7	9.0	50.3	100.0
Descriptive statistics:				
Pearson's chi-square = 88.84 (*p* < 0.001)				
Gamma correlation coefficient = 0.63				

*In the questionnaire, respondents were asked to indicate all methods used for watering their landscapes and to approximate the percentage of the landscape that was watered with each method. Based on these responses, the table displays the primary method used.

TABLE 5. Range of Water Use by Automation of Watering System, Comparing Households and Businesses.

Water Use Range Relative to Plant Need	Level of Automation of Watering System* (percentages within each category)			All Cases
	Low (manual hose watering)	Medium (manual start sprinkler)	High (programmed sprinkler)	
Households				
Low (conserving)	63.7	41.7	18.6	43.4
Medium (acceptable)	22.6	16.7	30.5	25.3
High (wasteful)	13.7	41.7	50.8	31.3
Column percentage totals	100.0	100.1	99.9	100.0
Number of households	146	24	118	288
Percentage of households	50.7	8.3	41.0	100.0
Descriptive statistics:				
Pearson's chi-square = 62.65 (*p* < 0.001)				
Gamma correlation coefficient = 0.63				
Businesses				
Low (conserving)	42.9	-	15.5	15.9
Medium (acceptable)	28.6	20.0	18.3	19.3
High (wasteful)	28.6	80.0	66.2	64.8
Column percentage totals	100.1	100.0	100.0	100.0
Number of businesses	7	10	71	88
Percentage of businesses	8.0	11.4	80.7	100.1
Descriptive statistics:				
Pearson's chi-square = 6.94 (*p* > 0.05)**				
Gamma correlation coefficient = 0.18				

*In the questionnaire, respondents were asked to indicate all methods used for watering their landscapes and to approximate the percentage of the landscape that was watered with each method. Based on these responses, the table displays the primary method used for each case.

**For businesses, five of nine table cells had fewer than five cases, resulting in an "unreliable" chi-square test statistic. This is due to a relatively small number of cases (89 businesses) and the prevalence of programmed watering systems among businesses (72 out of the 89 cases).

use in drought years (Table 1), it is possible that people's perceptions of drought and its effect on landscape vegetation contributed to overwatering in excess of plant need.

Analysis of the combined survey dataset confirmed some other obvious differences between household and business water use. Among the factors explored were the importance they place upon and the reasons for maintaining their landscapes, as well as use of a professional landscape maintenance service. Table 6 contains data on perceptions of landscape qualities and shows that business respondents (business owners or managers and landscapers or employees) placed a higher value on maintaining lush, uniformly green landscapes than household respondents. Even though business landscapers placed higher importance on a lush, uniformly green landscape than business managers, more of them
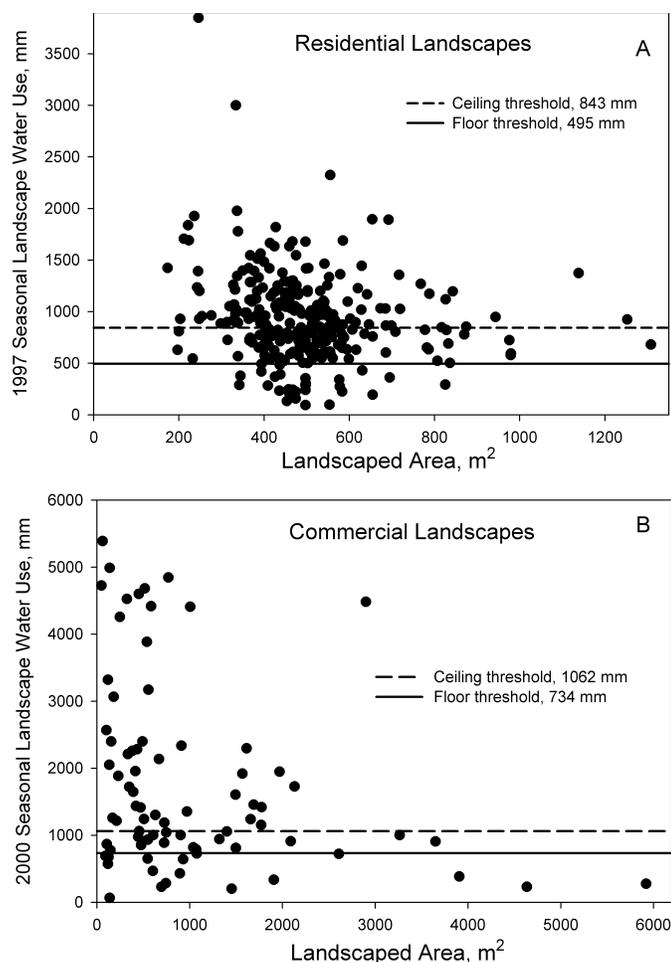
FIGURE 2. Seasonal Water Use by Surveyed Residential (A) and Commercial Landscapes (B) as Related to Landscaped Area and Maximum and Minimum Threshold Water Needs.

TABLE 6. Landscape Qualities: Comparison of Business and Household Respondents' Perceptions.

Questions Posed to Respondents	Business Respondents (percent)		Household Respondents (percent)
	Owners or Managers	Landscapers or Employees	
"How important is it to maintain a [lush green/uniformly green] lawn?"*			
Means	8.4	9.2	7.6
Response distributions			
0 Not at all important	0.0	0.0	0.3
1-3 Minimally important	3.2	0.0	3.4
4-6 Somewhat important	7.4	3.6	21.7
7-9 Important	52.6	35.7	48.6
10 Very Important	36.8	60.7	25.9
"What qualities of this landscape are most important to you?"**			
That is it colorful	54.7	66.7	n.a.
Ease of maintenance	69.5	74.1	n.a.
That it looks neat	91.6	88.9	n.a.
Having diversity in the plants	18.9	48.1	n.a.
It conserves water	29.5	59.3	n.a.
Other	5.3	14.8	n.a.
Number of respondents	95	27	290
Nonrespondents	0	8	6
All cases	95	35	296

*Responses rated on a 0-10 scale with 0 indicating "not at all important" and 10 indicating "very important."
**Percentages; multiple responses possible.

rated conserving water, having a diversity of plant material, color, and ease of maintenance as important qualities in a landscape.

Table 7 contains responses to the question of why survey participants think it is important to maintain their landscapes. All respondents generally think it is important to have a pleasing/nice landscape but they differ in other respects. Business owners and managers place higher importance on reasons related to attracting customers and business promotion. Landscapers place greater importance on personal pride, maintaining the reputation of their landscaping firm, satisfying the property owner, and enjoyment of yard work (significantly higher than for the other two categories of respondents). Household respondents are similarly concerned about personal pride and how a landscape reflects on them, but their reasons relate more to how the landscape is used (place for children to play, setting for family get togethers).

We explored the dataset broadly for bivariate statistical correlation to water use, using a variety of quantitative and qualitative statistical methods. These efforts did not reveal *any* relationships stronger than the two variables already explored in Tables 4 and 5 – type of watering system and type of water consumption unit (i.e., household *vs.* business). We paid particular attention to all of the household, business, respondent and interviewee characteristics reported in Tables 2 and 3 as some of these factors have been correlated with water use in other studies.

Household water use was also explored in greater detail in other analyses. Personal factors such as demographic characteristics, motivation to conserve, knowledge of water issues, environmental attitudes, and other conservation practices (recycling, indoor water conservation efforts) were not related to outdoor water use. However, the influence of the watering system was strong, even producing the counterintuitive result that manual system users who reported landscape watering practices and mindsets that would seem to promote water waste exhibited low levels of water use (Klien, 2004).

Recognizing some clear differences between household and business landscapes, and the prevalence of programmed systems among business landscapes, we

TABLE 7. Importance of Maintaining Landscapes: Comparison of Business and Household Respondents' Perceptions.

Question Posed to Respondents: "Why Is It Important to Maintain Your Landscape?"*	Business Respondents (percent)		Household Respondents (percent)
	Owners or Managers	Landscapers or Employees	
Response categories for businesses and households			
To make the landscape look pleasing/nice	91.6	89.3	86.4
It offers a sense of personal pride	55.8	89.3	78.9
Because you enjoy doing yard work	11.6	71.4	39.1
To increase the property value	49.5	n.a.	56.1
Just to keep the grass and plants from dying	36.8	n.a.	37.8
Other	13.7	25.0	3.1
Response categories for business respondents			
Neighboring businesses have nice landscapes	26.3	46.4	n.a.
To attract customers to your business	85.3	n.a.	n.a.
Landscape standards established by home office	24.2	n.a.	n.a.
Nice setting for customers to relax in	34.7	n.a.	n.a.
Nice setting for employees to relax in	24.2	n.a.	n.a.
It reflects well on your business	91.6	n.a.	n.a.
Landscape standards established by property management firm	n.a.	57.1	n.a.
That is what I am instructed to do	n.a.	71.4	n.a.
To please the property owner	n.a.	75.0	n.a.
Part of the terms of our landscaping contract	n.a.	50.0	n.a.
To maintain reputation of landscaping firm	n.a.	75.0	n.a.
Response categories for household respondents			
Nice setting for family get-togethers	n.a.	n.a.	55.8
Because neighbors have nice lawns	n.a.	n.a.	24.5
A place for children to play	n.a.	n.a.	57.1
Room for pets to roam	n.a.	n.a.	21.4
Nostalgia – reminds you of growing up	n.a.	n.a.	11.2
Required by homeowner covenant	n.a.	n.a.	3.7
It reflects well on you as a homeowner/renter	n.a.	n.a.	69.7
Number of respondents	95	28	294
Nonrespondents	0	7	2
All cases	95	35	296

*Percentages; multiple responses possible.

focused attention in this article on trying to find other factors which might explain the higher water use among businesses. These efforts culminated in an attempt to produce a multivariate logistic regression model predicting wasteful water use among businesses using survey data, based upon analyses of descriptive and correlation statistics. While results of these models were suggestive of some interesting independent variables predicting wasteful water use, analysis of residuals revealed that results of the regression models were highly dependent on a few outlier cases; removal of these cases resulted in an unsolvable logistic regression model (this result was also partly due to having a small number of business cases, even though over half of all businesses in the area were surveyed).

To reveal some of our thought process in conducting these analyses, Table 8 summarizes some of the more interesting correlations we explored in the logistic regression modeling. For this summary, we dummy coded water use for the cases that had wasteful use compared to those with acceptable or conserving use. (Cases that were wasteful were coded 1 and cases in the other two categories were coded 0.) We also used dummy coding for each characteristic of interest to indicate presence or absence of the characteristic in question. This resulted in a series of 2×2 bivariate cross-table comparisons. We summarize relationships observed by using the odds ratio (Knoke and Bohrnstedt, 1994). In 2×2 comparisons, the odds ratio is 1 when there is no correlation to the independent variable in question. An odds ratio greater than 1 indicates greater likelihood of wasteful use among cases with a given attribute, while an odds ratio between 0 and 1 indicates less likelihood of wasteful use.

Among both households and businesses ($n = 381$), locations with programmed sprinkler systems were more likely to be wasteful (odds ratio = 4.80). This relationship was also illustrated earlier in Table 4. Business locations were more likely to be wasteful compared to household locations (odds ratio = 4.07). This relationship was also illustrated earlier in Table 5.

Comparing all business locations ($n = 88$) in terms of wasteful vs. nonwasteful use, programmed systems were somewhat more likely to be wasteful, with the

TABLE 8. Odds Ratio Comparisons of Nonwasteful to Wasteful Water Use
for Subsets of Cases Representing Different Landscape Watering Contexts.

Characteristics of Landscapes in Subsets of Cases	Odds Ratio	95% Confidence Interval	
		Lower	Upper
All household and business locations (*n* = 381)			
Have a programmed sprinkler system (Table 4)	4.80*	3.05	7.54
Household versus business locations (Table 5)	4.07*	2.46	6.73
A professional landscape service does the watering (only businesses did)	-	-	-
All business locations (*n* = 88)			
Have a programmed sprinkler system (Table 5)	1.37	0.46	4.05
Sprinkler system more than 10 years old	1.15	0.32	4.19
Make watering adjustments after significant rainfall always/usually	0.37*	0.14	0.99
Landscape maintenance was done by			
The business or property *owner*	0.52	0.20	1.32
A business/property *manager* or employee	1.04	0.40	2.72
A professional landscape service	1.76	.71	4.40
Primary respondent indicated that she/he			
Also owns the property	0.38*	0.15	0.96
Resided in Utah 20 or more years	0.35	0.11	1.15
Maintains landscape "so it looks pleasing"	3.46	0.77	15.61
Maintains landscape because neighboring businesses have nice landscapes	1.46	0.53	4.02
Business locations that utilized a professional landscape service (*n* = 36)			
Have a programmed system (all cases did)	-	-	-
Make watering adjustments after significant rainfall always/usually	0.40	0.08	2.14
Landscape service also planted trees, shrubs	0.37	0.04	3.54
Do supplemental manual watering	2.12	0.37	12.16
Cost of service is $200 or more per month	1.73	0.31	9.57
Landscaper was in business more than 10 years	0.32	0.03	3.60

*$p < 0.05$.

odds ratio of 1.37. This ratio was not significant, as illustrated in Table 5 and here in Table 8 with the lower bound of the 95% confidence interval equal to 0.46. As discussed in relation to Table 5, this is due to the prevalence of programmed systems in business landscapes found in the study area.

Two variables suggesting less likelihood of wasteful use were where businesses made watering adjustments after significant rainfall (odds ratio = 0.37), and where the person overseeing the landscape also owned the property (odds ratio = 0.38). Primary respondents who had resided in Utah 20 or more years were also somewhat less likely to have had wasteful watering at their business locations, though variability in this observation resulted in a nonsignificant odds ratio.

None of the other factors presented in Table 8 with odds ratios greater than 1.0 (indicating greater likelihood of wasteful use) were statistically significant. These factors included having a sprinkler system older than 10 years (odds ratio = 1.15), use of a professional landscape service (odds ratio = 1.76), indication by the primary survey respondent that the landscape was maintained so that it "looked pleasing" (odds ratio = 3.46), and indication that the landscape was maintained because "neighboring businesses had nice landscapes" (odds ratio = 1.46).

Similarly, none of the variables explored among the subset of businesses using professional landscape services (*n* = 36) was significantly correlated with water use, suggesting that reasons differentiating conserving cases from those with wasteful water use were highly contextualized (this also reflects the small number of cases, though our high response rate and high proportion of businesses sampled in the study area–nearly half of all businesses–suggest that these results are a good representation of the study area). Tendencies observed were for businesses to be slightly more likely to be wasteful if the cost of landscape services was US$200 or more per month (odds ratio = 1.73) and/or where the landscaper did supplemental manual watering (odds ratio = 2.12). Similar to what we observed for all businesses, businesses where the landscaper always or usually made watering adjustments after a significant rainfall were less likely to be wasteful (odds ratio = .40). Cases where the landscaper also planted trees, flowers, and shrubs were also less likely to be wasteful (odds ratio = 0.37).

In an effort to understand these results, we undertook additional research after the study period to interview landscapers who worked for multiple businesses included in the survey. We found three landscapers who were responsible for maintaining

multiple business landscapes where some of those locations were in the conserving category and some were in the wasteful category of water use. In one case the landscaper was responsible for five different landscapes; two were categorized as wasteful, two were categorized as conserving, and one was in the acceptable range. A second landscaper had a similar situation in which four of the six businesses, whose landscapes he was responsible for maintaining, were in the wasteful water use category and two were in the conserving water use category. A third landscaper maintained three landscapes; one location was categorized as wasteful while the other two were categorized as conserving. In these instances, the sizes of the landscapes were not significantly different, the landscapers had stated during their interviews that they used comparable watering schedules and practices for each of the landscapes, and the landscapers had responded similarly to multiple attitude and knowledge questions. We were able to reinterview the first and second of these landscapers in the summer of 2006 to ask if they could explain the water use discrepancies for these businesses (they still provided the landscaping services). After some discussion, the landscapers were able to offer explanations that suggested the differences in water use were most likely the result of specific site conditions at each particular location. In some instances, the landscapers identified poorly designed or inefficient irrigation systems as responsible for wasteful water use, while landscape conversion to low water use plants at one of the large chain stores was offered as the explanation for conserving water use at that location. Thus, it appears that some of the variation in water use is related to situational factors in each case.

DISCUSSION

In returning to our original hypotheses in light of these findings, we venture an explanatory framework for understanding landscape watering practices that can best be described as "situational waste in landscape watering." We proceed to explain how we arrived at this explanation, what it means, and implications for further research.

Our first hypothesis involved what we thought was a general pattern of overusing water on landscapes, culpability of businesses in comparison to households, and some of the suspected causes. We found that landscapes were not generally overwatered, with only 39.1% of all cases, and 31.3% of households exhibiting wasteful landscape watering (Tables 4 and 5). A significantly larger percentage of businesses (64.8%) did overwater in relation to households, which was partly due to the overwhelming presence of programmed sprinkler systems at business locations. Furthermore, we had assumed that the primary cause of what we suspected to be widespread overuse of water was human behavior and, consequently, the study was designed to understand the perceptions, knowledge, incentives, and practices of people responsible for landscapes that would account for overwatering. What we found, however, was that the most significant factor affecting water use was the type of irrigation system: manual watering with a hose and spray nozzle tended to be associated with more conserving watering practices, while use of programmed sprinkler systems tended to be associated with more wasteful watering practices. One of the most common complaints offered by landscapers when we administered their surveys face-to-face was that programmed systems were frequently operated well below optimum efficiency due to flaws in their design, installation, maintenance, and operation for particular locations.

While programmed sprinkler systems may be designed to achieve watering efficiency, we think that, in practice, they are primarily operated as labor and time saving devices rather than resource (water) saving devices. However, it is important to note that the tendency for programmed sprinkler systems to result in wasteful water use is not as pronounced as the tendency for manual watering to result in conserving water use. This implies that sprinkler systems are less of an inducement to overuse (meaning people can achieve some operational efficiency) than manual systems are an inducement to conserve. We suggest that the same human behavior explaining wasteful water use with automated systems also explains conserving water use with manual systems: convenience. It is convenient to let an automated system water more than a landscape may actually need, because labor is required to adjust water application to meet the needs of the landscape (i.e., turn it off during rainfall, adjust it over the season to accommodate for ETo and rainfall). Alternatively, it is convenient to water less than a landscape may actually need with a hose and spray nozzle because labor is required to manually apply the water. Thus, it is not simply more abstract or generalized human perceptions and behaviors that differentiate wasteful from conserving landscape water use, but the human interface with landscape plant material as mediated by the irrigation technology. The key to explaining differences in landscape water use is understanding the *interface* between users (*human behavior*) and the watering application method (*technology*); any understanding of irrigation efficiency needs to take into account

how this infrastructure shapes the watering practices and habits of its users.

As part of our prediction that businesses overwatered more than households, we assumed the cause may be related to the different sets of responsibilities and incentives that shaped people's behaviors within each of these contexts. We had originally thought that wasteful water use might be the result of absentee owners not paying attention to the water bills at satellite locations, but the data we gathered on exactly who paid the water bill did not support this assumption. However, even in instances where water bills were received and/or paid by on-site managers, the low price of water in Layton likely made this a minor element of most businesses' overall operating budgets and probably did not provide enough of a conservation incentive in instances where landscapes were perceived to be important for the businesses' profitability (e.g., through attracting customers). However, we did find that among all business locations, more conserving water use may have occurred where the business owner also owned the property and may have paid more attention to landscape watering practices such as making adjustments after significant rainfall.

We had also hypothesized that landscapers might have an incentive to apply more water than landscapes actually needed because of pressures to keep them looking lush to maintain their landscaping contracts or jobs. While landscapers did report some of these pressures, we learned that their professional experience, knowledge, and pride in their work often enabled them to both maintain landscapes in good condition and conserve water simultaneously. However, a landscaper's ability to conserve water at a particular business location was also dependent on the specific services for which the landscaper had been hired and the constraints to efficient watering encountered at the site (e.g., poorly designed irrigation systems, nature of soil, and type of plant materials).

Our second hypothesis involved cultural traditions influencing landscape preferences and the possibility that people could conserve water even while maintaining these traditional landscapes. We found support for Americans' purported preference for lush, uniformly green landscapes (Jenkins, 1994; Bormann et al., 2001; Steinberg, 2006) and desire for them to look "neat" (Nassauer, 1995), which have been identified as causes of wasteful water use in urban areas (e.g., Nielson and Smith, 2005). Tables 6 and 7 present data related to landscape perceptions, but none of the variables associated with these data was predictive of actual water use, either individually or in combination (we created and tested a preference index that combined some of these variables). This is probably due to the fact that maintaining lush, uniformly green lawns (Table 6) and making the landscape look pleasing and nice (Table 7) were so important among such a high percentage of all respondents that these variables were not useful for distinguishing between wasteful and conserving water use. This result partly confirms our second hypothesis, that people can have nice landscapes while conserving water, under the assumption that people who were striving for the same aesthetic objective varied so widely in actual measured water use. As noted in Tables 4 and 5, significant percentages of cases were in the conserving or acceptable range of water use. This suggests that it is feasible to achieve water efficiency while maintaining existing landscapes.

While we did not systematically measure plant quality, observations of landscape condition were recorded by field workers, who had a relatively difficult time guessing which locations were wasteful and which were conserving. Field workers noted the relative homogeneity of business landscapes found in the study area, which were mostly clustered around the Layton Hills Mall. These landscapes typically consisted of small areas of green turfgrass highlighted with flowerbeds, shrubs, and trees which were surrounded by large parking areas and buildings and were watered with automated systems. These landscapes are probably difficult to water efficiently during hot summer months and automated systems probably increase the convenience of maintaining them. Having a "pleasing" landscape was perceived to be important but in only a few cases was the landscape an integral part of the services provided by the business (i.e., in a few instances they provided places for people to wait). Consequently, convenience of landscape watering was perceived as more important than watering efficiency as good business practice.

Our findings suggest that while landscape aesthetic is certainly important, it is not the only quality of a landscape that people prioritize. As illustrated in Table 6, other landscape qualities not directly related to aesthetics that business respondents felt were important included ease of maintenance and water conservation (this question was not included on the earlier household survey). In addition, functional purposes were identified as important reasons for maintaining landscapes (Table 7), such as being a place to relax, play, and do yard work. The multiple objectives that landscapes serve, their contribution to businesses' profitability and property values, and the effect that satisfying these objectives simultaneously has on landscape water use, deserves more careful attention in future research.

Our third hypothesis was that efficient water use is the result of conscious and intentional actions that are generally related to people's motivations,

knowledge, and experiences in relation to water conservation. The fact that we could find no significant correlations between any of the many variables designed to measure these factors and landscape water use was initially surprising. In attempting to find behavioral explanations by combining these variables in different ways, we realized that the data reflected the inherent complexity of landscape watering in the urban context. One element of this complexity relates to how the *amount of time* people watered (i.e., behaviors they reported on in answering questions about how many days per week, what time of day, and how long they watered various types of vegetation) corresponded to the *amount of water* used because of differences in the application rates of various types of sprinkler systems. Neither do we know the cumulative effects of small amounts of overwatering on a daily basis over the course of an irrigation season, but we suspect that occasional forgetfulness in leaving a hose running may not waste as much water as irrigating extra minutes every time sprinklers turn on and off. For participants, knowing how much water they were using may have been obscured not only by the irrigation technology, but also by poor information feedback via metering and billing data and by the fact that landscape water waste is generally invisible when it seeps into the ground (in contrast, for instance, to recycling waste that visibly accumulates). Furthermore, even if people knew how much water they were applying to their landscapes, we wonder how many of them knew how much water their plants actually needed based on ETo and rainfall. Consequently, people's ability to assess their own behavioral outcomes in relation to stated motivations and attempts to conserve water was likely limited by the complexity of landscape water use. This undoubtedly contributed to lack of correlations between intentions and behaviors, assuming that people try to reduce cognitive dissonance as some of the environmental behavior literature has demonstrated.

Four summary observations appear to best describe the complexity of urban landscape watering. First, behaviors are embedded in a place and need to be contextualized, as suggested by the previous discussion of the effect of the irrigation system on water use. While landscape watering is primarily influenced by the irrigation system, we nevertheless recognize that people design, install, maintain, and replace irrigation systems and their daily watering practices can either override or succumb to the behaviors that the type of irrigation system naturally reinforces. Second, the motivations and behaviors of more than one person affect water use in these urban "water consumption units" (households and businesses). Differences between the answers of the two respondents in many

business surveys reinforce this observation, as does the fact that several landscapers noted how the business owner or manager would adjust their sprinkler settings when they were not there. In short, each person has multiple motivations and the motivations of multiple people matter. Third, water conservation is not always a conscious act; sometimes it is the unintended outcome of a favorable set of circumstances or a structured set of habits. The motivations of people who manually watered and fell within the conserving water use range may not have been to conserve water but to conserve their time and effort (as the lack of correlations between questions about attempts to conserve water and water use would suggest). Finally, models of water consumption and water conservation need to pay more explicit attention to landscape irrigation technology because the role of this structural factor appears to be significant in determining overall water use.

Our findings and their interpretation lead us to conclude that wasteful watering is the result of many factors embedded in the complex context of urban landscapes and, therefore, can best be understood as "situational waste." Landscape watering involves the particularities and interaction of soil type, plant material, irrigation technology, and human behavior at each location and these factors can work together in unanticipated ways. Patterns of water use and conservation, then, involve the extent to which people understand these interactions and adjust their behaviors accordingly. While "situational waste" is undoubtedly characteristic of both indoor and outdoor overuse of water, we think it is especially influential in helping to explain overuse in landscape watering.

CONCLUSION

This research has important implications for water conservation strategies as well as the design of future research. The implication of the water use patterns we observed (where 68.7% of households and 35.3% of businesses are within the conserving or acceptable ranges) is that water conservation programs should identify and target wasteful water users to receive information and services. Our interdisciplinary research design tested an approach that cities could use to determine which locations have wasteful landscape watering practices. In the absence of resources to conduct such an analysis, cities might consider concentrating their water conservation efforts on businesses, locations with programmed sprinkler systems, and landscapers (since they often maintain multiple landscapes).

Our finding that the primary factor affecting wasteful watering is programmed irrigation systems has several implications. Water conservation programs could concentrate on ensuring that initial designs and installations of programmed sprinkler systems meet certain standards, especially because inefficient systems can "lock" people into long-term patterns and habits of wasteful water use. This is being accomplished in some places through installer certification programs and city inspections. In addition, water conservation programs could train people on how to maintain and operate their systems for greater efficiency, and could consider providing various types of subsidies for retrofitting dilapidated irrigation systems. Companies that design and produce irrigation system equipment might pay more attention to studying the human behavioral components of how people interface with this technology, and integrate that understanding into their conceptualization of efficiency. A final implication is that during periods of drought, perhaps the best way to implement water savings is to encourage or require people not to use their programmed sprinkler systems but to water manually.

Our summary observation that wasteful watering is the result of many factors embedded in the complex context of urban landscapes implies that, instead of providing water conservation recommendations broadly designed for the general public as is often done (such as recommendations on when and how much time to water), more water conservation programs might consider approaches that provide site-specific evaluations and recommendations. Water audits or water checks are one such tool that some communities have employed to help people understand and assess the quantity of water needed by and applied to their landscapes. This approach provides an opportunity to evaluate various constraints to efficiency at particular locations and design appropriate situational strategies for reducing water waste.

Our findings also have several implications for the focus and design of future research on water conservation and environmental behavior. First, this project affirmed the overall value of interdisciplinary research, especially through the integration of social science, engineering, and plant science components. Social scientists seldom have an independent measure of the human behaviors they are trying to explain and, in this instance, having an independent measure of landscape water use provided a powerful variable in our analysis. Similarly, irrigation engineers and plant scientists are often challenged to explain patterns of resource use without information that can only be provided by the users of those resources. Second, the interdisciplinary nature of the research enabled us to design an approach that controlled for several significant variables that clearly influence water use patterns (temperature, rainfall, landscaped area). This allowed for greater focus on behavioral and structural influences on water use and helped to reveal the situational complexity of landscape watering practices. Finally, in terms of our broader understanding of environmental behavior, the interdisciplinary cooperation provided an ecologically based standard for determining water use efficiency and waste and for assessing where to target water conservation programs and policies. Developing and applying such standards is critical for conceptualizing and understanding environmental behaviors.

ACKNOWLEDGMENTS

LITERATURE CITED

Aitken, C.K., T.A. McMahon, A.J. Wearing, and B.L. Finlayson, 1994. Residential Water Use: Predicting and Reducing Consumption. Journal of Applied Social Psychology 24(2):136-158.

Ajzen, I., 1991. The Theory of Planned Behavior. Organizational Behavior and Human Decision Processes 50(2):179-211.

Allen, R.G., M. Smith, L.S. Pereira, and A. Perrier, 1994. An Update for the Definition of Reference Evapotranspiration. ICID Bulletin 43:35-92.

Altman, I. and B. Rogoff 1987. Worldviews in Psychology: Trait, Interactional, Organismic and Transactional Perspectives. *In*: Handbook of Environmental Psychology, D. Stokols and I. Altman (Editors). John Wiley and Sons, Toronto. Ontario, Canada, Vol. 1, pp. 7-40.

Baron, R.M. and S.J. Misovich, 1993. An Integration of Gibsonian and Vygotskian Perspectives on Changing Attitudes in Group Contexts. British Journal of Social Psychology 32:53-70.

Bennett, R.E. and M.S. Hazinski, 1993. Water-Efficient Landscape Guidelines, Denver, Colorado, American Water Works Association.

Bormann, F.H., D. Balmori, and G.T. Geballe, 2001. Redesigning the American Lawn: A Search for Environmental Harmony (Second Edition). Yale University Press, New Haven, Connecticut.

Bruvold, W.J. and B.R. Smith, 1988. Developing and Assessing a Model of Residential Water Conservation. Water Resources Bulletin 24(3):661-669.

Burt, C.M., A.J. Clemmens, T.S. Strelkoff, K.H. Solomon, R.D. Bliesner, L.A. Hardy, T.A. Howell, and D.E. Eisenhauer, 1997. Irrigation Performance Measures: Efficiency and Uniformity. Journal of Irrigation and Drainage Engineering 123:423-442.

Cameron, L.D., P.M. Brown, and J.G. Chapman, 1998. Social Value Orientations and Decisions to Take Proenvironmental Action. Journal of Applied Social Psychology 28(8):675-697.

Chappells, H., J. Selby, and E. Shove, 2001. Control and Flow: Rethinking the Sociology, Technology and Politics of Water Consumption. *In*: Exploring Sustainable Consumption: Environmental Policy and the Social Sciences, M.J. Cohen and J. Murphy (Editors), Pergamon Press, London, Vol. 1, pp. 157-170.

Corral-Verdugo, V., 2002. A Structural Model of Proenvironmental Competency. Environment and Behavior 34(4):531-549.

Costello, L.R. and K.S. Jones, 1994. WUCOLS: Water Use Classification of Landscape Species (A Guide to the Water Needs of Landscape Plants). University of California Cooperative Extension, San Francisco.

Denver Water and Rob Proctor, 1996. Xeriscape Plant Guide: 100 Water-Wise Plants for Gardens and Landscapes. Fulcrum Publishing, Golden, Colorado.

DeYoung, R., 1988/89. Exploring the Difference Between Recyclers and Non-Recyclers: The Role of Information. Journal of Environmental Systems 18:341-351.

DeYoung, R., 2000. Expanding and Evaluating Motives for Environmentally Responsible Behavior. Journal of Social Issues 56(3):509-526.

Dietz, T., A. Fitzgerald, and R. Shwom, 2005. Environmental Values. Annual Review of Environment and Resources 30(1):335-372.

Ellefson, C.L., T.L. Stephens, and D. Welsh, 1992. Xeriscape Gardening: Water Conservation for the American Landscape. Macmillan Publishing, New York, New York.

Ervin, E.H. and A.J. Koski, 1998. Drought Avoidance Aspects and Crop Coefficients of Kentucky Bluegrass and Tall Fescue Turfs in the Semiarid West. Crop Science 38(3):788-795.

Farag, F.A., 2003. Estimating Farm and Landscape Water use at the Rural-Urban Interface Using Remote Sensing and Geographic Information Systems. PhD Dissertation, Utah State University, Logan, Utah.

Farag, F., C.M.U. Neale, and R. Kjelgren, 2001. Development of a GIS-Based Model To Estimate Landscape Water Demand in the Urban/Rural Interface. *In*: Proceedings of the Remote Sensing and Hydrology 2000 Symposium, Manfred Owe, Kaye Brubaker, Jerry Richtie, and Albert Rango (Editors). IAHS Publ. No. 267 (2001), International Association of Hydrological Sciences Press, Wallingford, Oxfordshire, United Kingdom, ISBN 1-901502-46-5.

Ferguson, B.K., 1987. Water Conservation Methods in Urban Landscape Irrigation: An Exploratory Overview. Water Resources Bulletin 23(1):147-152.

Green Associations Water Conservation Council Coalition, 2006. Water Action Guide. http://www.wateractionguide.com/index.htm, *accessed* January 2007.

Gregory, G.D. and M. Di Leo, 2003. Repeated Behavior and Environmental Psychology: The Role of Personal Involvement and Habit Formation in Explaining Water Consumption. Journal of Applied Social Psychology 33(6):1261-1296.

Guenter, M., 2006. The Role of Utah Garden Centers in Furthering Public Knowledge About Waterwise Plants and Landscaping. M.S. Thesis, Utah State University, Logan, Utah.

Hines, J.M., H.R. Hungerford, and A.N. Tomera, 1987. Analysis and Synthesis of Research on Responsible Environmental Behavior: A Meta-Analysis. Journal of Environmental Education 18(2):1-8.

Hooper, V.H., 2003. Understanding Utah's Native Plant Market: Coordinating Public and Private Interest. MLA Thesis, Utah State University, Logan, Utah.

Hormuth, S.E., 1999. Social Meaning and Social Context of Environmentally-Relevant Behaviour: Shopping, Wrapping, and Disposing. Journal of Environmental Psychology 19:277-286.

Irrigation Association, 2005a. Turf and Landscape Irrigation Best Management Practices. The Irrigation Association, Water Man-agement Committee. http://www.irrigation.org/gov/default.aspx?pg=BMPs.htm&id=104, *accessed* January 2007.

Irrigation Association, 2005b. Landscape Irrigation Scheduling and Water Management. The Irrigation Association, Water Management Committee. http://www.irrigation.org/gov/default.aspx?pg=BMPs.htm&id=104, *accessed* January 2007.

Irvine Ranch Water District, 2007. Irvine Ranch Water District Schedule of Rates and Charges. http://www.irwd.com/AboutIRWD/budget_rates/ratescharges.pdf, *accessed* July 17, 2007.

Jenkins, V.S., 1994. The Lawn: A History of an American Obsession. Smithsonian Institution Press, Washington, D.C.

Kaiser, F.G., S. Wolfing, and U. Fuhrer, 1999. Environmental Attitude and Ecological Behaviour. Journal of Environmental Psychology 19:1-19.

Kaplan, S., 2000. Human Nature and Environmentally Responsible Behavior. Journal of Social Issues 56(3):491-508.

Kilgren, D.C., 2001. Implementing Water Conservation in an Institutional Setting. M.S. Thesis, Utah State University, Logan, Utah.

Kjelgren, R., F.A. Farag, C. Neale, J. Endter-Wada, and J. Kurtzman, 2002. Quantifying Potential Urban Landscape Water Conservation Through Billing Data Analysis in Layton, Utah. 2002 Water Sources Conference: Reuse, Resources, Conservation, Las Vegas, Nevada, January 27-30, 2002.

Kjelgren, R., L. Rupp, and D. Kilgren, 2000. Water Conservation in Urban Landscapes. HortScience 35:1037-1043.

Klien, C.O., 2004. Understanding Household Landscape Water Conservation. M.S. Thesis, Utah State University, Logan, Utah.

Kneebone, W.R., D.M. Kopec, and C.F. Mancino, 1992. Water Requirements and Irrigation. *In*: Turfgrass, Agronomy Monograph no. 32. ASA-CSSA-SSSA, Madison Wisconsin, pp. 441-444.

Knoke, D. and G.W. Bohrnstedt, 1994. Statistics for Social Data Analysis (Third Edition). F.E. Peacock, Itasca, Illinois.

Knopf, J., 1991. The Xeriscape Flower Gardener: A Waterwise Guide for the Rocky Mountain Region. Johnson Books, Boulder, Colorado.

Kurz, T., 2002. The Psychology of Environmentally Sustainable Behavior: Fitting Together Pieces of the Puzzle. Analyses of Social Issues and Public Policy 2(1):257-278.

Kurz, T., N. Donaghue, and I. Walker, 2005. Utilizing a Social-Ecological Framework to Promote Water and Energy Conservation: A Field Experiment. Journal of Applied Social Psychology 35(6):1281-1300.

Larsen, L. and S. Harlan, 2006. Desert Dreamscapes: Residential Landscape Preference and Behavior. Landscape and Urban Planning 78(1-2):85-100.

McCool, D.C. (Editor), 1995. Waters of Zion: The Politics of Water in Utah. University of Utah Press, Salt Lake City, Utah.

Mee, W.J., R. Barnes, R. Kjelgren, R. Sutton, T. Cerny, and C. Johnson, 2002. Water Wise: Native Plants for Intermountain Landscapes. Utah State University Press, Logan, Utah.

Monroe, M.C., 2003. Two Avenues for Encouraging Conservation Behaviors. Human Ecology Review 10(2):113-125.

Montague, T., R. Kjelgren, R. Allen, and D. Wester, 2004. Water Loss Estimates for Five Recently Transplanted Landcape Tree Species in a Semi-Arid Climate. Journal of Environmental Horticulture 22:189-196.

Nassauer, J.I., 1995. Messy Ecosystems, Orderly Frames. Landscape Journal 14(2):161-170.

Nielson, L. and C.L. Smith, 2005. Influences on Residential Yard Care and Water Quality: Tualatin Watershed, Oregon. Journal of the American Water Resources Association (Paper No. 03093) 41(1):93-106.

Pacific Institute, 1999. Sustainable Use of Water: California Success Stories. Pacific Institute for Studies in Development, Environment and Security, Oakland, California.

Planning Management Consultants, Ltd., 1993. Evaluating Urban Water Conservation Programs: A Procedures Manual. American Water Works Association, Carbondale, Illinois.

Saunders, C.D., 2003. The Emerging Field of Conservation Psychology. Human Ecology Review 10(2):137-149.

Statistical Package for the Social Sciences for Windows, Rel. 14.0.2. 2006. SPSS Inc., Chicago.

Steinberg, T., 2006. American Green: The Obsessive Quest for the Perfect Lawn. Norton and Company, New York, New York.

Stern, P.C., 2000a. Toward a Coherent Theory of Environmentally Significant Behavior. Journal of Social Issues 56(3):407-424.

Stern, P.C., 2000b. Psychology and the Science of Human-Environment Interactions. American Psychologist 55(5):523-530, doi: 10.1037//0003-066X.55.5.523.

Syme, G.J., C. Seligman, and J.F. Thomas, 1991. Predicting Water Consumption from Homeowners' Attitudes. Journal of Environmental Systems 20(2):157-168.

Teyssot, G. (Editor), 1999. The American Lawn. Princeton Architectural Press, New York, New York.

Utah Code Annotated, 2004. 73-10-32: Water Conservation Plans.

Utah Division of Water Resources, 2001. Utah's Water Resources: Planning for the Future. http://www.water.utah.gov/Planning/SWP/SWP2001/SWP_pff.pdf, *accessed* July 2007.

Utah Division of Water Resources, 2003. Utah's M&I Water Conservation Plan: Investing in the Future. http://www.water.utah.gov/M&I/plan7-14-03.pdf, *accessed* July 2007.

Utah Division of Water Resources, 2007. Drought in Utah: Learning From the Past-Preparing for the Future. http://www.water.utah.gov/DroughtReport/binder2A.pdf, *accessed* July 2007.

Vickers, A.. 2001. Handbook of Water Use and Conservation: Homes, Landscapes, Businesses, Industries, and Farms. WaterPlow Press, Amherst, Massachusetts.

Vining, J. and A. Ebreo, 2002. Emerging Theoretical and Methodological Perspectives on Conservation Behavior. *In:* Handbook of Environmental Psychology, R.B. Bechtel, and A. Churchman (Editors). John Wiley and Sons, New York, New York.

Werner, C.M., 1999. Psychological Perspectives on Sustainability. *In*: Sustainability and the Social Sciences: A Cross-Disciplinary Approach to Integrating Environmental Considerations Into Theoretical Reorientation, E. Becker and T. Jahn (Editors). Zed Books, London, United Kingdom, pp. 223-242.

Wong, A.K., 1999. Promoting Conservation With Irvine Ranch Water District's Ascending Block Rate Structure. *In:* Sustainable Use of Water: California Success Stories. L. Owens-Viani, A.K. Wong, and P.H. Gleick (Editors). Pacific Institute for Studies in Development, Environment and Security, Oakland, California, pp. 27-35.