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Factors Influencing Household Outdoor Residential Water Use Decisions in Suburban Boston (USA)

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FACTORS INFLUENCING HOUSEHOLD OUTDOOR RESIDENTIAL WATER USE DECISIONS IN SUBURBAN BOSTON (USA)

A Thesis Presented

by

EMILY ARGO

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ABSTRACT

FACTORS INFLUENCING HOUSEHOLD OUTDOOR RESIDENTIAL WATER USE DECISIONS IN SUBURBAN BOSTON (USA)

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Water withdrawals for human use can reduce water in lakes and streams, with significant consequences for aquatic biota. Urbanization, particularly large lawn areas associated with low-density residential development, increases demand on freshwater resources. Outdoor water use accounts for the largest proportion of residential water use during the summer months, which corresponds to the lowest water levels in freshwater ecosystems. Prior studies have sought to understand property features associated with the highest water use; however, these studies do not consider other types of water use nor do they capture the decisions by residents that result in outdoor water use. Understanding these decisions is critical for developing policies and education tools that reduce outdoor water use by changing people's water use behavior. Focusing on the Ipswich River Watershed, which has been impacted by extreme low flows due to water withdrawals, a mixed-methods approach was used to understand residents' outdoor water use and the factors influencing the amount and timing of water use. To quantify water use meters were placed on outdoor spigots at

residences, participants were provided with a written survey before and after water metering, and in-person interviews were conducted. Irrigation systems used the most water; however, garden watering occurred as frequently as lawn irrigation and many participants indicated that their garden was a primary factor in water use decisions. Participants' water use decisions fell into categories from habitual (i.e., watering at the same time of day) to purely cognitive (i.e., watering based on weather and plant needs). While many participants felt that water conservation was necessary, their willingness to implement landscape-level conservation practices, such as rain barrels, did not differ from participants who believed water conservation was unnecessary. Interestingly, many residents reduced their outdoor water use behavior and increased their concern for other environmental issues in response to study participation. To have the greatest impact on overall water use, efforts should focus on residents running irrigation systems on a schedule. Outreach should emphasize individualized approaches to water conservation, regardless of water source (public or private), and include information and conservation options specific to the water needs of the individual property.

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CHAPTER 1

OUTDOOR WATER USE AT THE RESIDENTIAL LEVEL

1.1 Introduction

Residential water use accounts for approximately 13% of total water use in the United States (Maupin et al. 2014). Outdoor water use, although argued as non-essential for daily functioning by some researchers (Inman and Jeffrey 2006), comprises 30-50% of residential water use, which amounts to over seven billion gallons of water on average daily in the United States (US EPA 2008). Outdoor uses have placed pressure on water supplies and added to the challenge of meeting demand for potable water. The low-density residential development typical in suburban Boston includes large lawns and swimming pools, two residential features shown to have particularly high water demand (Syme et al. 2000, Martin et al. 2003, Wentz and Gober 2007, Harlan et al. 2009, Vidal et al. 2011, Runfola et al. 2013, Saurí 2013).

Water quantity is a prime concern in the Ipswich River Watershed (Fig. 1), which is considered one of the most threatened rivers in the United States (American Rivers 2003). Threats to the river include decades of unsustainable potable water use and exportation of waste water from the watershed (Bowling and Mackin 2003). No-flow conditions were routine in the Ipswich River until 2006 and unnatural low flow conditions have been documented as recently as 2013 and 2014 when the river flow dipped below 5 cubic feet per second (USGS 2014).

In an effort to reduce outdoor residential water use the State of Massachusetts, local municipalities and non-profit conservation organizations have instituted policies and ordinances and promoted methods to reduce water use. Massachusetts requires that all public water utilities send one water conservation-focused mailing a year to their customers and local municipalities and water providers have also offered incentives to encourage implementation of water conserving devices such as rain barrels. Local non-profits, such as Greenscapes, promote native plantings and provide education and outreach to the local community. Even with such efforts, concerns about the water supply in the Ipswich River Watershed persist indicating that more research is needed to encourage the adoption of an effective water conservation practices at the residential level.

This thesis is one part of a broader study that seeks to understand local water providers' perspective of water conservation, residents' landscape preferences, and residents' water use decisions to better guide water conservation efforts. The first phase of the study examined the engagement of water suppliers with demand side management decisions throughout the watershed and found that water supplier decisions were influenced by attitudes toward water conservation and perceptions of organizational capacity. Demand side management decisions were also made without information on lawn area, device-prevalence, residential attitudes, and community norms, which could influence the effectiveness of demand side management approaches (Rachel Danford, personal communication). The second phase of the study examined willingness and motivations for residents to implement landscape-level water

conservation practices (Stacy 2015). The survey used in this second phase, subsequently referred to as the Landscape Survey, served as the foundation for the my thesis, which sought to understand how residents are using water outdoors, how they are making water use decisions on their property, and factors that influence outdoor water use.

An understanding of residents' day-to-day water use decisions is critical for tailoring water conservation and effectively reducing water use. Mayer et al. (2015) suggested that the "human element of landscape management" is poorly understood, and that an understanding of residents' landscape decisions is critical for reducing water use. Since total outdoor water use is the cumulative result of day-to-day decisions, if we can understand the factors that lead people to decide to water and what influences their water use practices, we can identify more effective ways to influence outdoor water use and conservation.

Using a mixed-methods approach that includes monitoring outdoor water use, written surveys, and in-person interviews, this thesis addresses three questions:

1. How do people decide whether or not to use water outdoors on any given day?

   Hypothesis: People maintain a daily schedule for outdoor watering that can be altered by weather, soil and plant appearance, and water use restrictions.

2. Does a person's belief that residents need to be conserving water correspond to their total outdoor water use and willingness to implement conservation practices?

Hypothesis: Individuals who believe people need to be conserving water have lower total outdoor water use than those who do not believe conservation is necessary.

3. How does knowledge of the amount of water an individual is using outdoors influence that individual's behavior and belief regarding outdoor water use?

   Hypothesis: Knowledge of water use amount will lead to reduced outdoor water use per task and/or overall.

This thesis begins by reviewing existing literature on property features, decision-making, environmental beliefs and attitudes, and the impact of knowledge on behavior as it pertains to outdoor water use and conservation. In Chapter 2, I provide details about the study area and town selection, recruitment strategies, and descriptions of the data collection tools (water metering, surveys, in-person interviews) and associated analyses. Chapter 3 includes descriptive summaries of water use data and residential surveys, and results of analyses associated with the three research questions. The discussion (Chapter 4) interprets significant findings, provides implications for theory, policy, and outreach, and offers suggestions for future research.

1.2 Literature Review

Given the impact that outdoor residential water use can have on freshwater ecosystems, it is important to understand the factors that influence this water use. A study by Cook et al. (2011) developed a conceptual framework to examine the multi-scalar social-ecological interactions taking place on residential landscapes. This thesis seeks to delve more deeply into the human drivers identified by Cook et al. (2011) and how they impact outdoor water use decisions and the amount of water used outdoors. This literature review compiles literature pertaining to water use, environmental beliefs, and knowledge related to outdoor residential water use. This literature has been summarized according to the three questions I will be investigating in this thesis.

How do people decide whether or not to use water outdoors on any given day?

Although there are multiple components that may go into an individual's decision to water, a large portion of that decision could simply be based on what features are present on their property. Swimming pools (Wentz and Gober 2007) and lawn area (Syme et al. 2000, Martin et al. 2003, Harlan et al. 2009, Runfola et al. 2013, Saurí 2013) have been shown to account for a significant amount of outdoor water use at the residential level, however, lawn area is of particular concern given the large lawn areas associated with the low-density residential development common in suburban Boston (Runfola et al. 2013). Turf grass (lawn) is the largest irrigated crop in the United States (Milesi et al. 2005) and at the residential level is often managed by an in-ground irrigation system. Residential landscaping can account for greater than 50% of a household's annual water budget in the western United States (Hurd 2006) and landscape irrigation has been shown to account for 54% of single-family water use in the

city of Los Angeles, California (Mini et al. 2014). Given that irrigation systems can be run on a set schedule, it is also important to consider that 57% of programmed irrigation systems are not operated efficiently and are therefore wasting water (Mayer et al. 2015). A mailed survey of homeowners with and without in-ground irrigation systems showed that residents with in-ground irrigation systems were more likely to water their lawn on a schedule and apply the same amount of water each time, whereas residents without irrigation systems were more likely to water when their lawn appeared dry or there was hot and dry weather (Bremer et al. 2012). It is also apparent that residents may not know how much water they were applying to their lawns when they watered nor how much water their lawn required each week (Bremer et al. 2012).

Studies identifying the primary features contributing to outdoor water use are often conducted by relating estimated total outdoor water use to property features. The results of these studies play a crucial role in policy development by providing information that allows policies to target the highest water use tasks. However, total outdoor water use actually encompasses a series of individual events and decisions by the resident and homeowners are not necessarily making decisions in isolation since neighborhood norms have been shown to impact landscape decisions (Cook et al. 2012). For example, Ohio residents were more likely to hire a lawn care company or use chemicals if a neighbor did and if they were in a more urban or suburban neighborhood (Blaine et al. 2012). A similar result was found comparing attitudes and behaviors of residents in apartments versus houses, showing that water use was related to resident's

communities, social norms, and relationship to their household (Randolph and Troy 2008).

Social norms in a community may also be driven, in part, by local policy and water use restrictions or bans are often used to reduce outdoor residential water use by impacting how water is applied, when water is used, and how much water is used by residents (Shaw and Maidment 1987, Renwick and Green 2000, Kenney et al. 2004, Survis and Root 2012, Castledine et al. 2014). The term water use restriction encompasses a broad range of policies that can be implemented in a community. These policies can include restrictions on time of day, day of the week, mechanism of water application, and/or the type of tasks water can be used for outdoors. Additionally, whether or not a restriction is mandatory or voluntary can vary between communities and through time. A town may employ stages of outdoor water use restrictions that can increase or decrease in severity in response to rainfall, water supply, or river flow. Alternatively, a water use ban (often the terminal level of staged restrictions) indicates that no water may be used outdoors for any purpose regardless of day, time, mechanism, or task.

Water use restrictions have been shown to reduce out water use in some situations (Shaw and Maidment 1987, Renwick and Green 2000, Kenney et al. 2004), but this is not always the case (Castledine et al. 2014). During drought years, Shaw and Maidment (1987) saw a 3-5% decrease in demand from in Austin, Texas and Renwick and Green (2000) saw a 30% decrease in California. Outdoor water use restrictions following a drought in Colorado in 2002 resulted in an 18 – 56% reduction in expected

water use when restrictions were mandatory (Kenney et al. 2004). However, when the restrictions became voluntary the authors only saw a savings of 4-12%. Additionally, residents in Nevada used more water when they were prescribed a specific day during the week to use water compared to when they were allowed to select the day of the week on which to water (Castledine et al. 2014). Allowing residents to select a specific day to water reduced irrigation system inefficiencies due to weather conditions. However, given that water use data was not available prior to the implementation of restrictions in 2008 it is unclear from this study if outdoor water use also decreased in response to restrictions (Castledine et al. 2014). Survis and Root (2012) were the first to examine effectiveness of restrictions on achieving a target water use (i.e., the amount of water required for the lawns). They found that for half their study period the rainfall provided the appropriate amount of water for the lawns to be maintained, meaning the target use was zero. However, even during times of water use restrictions, the residents in the study were found to be overwatering their property (Survis and Root 2012). These results are similar to a study by Hill and Polsky (2007) conducted in Massachusetts using qualitative interviews that found that the presence of irrigation systems with new development translated into stress on the water supply and that lawn watering via an irrigation system often occurs regardless of the weather (Hill and Polsky 2007).

The results of these studies indicate that water use restrictions may elicit a different response from residents in humid climates compared to arid climates, warranting further research. Given that water use bans and restrictions seek to manage demand for water by managing people's behavior, understanding how people make

water use decisions, particularly in more humid climates such as the Northeastern United States, is crucial to the continued development of effective policies and in turn effective management of freshwater resources.

Does a person's belief that residents need to be conserving water correspond to their total outdoor water use and willingness to implement conservation practices?

Beliefs and attitudes towards the environment or water conservation are thought to influence water use; however, results from previous studies have not consistently shown a positive relationship between beliefs and water use. Some studies found that positive environmental beliefs, concern about water shortage, and awareness of water conservation issues corresponded with lower overall residential water use (Corral-Verdugo et al. 2003, Gregory and Di Leo 2003, Willis et al. 2011). For example, self-reported water conservation behaviors have been shown to correspond to general pro-environmental behavior and seeking out information about water-related issues (Dolnicar et al. 2012). A study developing a model to examine predictors of water conservation behavior also found that the decision to use water was associated with personal involvement in decision-making and the formation of habits that resulted in lower consumptive water use (Gregory and Di Leo 2003). Additionally, habitual behavior is also seen as a factor in water savings and these behaviors can be separated into categories based on frequency of performance and type of activity indicating difference levels of behavioral commitment (Gilg and Barr 2006).

Alternatively, other studies have not found relationships between environmental beliefs and water use behavior. For example, in Spain, researchers could not identify a

consistently significant relationship between pro-environmental water conservation attitudes and behaviors (Garcia et al. 2013). When examining the relationship between affluence, property features, and attitudes, again researchers did not find a significant relationship between attitude towards the community and environment and water use (Harlan et al. 2009). While residents may state a strong positive attitude towards conservation, their actions may not reflect this statement. This was demonstrated in a study where survey respondents expressed support for water conservation but did not express such strong support when it came to actual development of conservation-focused policy (de Oliver 1999). The availability of water in different areas has also been shown to have an impact on resident's attitudes to water conservation with residents in a water-scare location more willing to support conservation behaviors than residents residing where water is more readily available (Gilbertson et al. 2011).

How does knowledge of the amount of water an individual is using outdoors influence that individual's behavior and belief regarding outdoor water use?

While there are studies examining outdoor water use and changes in water use associated with water conservation outreach and education (Syme et al. 2000, Clark and Finley 2008, Keen et al. 2010, Gabe et al. 2012), studies have yet to evaluate the impact of providing residents with specific information about their actual outdoor water use. However, one study on indoor water use did examine the impact of a showerhead equipped with an alarming visual display that engaged after 40 liters of water use and found a significant per shower water savings of 27% (Willis et al. 2010). Providing residents with feedback on their energy consumption via immediate feedback from a

smart meter or similar device (Wood and Newborough 2003, Bird and Rogers 2010) or on a utility bill (Darby 2006) is more common, but both methods have been shown to have been shown to reduce energy consumption to varying degrees.

The Reasonable Person Model (RPM) (Kaplan and Kaplan 2009) serves as an excellent framework to describe the positive impact of knowledge on resource use. Although developed and applied more broadly in environmental psychology, the three components of RPM can be easily applied in this context. The first component of RPM is *model building* where the individual makes a mental model of a situation in order to evaluate consequences. *Meaningful action*, the next tenement of RPM, is where the individual is able to participate and in doing so feels respected, listened to, and heard. The third component is *effectiveness*, which includes our ability to effectively process new information without becoming overwhelmed and to feel competent. This model suggests that more knowledge of individual water use residents have the more likely they will be to make reasonable water use decisions on their property.

CHAPTER 2

MIXED-METHODS DATA COLLECTION IN THE IPSWICH RIVER WATERSHED

2.1 Study Area

This study was conducted in the Ipswich River Watershed, a 404-km^2 area that encompasses some or all of 21 towns North of Boston, Massachusetts (Fig. 1). The Ipswich River experiences considerable low and no-flow conditions (Polsky et al. 2009) and following decades of unsustainable potable water use and exportation of wastewater from the watershed portions of the river have run dry (Bowling and Mackin 2003; Ipswich River Watershed Association 2014). As a result, in 2003 it was considered one of the most endangered rivers in the United States (American Rivers 2003, Bowling and Mackin 2003, Ipswich River Watershed Association 2014). In recent years, land use and drinking water withdrawals have been cited as the cause for water shortages experienced throughout the watershed (Stacy 2015).

Massachusetts experiences what are known as socioeconomic droughts, which refers to the period of time where water demand comes very close to the water supply (Hill and Polsky 2007). Towns within the watershed are experiencing increased low-density residential development and a corresponding increased demand on water resources (Polsky et al. 2009, Runfola et al. 2013). Even in years of above average rainfall, outdoor water use bans and restrictions have been necessary to prevent demand from outstripping supply (Hill and Polsky 2005); however the duration of these

bans and restrictions continues to increase independent of climactic conditions (Hill and Polsky 2007).

With the Ipswich's coastal New England location, the Watershed provides an excellent location to study water use as the climate conditions are similar to those found across the Northeastern United States. Since considerable research has been conducted in the West and Southwestern United States and Australia where precipitation patterns differ considerably this study provides an opportunity to contribute literature that addresses behaviors that may be unique to the Northeastern United States and other more humid climates. Information about outdoor water use behavior and conservation in the Northeast can help address the applicability of water conservation outreach, education, and policies used in drier regions to the Northeastern United States.

2.2 Study Design

2.2.1 Town selection

Four towns within the Ipswich River Watershed were selected for this study – Topsfield, Middleton, Wilmington, and North Reading (Fig. 1). These towns were the same as those used for a Landscape Survey by Stacy (2015; Appendix A) that served as a precursor to this study. Selected towns had greater than 50% of their land area within the watershed and the majority of residents received water from the town water supply, although Wilmington could supplement from the Massachusetts Water Resources Authority (MWRA) in times of need (Stacy 2015). Two of the towns selected represented high population growth (>9% over last 13 years) and the remaining two

represented towns with moderate population growth (Table 1). Additionally, conservation endorsement varied (low versus high) among the towns within each population growth category (Table 1).

2.2.2 Participant recruitment

Within the four towns homeowners were recruited through direct mailing, neighborhood flyering, and general broadcasting through the internet, as described below. All participants were compensated for their time participating in the study by keeping the meter(s) installed at their property ($20/meter) and receiving a complimentary soil test ($15/test) to use anytime in the future.

Direct mailings

In June 2014 a survey (Appendix A) was mailed to 250 residents in each of the four towns for a total of 1000 mailings (Stacy 2015). A postage-paid return postcard was enclosed in each mailing for residents to express interest in participating in water metering. Two subsequent reminder postcards were also sent in late summer 2014 that included a URL for an online version of the survey. If respondents completed the survey online, there was a link for respondents to indicate interest in the water metering.

In April 2015, a postcard was sent to 250 residents randomly selected from the tax assessors' database in each of the four towns for a total of 1000 mailings. Postcard recipients were randomly selected from entries with residential dwelling and a local mailing address. Selected postcard recipients did not overlap with the initial survey recipients. The postcards contained information about the study and a postage-paid return postcard for residents to express interest in participating in water metering.

Water utilities in each of the four towns were asked if they were willing to place a research study announcement in a forthcoming water bill to a portion of their residents. North Reading agreed to include a flyer with information about the study and how to participate in 1000 randomly selected water bills in May 2015.

Neighborhood flyering

Fliers inviting participation in water metering were placed on doors of residents in selected neighborhoods in early summer 2014 and 2015. In 2014 flyers were placed at homes adjacent to already-recruited residents to encourage additional participation in the same neighborhood. Flyers were also placed in areas of North Reading where residents are known to have water-conserving practices such as rain gardens (J. Stacy, personal communication). In 2015, 800 flyers were placed on doors of residents in walkable neighborhoods that had not received fliers previously in North Reading, Wilmington, and Topsfield.

General broadcasting

In summer 2014, the Ipswich River Watershed Association included a study announcement in their July e-newsletter sent to their membership list.

2.3 Data Collection

2.3.1 Water metering

Water meters (Save A Drop^{TM}, P3 International) were placed on all active outdoor spigots at participating residences for some or all of August to October 2014 and May to October 2015 depending on when they first volunteered and if they left the program. Participants recorded the amount of water used in gallons for individual

outdoor watering events, including an event description (i.e., washing the car, filling the pool), date, time, and amount. This information was recorded on either a paper water use log or online via a project webpage. Paper logs were collected once monthly or as needed depending on frequency of water use by the participant. For properties with in-ground irrigation systems, the following information was obtained from homeowners: brand of system, number of zones, number of sprinkler heads per zone, time, duration, frequency, and output of each sprinkler (gallons per minute). The time of day that water was used was grouped into three categories where morning included any water use event between 12am and 8:59am, mid-day covered 9am to 4:59pm, and evening included 5pm to 11:59pm. These groupings were chosen to reflect the timing of most water use restrictions and a typical workday. Additionally, to evaluate whether more water uses occurring during the weekend the date provided by participants was used to group water uses into weekday or weekend categories.

2.3.2 Written surveys

Surveys are a commonly used tool to collect data on opinions and self-reported behavior (Corral-Verdugo et al. 2003, Bremer et al. 2012, Dolnicar et al. 2012) and pre and post surveys used in connection with water consumption data have been used to evaluate the effect of educational programs on water use (Lawrence and McManus 2008).

Water metering participants were provided with the Metering Survey (Appendix B), which included all the questions from the Landscape Survey (Appendix A) used during recruitment and seven additional questions (question numbers 8-10, 20-22, and

35) for a total of 55 questions (Appendix B). The survey could be completed on paper or online at the discretion of the respondent. The online survey was distributed via Survey Monkey and included the same questions in a format as close to the paper survey as possible. All questions we close-ended and addressed the following topics:

How people use water outdoors – This series of questions sought to describe how participants used water outdoors, property features that may influence their usage, knowledge of tap water origin, and estimates of water used for common outdoor water use tasks (include information on how people struggle to estimate water use – add citation). Reponses to these questions were categorical. Two sets of 5-point Likert scale response questions sought to evaluate how people were using their outdoor space and their sources for landscaping information. A response of 1 indicated 'not at all' and 5 represented 'a great deal.'

Perceptions of the effectiveness of outdoor water conservation practices – These questions addressed conservation practices that did not require considerable property modification to implement, including watering less often, spreading mulch, and using a timer during watering. Participants evaluated the effectiveness of these practices using a 5-point Likert scale with 1 indicating 'not at all' effective and 5 meaning 'extremely' effective. They also indicated their willingness to practice them in the future by selecting 'yes' or 'no'.

Water conserving landscape installations – Photos of water conserving practices including a rain barrel, rain garden, green roof, drought-tolerant lawn, and drought-tolerant landscape were used to help participants indicate their willingness to

implement the practices and if a practice was already present on their property. Two follow-up questions asked what factors would encourage a participant to install a rain garden and/or a rain barrel at their property. Participants were also asked if they would be willing to change lawn on their property to meadow or ground cover and what factors were considered in their decision. Again, all responses were on a 5-point Likert scale with 1 representing 'not at all' and 5 indicating 'extremely' or 'a great deal.'

Town-level outdoor water use restrictions – The majority of towns within the Ipswich River Watershed employ annual outdoor water use restrictions from May 1 – October 31. Participants used a 5-point Likert scale to indicate their general opinion about restrictions in accordance with the following statements: they are necessary, they are an effective way to reduce outdoor water use, they do not affect me significantly, they are an inconvenience, and I don't understand why we have them.

General level of environmental concern – Respondents were asked to rate the seriousness of various environmental problems in Massachusetts such as poorly planned development, climate change, availability of drinking water, and flooding using a 5-point Likert scale.

Homeowner motivations for water conservation – Participants were given the prompt "I would reduce my outdoor water use if…" followed by six statements (e.g. "…my water bill doubled", "…my property had less lawn") and asked to indicate how much they agreed with each statement using a 5-point Likert scale. Respondents also had the option to select 'N/A' if the statement did not apply to them.

Demographics – Demographic information was collected in order to compare participants to the populations within each town as well as to the total Landscape Survey respondents. Specifically, data on household income, education level, household size, age, tenure, and gender was recorded using categorical responses.

Landscape preference photographs – To understand how much participants would like to implement water-conserving practices on their own property, twenty photographs of residential landscapes depicting these practices were included at the end of the survey. Respondents were asked to rank how much they would like to have the practice on their own property using a 5-point Likert scale. The results from this section of the survey are not presented in this thesis.

A Post Survey (Appendix C) was administered in October 2015 to water metering participants that included 17 of the questions from the Metering Survey (questions 2, 5, 7-11, 14, 17, 19, and 21-27; Appendix B) to evaluate if there had been any change during the course of the study. Questions included in the Post Survey addressed perceptions of the effectiveness of outdoor water conservation practices (question 11), water conserving landscape installations (question 13), town-level outdoor water use restrictions (question 14), general level of environmental concern (question 15), and homeowner motivations for water conservation (questions 12, 16, and 17; Appendix C). Additionally, some of the questions addressing how respondents used water outdoors were included (questions 8 and 9; Appendix C).

2.3.3 In-person interviews

Interviews allow researchers to go beyond a categorical or Likert-scale survey response and better understand how the respondent made a decision to select a particular response. This information helps identify if particular groups of respondents selected the same answer but for different reasons. Interviews may also bring out information that had not been considered in the survey.

Interviews were conducted from July through October 2015 and consisted of 6 sections (Appendix D) and took 1 hour or less to complete. Interviews were practiced on 2 non-study volunteers. Interviews were recorded using an Olympus DM-420 digital stereo tape recorder (Olympus America, Inc.) and stored only with an alphanumeric identifier to protect participant identity in accordance with IRB protocol 2013-1896. The interviews consisted of the following sections:

Introduction – Prior to beginning the formal interview participants were provided with a brief description of the topics the interview would cover, had the recording and data storage processes explained, and were given the opportunity to ask any questions before recording began.

Section 1 – This section addressed decisions to water and participants were asked to describe how they viewed their property in terms of outdoor watering, what areas they considered different from one another, and how they treated them differently. Participants described how they decided on their current watering regime with a specific focus on scheduling (daily, weekly, every other day, etc.), time of day (morning, mid-day, evening), and any visual or tactile cues they used. Participants were

also asked what plants they had on their property, if anyone else was responsible for outdoor watering, and, if so, how their opinions regarding outdoor watering differed.

Section 2 – Outdoor watering restrictions were addressed in this section. I prefaced the questions with the disclaimer that I was not there to evaluate whether or not they were following restrictions, but rather that I wanted to better understand how they responded to the water use restrictions. Specifically, participants were asked how they modified water use at their property when they noticed a new or upgraded restriction. If they did not specifically address water use frequency or the time of day follow-up questions were used to obtain this information.

Section 3 –Implementation of conservation practices was addressed in this section. First, I clarified that I was not suggesting that they make any changes on their property but rather wanted to hear about any modifications they were interested in making but had not had the opportunity to implement yet. This was followed by more focused questions regarding what they would or would not be willing to change on their property. If a participant had a conservation practice implemented on their property, additional questions were used to address how their behavior has changed since implementing the practice and the likelihood that they would suggest the practice to others.

Section 4 – This section addressed the need for water conservation in suburban Boston. Participants were specifically asked to focus on their local area and not California or other locations that had been in the media recently due to water supply issues associated with droughts. Participants were then asked the following questions: Is

water availability an issue in suburban Boston? Why do you think it is or is not an issue? Is it necessary for residents to be conserving water?

Section 5 – Participants were asked if they ever discussed water conservation with others and, if so, in what context.

Section 6 – This section addressed participant's experience participating in the study, including what had been working well and what was a problem or challenge. In this section I also asked if knowing their water use changed how they used water outdoors if this topic had not been covered by their responses in a previous section.

Wrap-up – The final question in the interview asked participants if there was anything I had not addressed in the interview that they felt was relevant to share.

2.4 Data Analysis

2.4.1 Water metering

I calculated the range, mean, and standard deviation for each water use task for all participants. Additionally, the following metrics were calculated: the number of times each task was performed overall, by participant, by time of day, and by day of the week (weekday or weekend); average amount of water used per task event for a given time of day or day of the week; total volume of water used overall and by task for each participant; and the number of months each participant was involved in the study. All statistics were calculated using R Statistical Programming Language (R Development Core Team 2014) and Microsoft Excel (2011).

I also examined the effects of presence of a pool, property size, lawn area, and number of months participating in the study on total household water use. The

presence of a swimming pool was determined from Metering Survey responses (Question 4, Appendix B). Property size was identified from tax assessor documents and lawn area was calculated in GIS using land cover data published by Polsky et. al. (2012). A t-test was used to compare total water use for households with and without a pool. Linear regressions were used to evaluate relationships between the other variables and total water use. Prior to analysis total was use data was log transformed to achieve a more normal distribution. Due to the considerable amount of water used by the 4 participants running irrigation systems, these analyses conducted with all participants (n=34) excluding those with irrigation systems (n=30). All analyses were conducted using R Statistical Programming Language (R Development Core Team 2014).

2.4.2 Written surveys

Survey responses for all participants were entered into a Microsoft Excel (2011) spreadsheet. Surveys completed on paper and online were combined for analysis. Non-Likert scale responses were coded numerically for ease of analysis. Likert-scale data were coded from 1 to 5 where 1 represented 'not at all' or 'not very' responses and 5 represented 'extremely' or 'a great deal.' Questions 19 and 27 from the Metering Survey (questions 15 and 21 on the Landscape Survey) also permitted a response of N/A; these respondents were not included in the analysis of these questions. Additionally, if a participant did not respond to a question they were removed from analysis for that question.

Likert scale responses, although technically categorical, were analyzed as a continuous variable. The mean and standard deviation were calculated for all Likert

scale questions and percentages were calculated for all categorical questions using Microsoft Excel (2011). Since the Landscape Survey (Stacy 2015) was used as a primary recruitment tool, I evaluated any differences between Metering Survey respondents and Landscape Survey respondents. T-tests were used to compare responses to Likert scale questions and Chi-squared tests were used to evaluate differences in demographics between Metering Survey and Landscape Survey respondents. To account for the small sample size associated with the Metering Survey a simulation was used within the Chi-squared test to generate a p-value.

2.4.3 In-person interviews

Interviews were fully transcribed using Microsoft Word (2011) and Express Scribe Transcription Software Pro (version 5.77 Intel). Coding was conducted in NVivo qualitative data analysis Software (QSR International Pty Ltd. Version 11.1.1, 2015) using codes derived from the research questions and the transcripts themselves (Miles et al. 2014). Gender, town, and water source data were added as attributes in NVivo to allow for further analysis.

2.4.4 Question 1: How do people decide whether or not to use water outdoors on any given day?

The first section of the interview included questions on decisions to water (Table 2; Appendix D). From these responses I developed a code structure addressing the weather (i.e., hot, dry, rain), soil appearance (i.e., wet/dry, dark/light), plant appearance (wilted), and individual scheduling (daily or weekly). I evaluated the frequency of coded

comments and summarized general patterns of factors influencing daily water use decisions.

2.4.5 Question 2: Does a person's belief that residents need to be conserving water correspond to their total outdoor water use and willingness to implement conservation practices?

Section 4 of the interview asked participants if they believed it is necessary for residents to be conserving water. I used two codes (yes or no) to identify whether or not participants believed residents should be conserving water. Total outdoor water use was standardized using the number of months each participant was involved in the study. A metric for willingness to implement conservation practices was derived from question 19 on the Metering Survey. This question asked participants to indicate if they had the following features on their property: rain garden, rain barrel or catchment system, reduced lawn area, green roof, drought-tolerant lawn, and drought-tolerant landscape. Participants also reported their willingness to implement each of the features using a 5-point Likert scale with 1 indicating 'not at all' and 5 indicating 'extremely' (Appendix B). Correlation and Cronbach's alpha were used to identify which features would be used to derive an overall willingness metric for each interview participant. Belief in need for conservation was compared to standardized total water use and willingness indexes to identify any relationships using t-test. Analyses were conducted using R Statistical Programming Language (R Development Core Team 2014).

2.4.6 Question 3: How does knowledge of the amount of water an individual is using outdoors influence that individual's behavior and belief regarding outdoor water use?

The final section of the in-person interviews addressed study experience and specifically asked participants if they changed their behavior in response to participating in the study and having the meter. These responses, and any other section of the interview where they mentioned a behavior change in response to the study, were coded using two codes (yes or no). Additionally, participants' responses to the pre and post survey were analyzed using paired t-tests to evaluate any changes in beliefs regarding outdoor water use and conservation following participation in the study.

To identify changes in opinion and willingness before and after participation in water metering, within-subjects paired t-tests were used to compare responses between the Metering Survey and Post Survey for questions 11, 13, 14, 15, 16, 17 on the Post Survey which correspond to questions 18, 19, 24, 25, 26, and 27 on the Metering Survey. All statistics were conducted using R Statistical Programming Language (R Development Core Team 2014).

CHAPTER 3

EVALUATING FACTORS INFLUENCING OUTDOOR RESIDENTIAL WATER USE: STUDY RESULTS

Over the two years of this study, 34 participants (households) agreed to participate. In 2014, 21 participants had water meters installed at their property and of these participants 15 returned for the 2015 study season. An additional 13 participants were added during the 2015 season that only participated for all or part of this season. Out of 34 participants across the 2014 and 2015 study seasons, 26 returned the Metering Survey provided to them on or before their first water meter was installed and 20 returned the Post Survey that was provided at the conclusion of data collection on October 31, 2015. Interviews were also conducted with 20 participants during the 2015 season.

3.1 Water metering

The 34 water metering participants were from Topsfield (13), North Reading (12), Wilmington (6), and Middleton (2). There was a maximum of 9 study months (276 days) and participants metered their water from 2 to 9 months depending on the participant (Table 3). Three participants did not record any outdoor water use during the study period (Table 3).

Water was used outdoors on average every 3.9 days across all 1706 individual water use events for all study participants combined (Table 4). The participant with the greatest number of water use events used water 231 times and all the uses were

associated with an irrigation system. The other participants with irrigation systems used water outdoors 168, 90, and 77 times, with the majority of those events associated with the irrigation system. Only 3 participants used water on a daily basis, 2 of which were running an irrigation system fed from a private well daily. Ten participants used water every 1.4 to 2.8 days, approximately every other day (Table 4).

Irrigation systems used the most water over the course of the study ($3.23x10^6$ L) and accounted for 551 water use events (Table 5, Figure 2) across 4 participants. The average water used per event was also highest for irrigation systems with $5.9x10^3$ L used per event (Table 5). Although the main focus of all the irrigation systems was lawn watering, participants did note that the irrigation provided some water to their gardens. Garden watering accounted for the second highest amount of water used during the study with $7.0x10^4$ L of water used across 552 watering event over 21 participants; however, the mean water used per watering event was 133.4 L (Table 5). Bird bath filling and maintenance was the third most common usage with 186 events spread over 6 participants; however, the mean amount of water used per event was only 12.1 L, which was the lowest mean usage across all tasks, and the total water used across all events was $2.2x10^3$ L. Watering the lawn using a hand-held nozzle was performed 158 times during the study and was spread over 14 participants with an average of 310.2 L used per event. Six participants used water to care for animals for a total of 108 individual events, which included uses such as filling a pet's water dish or a small pool for a turtle and cleaning litter boxes. Fourteen participants washed their cars 43 times using an average of 135.9 L during each event. Only 5 participants filled a pool during

the study resulting in 13 events with a mean water use of $1.5x10^3$ L per event. Washing boats was performed by three participants who used an average of 153.5 L per event and accounted for the smallest amount of total water used with 414.8 L over the course of the study (Table 3). The two remaining categories are 'Other' and 'Unknown.' 'Other' includes tasks that do not fit into any of the other categories but were not performed by more than one participant (e.g. water games, putting out a fire pit). 'Unknown' encompasses water use events where the amount of water and the date and time were recorded but no specific use was indicated (Table 5).

The most outdoor water use events (591) took place between 9am and 5pm (Table 6, Figure 3). This contradicts the survey results where 80% of respondents said they watered primarily in the morning and evening and only 20% said they watered mid-day (Figure 3). Although garden watering was most frequently conducted in the evening, the highest mean amount of water used per garden watering event occurred during morning hours. Irrigation systems were typically run in the early morning hours, but the the highest mean amount used per irrigation event occurred mid-day (Table 6, Figure 3).

Although most individual water uses occurred during the week (Monday through Friday) the mean amount of water used for each task was higher during the weekend (Table 7). For example, irrigation systems were run 397 times during the week and 154 times over the weekend across all participants, however the mean water used during the week was $1.1x10^3$ L and on weekends $2.9x10^3$ L was used per event. Additionally, 389 garden watering events took place during the week and used an average of 25.9 L

per event, but 159 garden watering events took place on weekends and used 63.0 L per event (Table 7).

There was considerable variation among individuals in the amount of water used for specific tasks (Tables 3 and 8). For example, across participants who watered their garden, some kept to about the same amount of water used per event while others had a wide range (>1000 L) in water use for this task (Fig. 4).

There was a significant difference in total outdoor water use between participants with or without a pool (Fig. 5a) and this was also the case when participants running irrigation systems were excluded from the analysis (Fig. 5b). There was also significant difference between the number of months participating in the study and total water use, regardless of the inclusion of participants running irrigation systems (Fig. 6a and b). Although total water use was higher on larger properties, the relationship was not significant with (Fig. 7a) or without (Fig. 7b) participants with irrigation systems included in the analysis. Lawn area was not related to total water use either, regardless of the inclusion of participants with irrigation systems (Fig. 8a and b). For subsequent analysis addressing water use and belief in the need for conservation, the number of months participating in the study was used to standardize total water use.

3.2 Written surveys

Metering Survey. The majority of Metering Survey respondents (57.1%) have lived in their residence 15 years or more even though most participants were 25-44 years of age (62.0%). The gender split between participants was pretty even with 55.2%

males and 44.8% females. Participants' education level was also quite high with 39.3% having a graduate degree and 42.9% holding a Bachelor's degree. The majority of households had 3 or more people residing in them (75.9%) and 46.4% of households had a child under the age of 18 living with them (Table 9).

Study participants primarily use their outdoor space for appreciating nature/beauty (mean = 3.72) and watching or feeding wildlife (mean = 3.45) and less for recreation (mean = 2.83) and socializing and entertaining (mean = 2.62) (Table 10).

When it came to seeking information about landscaping decisions for their outdoor space participants were primarily using the following sources: family, friends, or neighbors (mean = 2.37), the internet (mean = 2.37), books and magazines (mean = 2.34), and landscape companies and garden centers (mean = 2.33) (Table 10). Environmental organizations (mean = 1.67) and the University of Massachusetts website (mean = 1.16) were less popular options for landscaping information (Table 10).

Participants believed most of the water conservation practices listed in the Metering Survey were effective; however, checking soil moisture and only watering as needed (mean = 4.30) and watering at dawn and dusk (mean = 4.25) were evaluated as more effective than the other practices. Watering the lawn less often (mean = 4.11), using mulch on garden beds (mean = 4.07), adding organic matter to the soil (mean = 4.04), and using a timer during watering (mean = 4.00) were all similar in their evaluated effectiveness, while installing a moisture sensing irrigation system was rated as least effective (mean = 3.73) by participants (Table 10).

Participants were most willing to install a drought-tolerant lawn (mean = 3.71), which was closely followed by a drought-tolerant landscape (mean = 3.60). Rain barrels (mean = 3.35) and reducing lawn area (mean = 3.21) were also popular options. Participants were less willing to install rain gardens (mean = 2.91) and green roofs (mean = 1.73) (Table 10). When asked what would encourage participants to install a rain garden, not having to pay for it (mean = 4.20) was by far the most likely option and was followed by receiving technical assistance (mean = 3.62). Participants evaluated a reduction in sewer and water bill (mean = 3.28), making their property look more interesting (mean = 3.26), and increasing stream water quality (mean = 3.25) similarly. Decreasing flooding (mean = 2.92) and having a friend or neighbor install one (mean = 1.74) were less likely to motivate a participant to install a rain garden on their property (Table 10). The same series of questions was asked about encouragement to install a rain barrel on their property and again not having to pay for it (mean = 4.67) was the top ranked motivator. This was followed by a reduction in participant's sewer and water bills (mean = 3.55), increasing stream water quality (mean = 3.50), and receiving technical assistance (mean =3.42). Decreasing flooding (mean = 2.40), making their property look more interesting (mean = 2.00), and having a friend or neighbor install one (mean = 2.00) were considerably less popular motivators for rain barrel installation (Table 10).

When asked to rate how much a series of statements reflected their opinion of outdoor water use restrictions, the general consensus of participants was that they were necessary (mean = 4.28). And although participants felt the restrictions were an

effective way to reduce outdoor water use (mean = 3.86), they did not believe that they were affected significantly by the restrictions (mean = 3.55) and did not consider them an inconvenience (mean = 2.14). Participants also felt they understood why restrictions were in place which was supported by the low mean (1.18) associated with the statement 'I don't understand why we have them' (Table 10).

Participants believed that the most serious environmental concerns in Massachusetts were fewer fish in rivers and ponds (mean = 3.44) and climate change (mean = 3.22). Flooding (mean = 3.04), poorly planned development (mean = 2.84), and the availability of drinking water (mean = 2.59) were not as concerning to participants. Too many environmental regulations (mean = 1.81) were also not something that concerned participants (Table 10).

Participants rated several factors as encouraging them to reduce their water use, including cost (i.e., doubling in their water bill, mean = 3.83; a $100 surcharge, mean = 3.15), less need for use (i.e., if their property required little or no water, mean = 3.46; if their property had less lawn, mean = 3.11), and regulations (i.e., regulations limiting irrigation; mean = 3.07; Table 10).

Comparison to Landscape Survey. Although demographic information differed between Landscape Survey and Metering Survey respondents, there were few significant differences. The metering participants lived in their homes for a shorter average period then the Landscape Survey respondents ($X^2 = 11.976$, $p = 0.043$) and had more children under age 18 living at home ($X^2 = 7.181$, $p = 0.041$) (Table 11). Metering participants also indicated that they obtained significantly more information about

landscaping from family, friends, and neighbors (mean = 2.76) than Landscape Survey respondents (mean = 2.38, t = -2.254, p = 0.030, Table 11).

Opinions about outdoor water use restrictions between Landscape Survey respondents and metering participants only differed significantly in one case, 'I don't understand why we have them', where Landscape Survey respondents were more likely to not understand why we had restrictions than metering participants (t = 4.065, p = <0.001, Table 11). Landscape Survey respondents believed there were too many environmental regulations (mean = 2.34) compared to metering participants (mean = 1.81, t = 2.359, p = 0.024, Table 11).

When asked to evaluate the effectiveness of various practices at reducing outdoor water use, Metering Survey respondents believed that adding organic matter to the soil was more effective than Landscape Survey respondents (t = -2.049, p = 0.048)(Table 11). Metering participants were overall more willing to install all conservation practices than Landscape Survey respondents, although the only significant difference was found for installation of a green roof (t = -2.067, p = 0.050, Table 11). When asked what factors would encourage respondents to install a rain garden on their property, metering participants evaluated all factors as more likely to encourage them to install a rain garden than Landscape Survey respondents; however, only receiving technical assistance was significantly higher (t = -2.146, p = 0.040, Table 11). The only factor that was significantly different between Landscape and Metering Survey respondents when asked what would encourage them to reduce their outdoor

water use was if their water bill doubled (t = -3.697, p = 0.001), increasing the likelihood that Metering Survey respondents would reduce their outdoor water use (Table 11).

3.3 In-person interviews

Twenty interviews were conducted with 17 interviews consisting of just one person (male = 8, female = 9) from the household who was primarily responsible for outdoor watering being interviewed and 3 couples where watering duties were divided between them. Interview participants were from North Reading (7), Wilmington (4), and Topsfield (9). Eighteen of the participants were using water from the public water supply for their outdoor watering and the remaining 2 had private wells.

3.4 Question 1: How do people decide whether or not to use water outdoors on any given day?

Interview responses fell into 3 categories: weather mediated scheduled watering, weather and plant appearance mediated non-scheduled watering, and unmodified irrigation schedules.

Weather mediated scheduled watering included residents that maintained a general water use schedule, such as every day when they return home from work or once a week, that they adjust in response to rainfall or dry conditions. This behavior is illustrated by an interview with a participant who, in response to a question asking if they maintained a watering schedule, said:

> "You know if it rains obviously I am not going to water that day and I can probably get by a day or two after that. But yeah I have it pretty much scheduled. It's almost always when I can, most of those things that you see filled out will be 5 o'clock 5:30 that's when I get home. Sometimes I'm

> not motivated the minute I get home, but that is typically the time that I do it."

Similarly, another participant said:

> "Well it is definitely a routine, I always do it on a Friday because we go to our summer place for the weekend. And if it needs it during the week if it's really dry, really hot I'll put a little in there. But it is usually once a week I do it."

Weather and plant appearance mediated non-scheduled watering encompassed residents who did no water on any type of water use schedule and simply watered in response to weather conditions and associated plant wilting. For example, one participant stated:

> "No, I guess we just kind of watch the rain fall and when things get really dried out we water. You can see my hydrangea bush is kind of wilted on a day like today, so we would probably, I mean I can wait that out but it would probably need watering later in the day and it will spring back when you put a little water on there."

Additionally, another resident expressed a similar sentiment:

> "It's gauged on weather, whether or not we've had rain in the past 3 days, soil moisture level. It is subjective, not objective."

One participant operated their irrigation system manually in response to weather patterns and ended up setting up a schedule while they were away because of the recent dry weather:

> "So I'm a little unhappy how much I have to use the irrigation, this year's been pretty dry, May was just amazingly dry, so you saw in the email you saw that we

> were away for two weeks and I at the last minute, I'm watching the weather forecast and everything, just when we left I said I left it on the odd program, so basically running every other day for about two weeks."

Unmodified irrigation schedules included 2 participants who ran their irrigation systems on a daily schedule that was not modified in response to weather patterns (i.e. no moisture sensor or manual control). These participants were both drawing their outdoor water from a private well and maintained a distinctly different opinion about water use on their property compared to participants in the previous two behavior groups. When asked about their current irrigation schedule, one participant responded:

> "…the schedule, well we start it early in the morning because you are supposed to water it before the sun really comes up and evaporates a lot of it, uh, I do it every day because its basically free."

Likewise, one of the other participants who maintained a private well made a similar statement:

> "A: It's running everyday. We haven't had very good luck with rain sensors.
> B: We've tried a couple different rain sensors and they've never successfully done what they were supposed to do.
> A: So because we're not constrained in the amount of water we use our water is also not very expensive, so we just do catch and release."

Beyond schedule and appearance, the source of water emerged as another factor influencing outdoor water use decisions. Distinct differences were observed between participants receiving their water from the public water supply and those who maintained a private well. Of the 2 study participants running private irrigation systems

both have unique situations that exemplify the challenges of addressing water conservation and private water supplies. One participant's view of their lawn irrigation as "catch and release" demonstrated that they do not view themselves as connected to the aquifer as a whole but rather as a recycler of their own water, which unfortunately is not the case in most situations because so much water is lost to evapotranspiration and run off from compacted soils. Evapotranspiration is a particular issue in this participant's case because they run their irrigation system daily, throughout the day. It is interesting that these participants are unconcerned with their water use and do not believe conservation is necessary for residents in the Ipswich River Watershed given their ownership of a second property in a location where freshwater is in incredibly short supply. This participant was incredibly aware of their water usage, management, landscaping, and irrigation practices and discussed their water use at this property with me in great detail. They also served on the water board in their town and had expansive knowledge of water use policy and pricing, even commenting that,

> "…even with the restrictions it's very expensive to water your lawn all summer, it's not an issue because we are using a well…"

The second participant using a private well has interior water from a public water supply but their irrigation system is run by a private well they installed after they moved into the property,

> "Actually, well originally, I had the system first not that I remember and I drew water out of the pond, but there was so many little pieces of algae and stuff that kept gumming up the sprinklers that turned out not to work, so that's when I put the well in after that. But I never had it hooked up to house water."

Although this participant ran their irrigation system at night to reduce evaporation, it was still running daily. Of the remaining participants running an irrigation system, one ran their system every other day and the other did not maintain a schedule and controlled their system manually in response to lawn appearance. The use of irrigation systems by residents with private wells served as a source of frustration for many participants,

> "…you can see right over there the sprinklers are running over there now but people that get their own wells, and maybe that's an issue that's in the future somehow needs to be attacked…I mean right now they'll put a little sign out front that just says well water and the town provided those things…its designed to allow you to look the other way from people watering from that house because you are supposed to think its ok because they paid for a well…"

Participants clearly distinguished garden water from other outdoor water use tasks. Participants noted violating restrictions to care for their garden,

> "The garden, that's sort of where I have a little bit of violation of the water restrictions, but I did I only use the soaker hose or I do it by hand watering, I think the requirement is hand watering and I do it in the evenings or in the mornings to try to avoid evaporation."

Participants also felt justified in their use of water for their garden compared to other uses as one participant noted,

> "…since we don't wash cars every week, if I spend 20 gallons of water watering my garden and I'm not washing my truck every week, I think you ought to give me some brownie points."

Additionally, participants expressed that they were unsure how to apply water use restrictions to their property since they did not water their lawn and instead focused on their garden area,

> "We try to be as faithful as we can with it. You know the hand watering, its not their not real specific on it, they talk about lawn watering but they don't talk about your vegetable garden or anything like that, so I don't know what they actually mean by that [in reference to hand watering]."

Study participants often considered themselves small water users because they were not using an irrigation system to water their lawn. Comparatively these participants were not using much water, but because they held this view they were less inclined to adhere to water use restrictions even if there were ways for them to use less water outdoors on their property.

3.5 Question 2: Does a person's belief that residents need to be conserving water correspond to their total outdoor water use and willingness to implement conservation practices?

Three participants did not believe it was necessary for residents to be conserving water and 15 believed residential water conservation was necessary. The remaining 2 participants could not be categorized. A willingness-to-conserve metric was calculated for 12 of the respondents (3 who did not believe it was necessary and 9 who believed it was necessary). The willingness-to-conserve metric was created based on responses to question 19 of the Metering Survey (Appendix B). Correlation analyses indicated that a participant's response to the rain garden feature correlated very strongly ($r = 0.68$) with all other responses and that responses to drought-tolerant lawn and landscape were

highly correlated (r = 0.96) (Figure 5). Standardized Cronbach's alpha for each feature was between 0.78 and 0.86, indicating that if a feature were dropped the result would still be reliable (Table 12). For this reason, rain garden was dropped from the metric and scores for drought-tolerant lawn and landscape were averaged and then that average score was averaged with the participant's responses to rain barrel, green roof, and reduced lawn area to develop an overall willingness metric (Table 12).

No significant difference was found between willingness to implement conservation practices and belief in the need for residents to be conserving water (Fig. 6). The mean willingness score for participants who did not believe conservation was necessary (mean = 2.50) and those who did (mean = 2.53) were nearly identical. The mean monthly water use for participants who did not believe conservation was necessary (mean = $2.5x10^4$ L) was much larger than those that did believe conservation was necessary (mean = $1.6x10^3$ L); however, this difference was not significant (Fig. 7).

3.6 Question 3: How does knowledge of the amount of water an individual is using outdoors influence that individual's behavior and belief regarding outdoor water use?

During the interview 8 participants indicted that they changed their water use behavior in response to participating in the study while 9 participants said they did not deviate from their typical water use behavior. The 9 participants who did not change their behavior provided very confident responses indicating that they had not varied their behavior during the interviews. Additionally, conversations during visits to participant's residences during the study period were consistent with their interview responses providing additional confidence.

Of the participants who changed their behavior, they indicated changing the length of time they watered, the amount that they watered, and task prioritization. For example one participant changed the length of time they turned their garden sprinkler on for,

> "It did actually, because I initially set it to 25 minutes and then I downed it to 20. I was, especially with the sprinklers, I was like wow it uses a lot…I looked at the meter after that whole back and forth and back and forth. It was like oh my god it was like 40 gallons and I was like wow."

Other participants used the meter to maintain a consistent amount of water use,

> "Well once you gave me the meter I was looking at the meter and then I could see what I was using and then I would kind of go for the same amount. That was very helpful. Prior to that I really didn't pay any attention, it was give it a soak. There was no measure."

This same behavior change was expressed by another participant who stated,

> "I try and stay within that average of 20, because now you know exactly how much you're using. You don't want to go overboard but you do want to be conscientious."

Alternatively, another participant changed which tasks they performed based on the amount of water they were using,

> "…it's good to know how much use was happening, so you can go I'll wash the car or I'll trade it for the garden."

Analysis of Metering and Post Survey responses showed that participants' willingness to install conservation practices increased following study participation; however, these changes were not significant (Table 10). Metering participants were also asked how much these factors would encourage them to install a rain barrel; however,

only two of the factors received enough responses to be evaluated statistically and these did not show any significant changes following study participation (Table 10). Interestingly, in the Post Survey, respondents were more likely to indicate that they did not understand why outdoor water use restrictions were in place compared to both the Landscape Survey respondents and the Metering survey. However, the sample size was not large enough to evaluate this statistically. Additionally, paired t-tests showed that Post Survey respondents significantly decreased their belief that that they were affected by outdoor watering restrictions ($t = 3.011$, $p = 0.008$) but were more likely to consider restrictions an inconvenience ($t = -2.425$, $p = 0.028$) (Table 10). When paired t-tests were conducted of metering participant's responses before and after study participation their evaluations of environmental problems increased significantly in all but the case of having fewer fish in rivers and ponds, which did increased, but not by a significant amount (Table 10).

CHAPTER 4

AN INDIVIDUALIZED APPROACH

Low-density residential development is the dominant development strategy in suburban Boston and has been linked to water supply issues in the Northeast (Hill and Polsky 2005, Polsky et al. 2009, Runfola et al. 2013). Irrigation systems have been shown to use the greatest amount of water outdoors at the residential level (Hanak and Browne 2006, Polsky et al. 2009, Mini et al. 2014, Neel et al. 2014) and this was also seen in this study, further supporting the association of residential development and strain on the water supply. Although only 4 participants used irrigation systems during the study, another 14 participants watered their lawn by using a hand-held nozzle to apply water to newly planted grass seed and larger areas of their lawn. Interestingly, most participants (59%) watered their garden during the study, but overall water use was much lower than irrigation systems. Therefore, reducing the amount of water used by irrigation systems is imperative for making a significant impact on residential outdoor water use.

This study identified several combinations of factors that influence residents' decisions to water. The three distinct water use behaviors identified in this study (weather mediated scheduled watering, weather and plant appearance mediated non-scheduled watering, and unmodified irrigation schedules) are consistent with categories identified by Svenson (1992) who classified environmental decisions into four categories ranging from habitual behaviors to purely cognitive behaviors. Here, the unmodified

irrigation schedules represent a behavior not modified by additional cognitive information, whereas those who watered based on weather and plant appearance were employing cognitive behaviors. The third behavior category identified in this thesis, weather mediated scheduled watering, fits nicely in the middle of this spectrum. Svenson's work (1992) applies to behavior more broadly allowing it to be applicable to a range of environmental behaviors, including outdoor water use and conservation.

The consistency between Svenson's study (1992) on environmental decision-making and this thesis suggests that education and outreach targeted to behavior categories ranging from habitual to purely cognitive may effectively encourage water conservation. However, changing habitual behavior can be challenging because the changes still need to address the individual's desire to maintain a schedule. Therefore, developing outreach and education tools that specifically address developing a new habit are needed. For example, irrigation systems are often run on a schedule, and since they are the largest outdoor water use task creating an appropriate irrigation schedule for an individual's property is critical for reducing water use. Other studies have noted that residents often do not know how much water their property needs or how much water they are applying (Bremer et al. 2012) and this can result in over watering of the lawn when the needs of the lawn have actually been met by the rain (Survis and Root 2012). To limit watering during or shortly after a rain event, rain/moisture sensors should be installed on irrigation systems. However, sensors only address part of the issue because regardless of rainfall, irrigation systems may still be running more frequently than needed. Overwatering can be addressed by providing residents with a

way to calculate the water needs of their property and the output of their irrigation system in order to develop a watering schedule that suits the needs of their property, reduces overall water use, and allows them to maintain a set routine. This personalized approach extends to residents whose typically scheduled behavior could be mediated by weather and plant appearance. Providing these residents with information about their property's water needs allows the resident to modify their water use in a way that reduces their water use while simultaneously meeting the needs of their property. Additionally, providing appropriate information about how to respond to particular weather patterns based on property features may also help effectively reduce outdoor water use for people who are prone to making decisions based on case-specific information. Although decision-making approaches may differ, individualized information about water needs will result in more efficient water use.

The day of the week seems to also impact how much water is being used outdoors. Although more individual water uses occurred during the week (Monday-Friday) the mean amount of water used by task increased on weekends. This is not surprising because people may have more time to spend outside focusing on property features such as gardens on Saturdays and Sundays. Therefore, information provided to residents should take into account standard work hours when providing suggestions for water use on their properties.

While understanding how residents make water use decisions is important to encourage outdoor water conservation it is also necessary to evaluate whether residents believe they should be conserving water outdoors and their willingness to

implement conservation approaches. Participants in our study generally believed conserving water is necessary; however, many are not willing to implement a landscape level modification to their property, such as drought-tolerant landscape or rain barrel. Their responses to questions about willingness to adoption conservation practices may be a reflection of cost, aesthetic preferences, knowledge of how to implement the practice, and applicability of the method for their individual property, not just their theoretical openness to making a change. Teasing these components apart can be challenging, and given that many participants responded that they would be willing to install a rain barrel or a rain garden if they did not have to pay for it, economics are clearly an important aspect of this willingness metric. Therefore, providing financial incentives for installation of conservation practices and smaller scale tools may be more effective at encouraging implementation of water conserving practices.

An additional approach for water conservation may be to provide residents with water meters for their outdoor spigots. This study demonstrated that when a resident is aware of their outdoor water use they often decrease their outdoor water use. While a meter on an outdoor spigot does not address the greatest water use task (i.e., irrigation systems), it provides an opportunity to engage many community members in conservation initiatives. Engaging a larger number of people in outdoor water conservation may increase residents' concerns for other environmental problems in Massachusetts, as was seen in this study. Providing residents with information about their specific water use compared to the town average or others on their street in their water bills may impact of water use more than short-term educational campaigns. An

individualized comparative approach such as this has successfully been used to reduce energy use (Bird and Rogers 2010), and there is the potential for this to be an effective strategy for encouraging a reduction in water use in the Ipswich River Watershed.

Individualized information also fills a knowledge gap identified during this study. Many participants expressed a desire for personalized ways to reduce water use at their property and some also commented that they did not understand how to apply water use restrictions, especially when the restrictions limit water application to hand-watering. This information is important when taken in the context of the Reasonable Person Model (RPM) (Kaplan and Kaplan 2009) which addresses the relationship between three components: effectiveness, model building, and meaningful action. The findings in this thesis suggest an issue in the *effectiveness* component of the Reasonable Person Model (RPM). Residents are being provided with information that they are unsure how to translate into *meaningful action*, in this case reducing water use at their property. In order to address this, a way for residents to easily calculate the water use needs on their property and to identify how much water they are actually using is necessary. This information could come in the form of an online calculator where residents input property features and are provided with an estimated water use or by indicating the amount of water they use outdoors on their water bill or a provided meter. The feasibility in terms of cost and potential water savings still needs to be evaluated, but based on the work by Kaplan and Kaplan (2009), when people are provided with information appropriate to their situation that addresses their specific needs they are in a better position to make reasonable decisions. For example, although

some water use restrictions and bans may address when and how to provide water to features such vegetable gardens, there appears to be some confusion or a lack of communication regarding how restrictions apply to gardens. Given residents' responses to interview questions indicating that habits can be mediated by an external force, there is an opportunity to provide residents with information that may more effectively encourage residents to develop a habit that reduces outdoor water use.

The source of water—whether it is from a public versus private water supply—also influenced water use behaviors and perspectives toward conservation. Concerns over private wells in Massachusetts is not new, an article in the Boston Globe (Daley 2009) addressed the prevalence of homeowners digging private wells which allowed them to avoid being subject to restrictions while still drawing from the same water supply. In this thesis, the two participants using private wells used daily irrigation systems and viewed their property as isolated from the larger watershed and their water as free (due to the minimal cost to run the well pump), while those on public water supply were more likely to feel water conservation was necessary and were not as concerned with the cost of water but for a different reason. Participants on public water supplies expressed that their water was cheap since most were not running irrigation systems, limiting their motivation to implement conservation practices that required financial investment. This demonstrates that addressing the impact of economics on water use decisions may differ based on water supply and many water use decisions by residents on a private water supply may be driven by cost and not by a belief in the need for conservation. Therefore, a different approach to encouraging a reduction in

outdoor water use for private well users is needed, particularly those running an irrigation system. Given the use of private wells in Massachusetts, understanding how water use compares between private and public water users would be useful for further development of water policies and restrictions.

Research by Rachel Danford and colleagues (in prep) demonstrates that the decisions made by utilities regarding demand-side management approaches, such as restrictions, are often made without information on residential attitudes and community norms, which can directly influence the effectiveness of demand-side management tools. This thesis provides useful information to water providers as they seek to develop water conservation tools and management approaches, a Massachusetts requirement, in their municipality. Since the Ipswich River Watershed has suffered from considerable water supply issues for multiple decades (Armstrong et al. 2000, Bowling and Mackin 2003, Polsky et al. 2009), providing useful information to water provides will help them more effectively address water supply issues throughout the watershed.

The statistical power of this study, particularly for water use and survey information, is limited due to a small sample size. Other studies examining outdoor water use data are typically much larger, employing data from hundreds of households (Cardell-Oliver 2013, Runfola et al. 2013, Kenney 2014, Mini et al. 2014). These studies examine total outdoor water use, which can be estimated from water utility bills supplied by the town allowing a larger sample size to be used. The number of surveys used in this study was also small compared to other studies, which typically use

hundreds of survey responses in their analysis (Larsen and Harlan 2006*a*, Barrett and Wallace 2009, Attari 2014). For studies incorporating a pre and post study survey component it is not uncommon for the response rate and total number of participants to be smaller. However, the number of interviews used in this study is comparable to the numbers used in other studies (Hill and Polsky 2005, Clark and Finley 2008, Gabe et al. 2012, Harris et al. 2012). While small, this study provides a unique perspective by providing data on the specific end-uses of water outdoors and correlating this information to survey and interview responses.

Although many studies have examined the factors influencing outdoor residential water use in the Western US (Renwick and Green 2000, Martin et al. 2003, Hurd 2006, Larsen and Harlan 2006*b*, Wentz and Gober 2007, Kenney et al. 2008, Mini et al. 2014) and Australia (Herzog et al. 2000, Miller and Buys 2008, Barrett and Wallace 2009, Gilbertson et al. 2011, Dolnicar et al. 2012), there has been comparatively limited worked conducted in the Northeastern US, making the information provided in this study important for focusing further research. The studies from the Western US and Australia often address water supply shortages resulting from a lack of rainfall, however, in the Northeastern US water supply shortages can be created through a socioeconomic drought (Hill and Polsky 2005, 2007, Polsky et al. 2009, Runfola et al. 2011, Tsai et al. 2011, Runfola et al. 2013). Therefore, research to determine if decision-making and water use behaviors are similar between these regions is necessary. The impact of irrigation systems and decision-making patterns observed in this thesis were consistent with studies conducted in other regions and within the environmental psychology

literature. However, private wells are more common in the Northeastern US and these residents differed in their water use decision-making, indicating that additional research is needed to encourage outdoor water use conservation across all residents within the Ipswich River Watershed. Addressing "the human element of landscape water management," a gap in the literature (Mayer et al. 2015), demonstrated the need for individualized water use information and the potential impact this information can have on reducing outdoor residential water use in in the future.

TABLES

Table 1. Town data and population growth/conservation priority category for selected towns.

Town	Wilmington	North Reading	Middleton	Topsfield
Water Source	Ground, MWRA[1]	Surface	Surface	Ground
% of population on Public Water Supply[2]	95	97	65	79
Population[3]	22,325	14,892	8,987	6,085
Median Yearly Household Income[3]	99,508	110,852	104,245	111,696
Watering Restriction Trigger[4]	Streamflow	Streamflow	Not flow-based	Streamflow
Category[5]	Low conservation/Low growth rate (6%)	High conservation/High growth rate (9%)	Low conservation/High growth rate (18%)	High conservation/Low growth rate (1%)

[1]Massachusetts Water Resources Authority
[2]Anita Milman, "Mass Community Water Public Water Systems"
[3]Median income data from the US Census Bureau 2010
[4]Anita Milman, unpublished data
[5]Stacy 2015

Table 2. Data and variables to be used to address research questions.

Question	Data	Dependent Variables	Independent Variables
How do people decide whether or not to use water outdoors on any given day?	**Interview data** – Section 1: Decision to Water • Why did you select a certain time of day to water? • How do you decide how long to water for? • What makes you decide that it is time to water?	**Watered** (Yes/No)	**Weather** (hot, dry, rainy) **Soil Appearance** (color –light/dark, wet/dry) **Plant Appearance** (wilted) **Restrictions** (day – odd/even) **Schedule** (daily or weekly)
Does a person's belief that residents need to be conserving water correspond to their total outdoor water use and willingness to implement conservation practices?	**Meter data** –total water use **Survey data** – Landscape Survey • Question 15) Please indicate if you have any of these features on your property and your willingness to implement them. **Interview data** – Section 4: Need for Conservation • Is it necessary for residents to be conserving water?	**Total outdoor water use** **Willingness to implement** (factor combining 4 variables; 5 point scale)	**Belief in need for water conservation** (Yes/No) **Controlling variables:** Months in Study
How does knowledge of the amount of water an individual is using outdoors influence that individual's water use decisions?	**Interview data** – Section 6: Study Experience Did knowing your water use change how you used water? If so, in what ways?	**Total water use** **Amount per watering event** **Frequency of watering**	**Knowledge of water use**

Table 3. For each study participant the total number of months in the study, their total water use across all tasks, and total volume in L and count of water use events (in parentheses) for each water use task.

Participant	Months	Total water use (L)	Animal care	Bird bath	Washing boat	Washing car	Watering garden	Watering lawn (by hand)	Irrigation system	Property maintenance	Filling pool	Other	Unknown
142PRT	9	8103.4		999.7 (6)			6284.9 (50)			541.3 (3)	277.5 (1)		
17GRN	9	15415.3					13462.4 (64)	1172.0 (4)		18.9 (1)			762.0 (3)
29CET	9	3287.6					3134.3 (37)	102.2 (1)		51.1 (2)			
36BHT	9	659.4		26.1 (2)	42.4 (2)		678.3 (9)			7.2 (1)			
6NHN	9	19045.2				22.7 (2)	1048.2 (65)	2541.9 (61)		1.9 (1)	15402.8 (5)	27.6 (2)	
13NAW	8	2483.2						2094.1 (4)			389.1 (2)		
151CHN	8	483446.1							483446.1 (168)				
1LAW	8	6987.1	138.9 (24)			1378.6 (9)	4290.8 (42)	851.7 (3)		238.9 (6)			88.2 (2)
66SMT	8	11094.7	2727.4 (42)			823.7 (3)	4106.8 (51)	2920.1 (5)		474.3 (24)			
9LOW	8	26284.4					844.1 (5)	22371.8 (27)		905.1 (3)			2163.4 (1)
3CRN	7	1236.7				615.5 (9)	609.8 (7)			11.4 (1)			
3GEW	7	1567159.7							1567159.7 (230)				
73BHT	7	2950.3				84.4 (2)		1516.8 (2)			1349.1 (2)		
8MIW	7	13703.2				223.3 (2)	3955.8 (12)	8399.8 (2)		730.6 (7)		393.7 (4)	
153PRT	6	7068.9	294.5 (20)			1.9 (1)	5616.0 (24)	859.3 (4)		297.2 (8)			
15RRT	6	662.8											
16PRT	6	6142.2	18.9 (1)	967.9 (142)	147.6 (2)	132.5 (1)	4759.4 (32)			64.4 (3)	2135.0 (2)		
38NOT	6	7730.6					7582.9 (19)						
158WAT	5	8879.4				344.5 (1)	7952.0 (52)						583.0 (6)

Participant	Months	Total water use (L)	Animal care	Bird bath	Washing boat	Washing car	Watering garden	Watering lawn (by hand)	Irrigation system	Property maintenance	Filling pool	Other	Unknown
4CCN	5	955.1					710.9 (22)						19.3 (1)
5RSN	5	180.2					48.5 (2)			131.7 (5)			
82MHN	5	886088.8							886088.8 (77)				
39HAW	5	0.0											
179PRT	4	1587.6				14.8 (1)	987.2 (34)	63.2 (7)		63.6 (2)			458.8 (21)
19TDN	4	304268.6			224. 9 (2)	675.7 (4)		280.9 (3)	302832.8 (76)	479.2 (5)			
6PIN	4	2180.4						2180.4 (23)					
9HTN	4	3925.1				599.6 (3)	3325.5 (16)						
10AVM	4	0.0											
150RIT	3	4724.9											
18LAM	3	439.9	22.3 (1)	272.2 (35)			145.4 (1)						
39COT	3	1102.7	227.9 (20)			5.7 (1)	673.8 (2)			195.3 (5)			
5FAN	3	1745.1				253.6 (1)	204.4 (2)	1287.0 (5)					
37BUN	2	728.4											
44BUN	2	0.0											

Table 4. Total number of outdoor water uses and average number of days between uses. Participants ordered from highest to lowest number of uses.

Property ID	Total number of uses	Average # of days between uses
3GEW	231	1.0
16PRT	183	0.9
151CHN	168	1.0
6NHN	136	1.4
66SMT	126	1.9
19TDN	90	1.9
1LAW	86	2.8
82MHN	77	2.0
17GRN	72	3.0
142PRT	66	3.7
179PRT	64	2.0
158WAT	59	1.8
153PRT	57	3.0
29CET	41	5.5
9HTN	40	5.4
18LAM	37	2.2
39COT	28	3.2
4CCN	23	6.9
6PIN	23	5.4
38NOT	19	3.8
8MIW	19	5.4
3CRN	18	8.4
36BHT	15	14.7
5FAN	8	7.9
13NAW	7	5.8
5RSN	7	2.8
6PIN	6	2.2
Overall	1706	3.9

Table 5. Number of times each type of outdoor water use task was performed and the water use (total, mean, minimum, maximum, and standard deviation) across all water use events for nine months (August through October 2014 and May through October 2015). Table ordered by total amount of water used by task over nine months of study.

Task	Number of participants	Count	Total (L)	Mean water use (L)	Min water use (L)	Max water use (L)	SD
Other[1]	3	7	414.8	70.2	12.5	136.3	61.0
Washing boat	2	7	421.3	153.5	17.4	659.8	14.8
Filling pool	6	186	2265.7	1512.4	107.9	4542.5	8.3
Unknown[2]	6	108	3429.6	118.0	1.1	2163.4	9.6
Washing car	6	36	4074.2	135.9	1.9	367.9	97.8
Property maintenance	16	82	4211.6	53.5	2.6	724.1	25.4
Animal care	14	43	5176.0	31.8	3.8	189.3	25.5
Watering lawn (by hand)[3]	5	13	19551.4	310.2	7.6	3825.9	399.7
Bird bath	14	158	46636.1	12.1	1.5	272.5	159.0
Irrigation system[4]	21	552	70413.9	5922.3	605.7	11507.6	55.0
Garden watering	4	551	3239176.5	133.4	2.3	2808.4	776.3

[1]Miscellaneous tasks that did not fit into a single category (e.g. putting out a fire pit or water games)
[2]Amount, date, and time were recorded but no specific task was indicated
[3]Watering with hose or a moveable sprinkler (not automated)
[4]In-ground irrigation system set on a timer or manually controlled

Table 6. Count of water use tasks and mean water used for each task during morning (before 9am), mid-day (9am-5pm), and evening (after 5pm) times for all participants for nine months (August through October 2014 and May through October 2015). NA indicates measurement was not applicable due to lack of task performance.

	Time of Day					
	Morning		Mid-Day		Evening	
Task	Count	Mean water use (L)	Count	Mean water use (L)	Count	Mean water use (L)
Animal care	23	13.6	63	42.4	15	20.4
Bird bath	144	6.8	23	50.0	19	7.2
Washing boat	0	NA	6	68.9	0	NA
Washing car	1	31.4	25	124.9	16	159.7
Watering garden	80	179.8	219	105.6	244	133.2
Watering lawn (by hand)	20	103.3	83	163.9	54	610.2
Irrigation system	210	3435.6	94	9700.5	16	2347.0
Property maintenance	5	87.8	54	54.9	14	54.5
Filling pool	1	128.7	9	1445.3	2	3208.1
Other	0	NA	3	14.0	4	98.4
Unknown	8	111.7	12	204.8	8	43.2
Totals	492	-	591	-	392	-

Table 7. Total number of times each task was performed on a weekday and a weekend (Saturday or Sunday) for all participants throughout the study period and the mean daily amount of water used per task for weekdays and weekends. NA indicates measurement was not applicable due to lack of task performance.

	Weekday		Weekend	
Task	Count	Mean water use (L)	Count	Mean water use (L)
Animal care	78	6.9	28	12.3
Bird bath	130	2.4	54	6.4
Washing boat	6	13.9	0	NA
Washing car	26	30.1	17	55.8
Watering garden	389	25.9	159	63.0
Watering lawn (by hand)	116	58.2	40	170.9
Irrigation system	397	1174.8	154	2946.4
Property maintenance	49	11.6	31	24.8
Filling pool	8	223.0	4	1329.2
Other	2	2.8	5	49.2
Unknown	26	28.7	9	26.7

Table 8. For each study participant the total number of months in the study, their total water use per months in study use across all tasks, and the mean amount used per water use event and monthly mean amount used per water use event (in parentheses) for each task. All measurements are given in liters.

Participant	Months	Standardized total water use (L)	Animal care	Bird bath	Washing boat	Washing car	Watering garden	Watering lawn (by hand)	Irrigation system	Property maintenance	Filling pool	Other	Unknown
142PRT	9	900.4		166.6 (18.5)			125.7 (14.0)			180.4 (20.0)	277.5 (30.8)		
17GRN	9	1712.8					210.4 (23.4)	293.0 (32.6)		18.9 (2.1)			254.0 (28.2)
29CET	9	365.3					84.7 (9.4)	102.2 (11.4)		25.6 (2.8)			
36BHT	9	73.3		13.1 (1.5)	21.2 (2.4)		75.4 (8.4)			7.2 (0.8)			
6NHN	9	2116.1				11.4 (1.3)	16.1 (1.8)	41.7 (4.6)		1.9 (0.2)	3080.6 (342.3)	13.8 (1.5)	
13NAW	8	310.4						523.5 (65.4)			194.6 (24.3)		
151CHN	8	60430.8							2877.7 (359.7)				
1LAW	8	873.4	5.8 (0.7)			153.2 (19.1)	102.2 (12.8)	283.9 (35.5)		39.8 (5.0)			44.1 (5.5)
66SMT	8	1386.8	64.9 (8.1)			274.6 (34.3)	80.5 (10.1)	584.0 (73.0)		19.8 (2.5)			
9LOW	8	3285.5					168.8 (21.1)	828.6 (103.6)		301.7 (37.7)			2163.4 (270.4)
3CRN	7	176.7				68.4 (9.8)	87.1 (12.4)			11.4 (1.6)			
3GEW	7	223880.0							6813.7 (973.4)				
73BHT	7	421.5				42.2 (6.0)		758.4 (108.3)			674.6 (96.4)		
8MIW	7	1957.6				111.7 (16.0)	329.6 (47.1)	4199.9 (600.0)		104.4 (14.9)		98.4 (14.1)	
153PRT	6	1178.1	14.7 (2.5)			1.9 (0.3)	234.0 (39.0)	214.8 (35.8)		37.1 (6.2)			
15RRT	6	110.5											
16PRT	6	1023.7	18.9 (3.2)	6.8 (1.1)	73.8 (12.3)	132.5 (22.1)	148.7 (24.8)			21.5 (3.6)	1067.5 (177.9)		
38NOT	6	1288.4					399.1 (66.5)						

Participant	Months	Standardized total water use (L)	Animal care	Bird bath	Washing boat	Washing car	Watering garden	Watering lawn (by hand)	Irrigation system	Property maintenance	Filling pool	Other	Unknown
158WAT	5	1775.9				344.5 (68.9)	152.9 (30.6)						97.2 (19.4)
4CCN	5	191.0					32.3 (6.5)						19.3 (3.9)
5RSN	5	36.0					24.2 (4.8)			26.3 (5.3)			
82MHN	5	177217.8							11507.6 (2301.5)				
39HAW	5	0.0											
179PRT	4	396.9				14.8 (3.7)	29.0 (7.3)	9.0 (2.3)		31.8 (7.9)			21.8 (5.5)
19TDN	4	76067.2			112.4 (28.1)	168.9 (42.2)		93.6 (23.4)	3984.6 (996.2)	95.8 (24.0)			
6PIN	4	545.1						94.8 (23.7)					
9HTN	4	981.3				199.9 (50.0)	207.8 (52.0)						
10AVM	4	0.0											
150RIT	3	1575.0											
18LAM	3	146.6	22.3 (7.4)	7.8 (2.6)			145.4 (58.5)						
39COT	3	367.6	11.4 (3.8)			5.7 (1.9)	336.9 (112.3)			39.1 (13.0)			
5FAN	3	581.7				253.6 (84.5)	102.2 (34.1)	257.4 (85.8)					
37BUN	2	364.2											
44BUN	2	0.0											

Table 9. Results of chi-squared tests of differences between demographic variables between Landscape Survey (n = 259) and Metering Survey (n = 28) respondents. Bold type indicates p<0.05.

Variable	Levels	Metering Survey	Landscape Survey	X^2	p
Time at current residence	0-4 yrs	10.7	7.5	11.976	**0.043**
	5-9 yrs	21.4	11.0		
	10-14 yrs	10.7	13.7		
	15+ yrs	57.1	67.8		
Age	under 24	20.7	0.4	6.048	0.235
	25-44	62.0	9.4		
	45-64	17.2	55.3		
	65 or over	17.2	34.9		
Gender	Male	55.2	61.7	0.703	0.641
	Female	44.8	38.3		
Highest level of education	High school	7.1	11.2	1.300	0.751
	Some college	14.3	17.6		
	Bachelors	42.9	32.4		
	Graduate	39.3	38.8		
Household income	<$50,000	6.9	12.1	2.155	0.643
	$50-100,00	24.1	32.2		
	$100-150,000	38.0	29.0		
	$150,000+	31.0	26.6		
How many people live in your household?	1	6.9	10.8	8.875	0.167
	2	17.2	41.2		
	3	38.0	21.2		
	4	27.6	18.0		
	5+	10.3	8.8		
Does anyone under 18 live in your household?	Yes	46.4	28.6	7.181	**0.041**
	No	53.6	71.4		

Table 10. Paired t-test between Metering Survey (n = 28) and Post Survey (n = 20) respondents. Bold type indicates p<0.05. Dashed line indicated test was not applicable due to a small sample size.

Question	Levels	Mean		Paired t-test	
		Metering Survey	Post Survey	t	*p*
How effective are the following practices at reducing outdoor water use?	Watering the lawn at dawn or dusk	4.25	3.85	0.566	0.579
	Watering the lawn less often	4.11	4.10	-0.940	0.361
	Installing a moisture-sensing irrigation system	3.73	3.53	-0.633	0.540
	Using mulch in garden beds to reduce evaporation	4.07	4.10	0.000	1.000
	Adding organic matter to the soil to increase water retention	4.04	3.83	0.591	0.563
	Using a timer during watering	4.00	3.67	-0.621	0.543
	Checking the soil moisture and only watering as needed	4.30	4.00	0.689	0.501
Please indicate your willingness to implement these practices.	Rain garden	2.91	3.72	-1.416	0.182
	Rain barrel	3.35	3.85	-1.465	0.171
	Reduce lawn area	3.21	3.38	-1.388	0.195
	Green roof	1.73	2.00	-1.908	0.079
	Drought tolerant lawn	3.71	4.11	-1.503	0.155
	Drought tolerant landscape	3.60	3.53	-0.400	0.696
Which of the following factors would encourage you to install a rain garden on your property?	Receiving technical assistance on how to construct one	3.62	3.53	1.000	0.339
	Not having to pay for it	4.20	4.13	0.321	0.755
	Reduction in your sewer/water bill	3.28	3.53	0.378	0.713
	Making your property look more interesting	3.26	3.47	1.000	0.343
	Decrease in flooding in your neighborhood/property	2.92	3.62	-1.835	0.104
	A friend or neighbor installing one	1.74	2.53	-0.612	0.555
	Increasing stream water quality	3.25	3.80	-	-
Which of the following factors would encourage you to install a rain barrel on your property?	Receiving technical assistance on how to construct one	3.42	3.42	0.000	1.000
	Not having to pay for it	4.67	4.08	-	-
	Reduction in your sewer/water bill	3.55	3.58	-	-
	Making your property look more interesting	2.00	3.00	1.000	0.391
	Decrease in flooding in your neighborhood/property	2.40	3.36	0.000	1.000

	A friend or neighbor installing one	2.00	2.50	-1.633	0.178
	Increasing stream water quality	3.50	3.75	-	-
How well do the following statements reflect your general opinion of outdoor water use restrictions?	They are an effective way to reduce outdoor water use	3.86	4.20	-1.508	0.149
	They do not affect me significantly	3.55	2.72	3.011	**0.008**
	They are necessary	4.28	4.37	-0.383	0.707
	They are an inconvenience	2.14	2.39	-2.425	**0.028**
	I don't understand why we have them	1.18	1.89	-	-
How serious are the environmental problems in Massachusetts?	Availability of drinking water	2.59	3.50	-2.200	**0.044**
	Fewer fish in rivers and ponds	3.44	3.95	-1.244	0.231
	Climate change	3.20	3.95	-3.922	**0.001**
	Flooding	3.04	3.80	-3.112	**0.006**
	Poorly planned development	2.84	3.80	-2.184	**0.044**
	Too many environmental regulations	1.81	2.95	-2.184	**0.044**
Please indicate how important the following factors are in the decision to replace part of the lawn on your property with a meadow or groundcover:	Amount of time spent on maintenance	3.46	3.56	0.717	0.484
	Lawn looks neater than meadow	3.11	3.39	-1.224	0.239
	To reduce water use	3.35	3.47	0.677	0.508
	Lawn is a better fit for my neighborhood	3.30	3.22	-0.511	0.617
	Concern about ticks	3.37	3.63	-0.697	0.495
	Landscape changes are expensive	3.71	3.84	-0.127	0.901
	Lack of free time to implement changes	3.39	3.84	-1.917	0.072
	Lawn is used regularly for outdoor activities	2.75	2.56	-0.489	0.632
	Cost of landscape maintenance	3.61	3.24	1.246	0.232
I would reduce my outdoor water use if…	My water bill doubled	3.83	4.00	-0.128	0.900
	There were more restrictions on outdoor water use	3.04	3.33	0.000	1.000
	I would pay a $100 surcharge for excessive use	3.15	3.44	0.565	0.581
	My town adopted regulations limiting irrigation use	3.07	3.57	-1.530	0.146
	My property had less lawn	3.11	3.82	-1.964	0.068
	My property required little or no water	3.46	3.79	-1.768	0.096

Table 11. Paired t-test between Landscape (n = 259) and Metering Survey (n = 28) respondents. Bold type indicates p<0.05. Dashed line indicated test was not applicable due to a small sample size.

Question	Levels	Mean		t-test	
		Landscape Survey	Metering Survey	t	p
Please rank how often you use your yard for the following activities:	Socializing and entertaining	2.48	2.62	-0.625	0.536
	Recreation	2.47	2.83	-1.422	0.164
	Appreciating nature/beauty	3.72	3.72	-0.025	0.980
	Watching or feeding wildlife	3.25	3.45	-0.659	0.515
How much information do you obtain from the following sources about landscaping?	Landscape companies or garden centers	2.33	2.28	0.241	0.811
	Family, friends or neighbors	2.38	2.76	-2.254	**0.030**
	Environmental organizations	1.67	1.72	-0.319	0.752
	UMass website	1.16	1.07	1.119	0.269
	Books and magazines	2.34	2.43	-0.393	0.697
	Internet	2.37	2.68	-1.230	0.228
How effective are the following practices at reducing outdoor water use?	Watering the lawn at dawn or dusk	3.99	4.25	-1.297	0.203
	Watering the lawn less often	4.06	4.11	-0.230	0.820
	Installing a moisture-sensing irrigation system	3.26	3.73	-1.542	0.133
	Using mulch in garden beds to reduce evaporation	3.97	4.07	-0.500	0.620
	Adding organic matter to the soil to increase water retention	3.59	4.04	-2.049	**0.048**
	Using a timer during watering	3.63	4.00	-1.316	0.198
	Checking the soil moisture and only watering as needed	3.82	4.30	-2.148	**0.039**
Please indicate your willingness to implement these practices.	Rain garden	2.23	2.91	-1.914	0.066
	Rain barrel	2.58	3.35	-1.856	0.077
	Reduce lawn area	2.70	3.21	-1.359	0.188
	Green roof	1.13	1.73	-2.067	**0.050**
	Drought tolerant lawn	3.25	3.71	-1.384	0.179
	Drought tolerant landscape	3.18	3.60	-1.132	0.270
Which of the following	Receiving technical assistance on how to construct one	2.89	3.62	-2.146	**0.040**

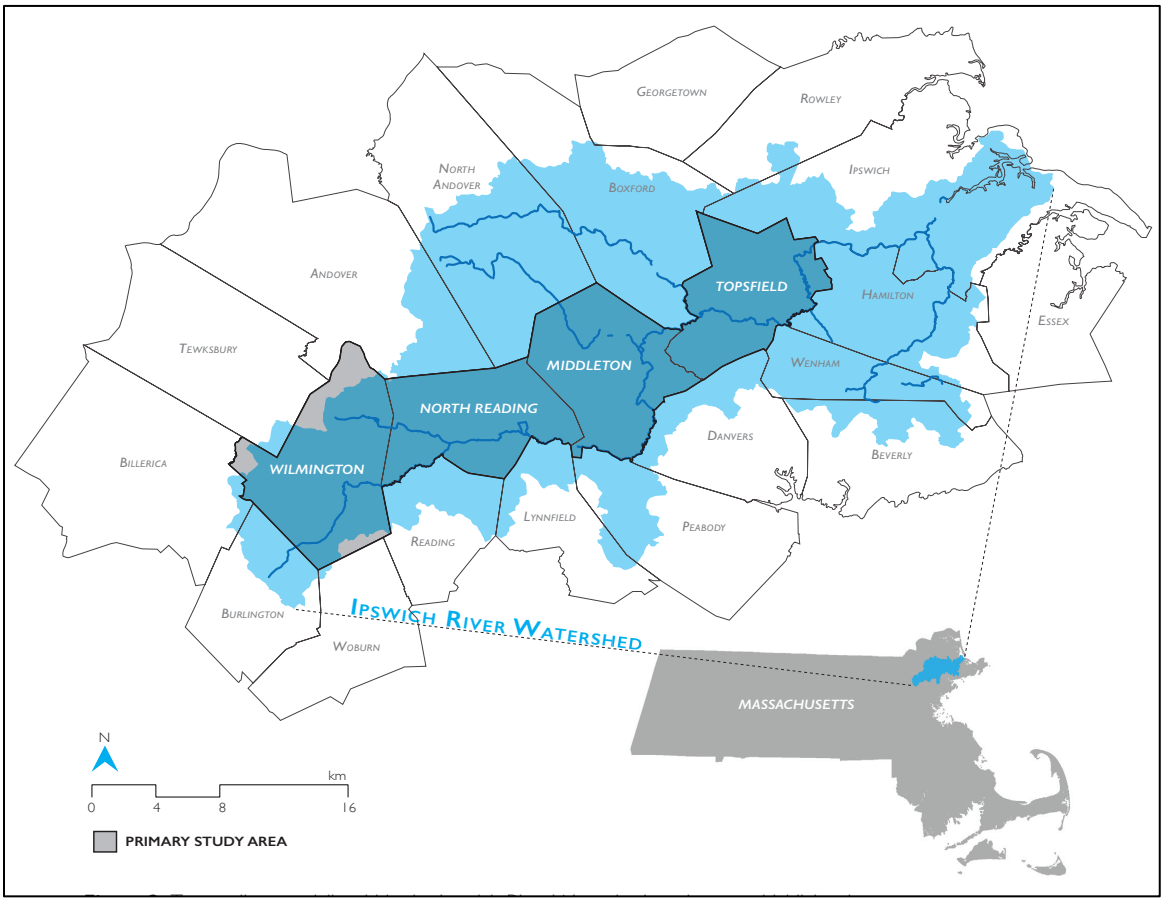
factors would encourage you to install a rain garden on your property?	Not having to pay for it	3.70	4.20	-1.639	0.112
	Reduction in your sewer/water bill	3.09	3.28	-0.568	0.575
	Making your property look more interesting	3.08	3.26	-0.572	0.573
	Decrease in flooding in your neighborhood/property	2.69	2.92	-0.643	0.526
	A friend or neighbor installing one	1.70	1.74	-0.141	0.889
	Increasing stream water quality		3.25	-	-
How well do the following statements reflect your general opinion of outdoor water use restrictions?	They are an effective way to reduce outdoor water use	3.79	3.86	-0.322	0.749
	They do not affect me significantly	3.28	3.55	-1.167	0.250
	They are necessary	4.10	4.28	-1.077	0.288
	They are an inconvenience	2.41	2.14	1.013	0.318
	I don't understand why we have them	1.68	1.18	4.065	**<0.001**
How serious are the environmental problems in Massachusetts?	Availability of drinking water	2.45	2.59	-0.486	0.630
	Fewer fish in rivers and ponds	3.03	3.44	-1.894	0.067
	Climate change	2.94	3.20	-0.969	0.340
	Flooding	2.76	3.04	-1.113	0.274
	Poorly planned development	3.04	2.84	0.858	0.397
	Too many environmental regulations	2.34	1.81	2.359	**0.024**
Please indicate how important the following factors are in the decision to replace part of the lawn on your property with a meadow or groundcover:	Amount of time spent on maintenance	3.26	3.46	-0.664	0.511
	Lawn looks neater than meadow	2.99	3.11	-0.384	0.704
	To reduce water use	3.20	3.35	-0.494	0.625
	Lawn is a better fit for my neighborhood	2.96	3.30	-1.066	0.295
	Concern about ticks	3.57	3.37	0.629	0.533
	Landscape changes are expensive	3.69	3.71	-0.089	0.930
	Lack of free time to implement changes	3.40	3.39	0.021	0.983
	Lawn is used regularly for outdoor activities	2.62	2.75	-0.418	0.678
	Cost of landscape maintenance	3.29	3.61	-0.989	0.330
I would reduce my outdoor water use if…	My water bill doubled	2.72	3.83	-3.697	**0.001**
	There were more restrictions on outdoor water use	2.68	3.04	-1.229	0.227

	I would pay a $100 surcharge for excessive use	2.84	3.15	-0.913	0.368
	My town adopted regulations limiting irrigation use	2.63	3.07	-1.294	0.205
	My property had less lawn	2.54	3.11	-1.715	0.096
	My property required little or no water	2.96	3.46	-1.585	0.121

Table 12. Factors included in willingness metric and associated Standardized Cronbach's α. Drought-tolerance metric is the average of a participant's scores for drought-tolerant lawn and drought-tolerant landscape. The rain garden was dropped from the metric calculation.

Factors	**α**
Rain barrel or catchment system	0.82
Reduced lawn area	0.86
Green roof	0.85
Drought-tolerant lawn	0.82
Drought-tolerant landscape	0.82
Dropped	
Rain garden	0.78

FIGURES


Georgetown
Rowley
North Andover
Boxford
Ipswich
Andover
Topsfield
Hamilton
Essex
Tewksbury
Middleton
Wenham
North Reading
Danvers
Billerica
Wilmington
Beverly
Lynnfield
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PRIMARY STUDY AREA

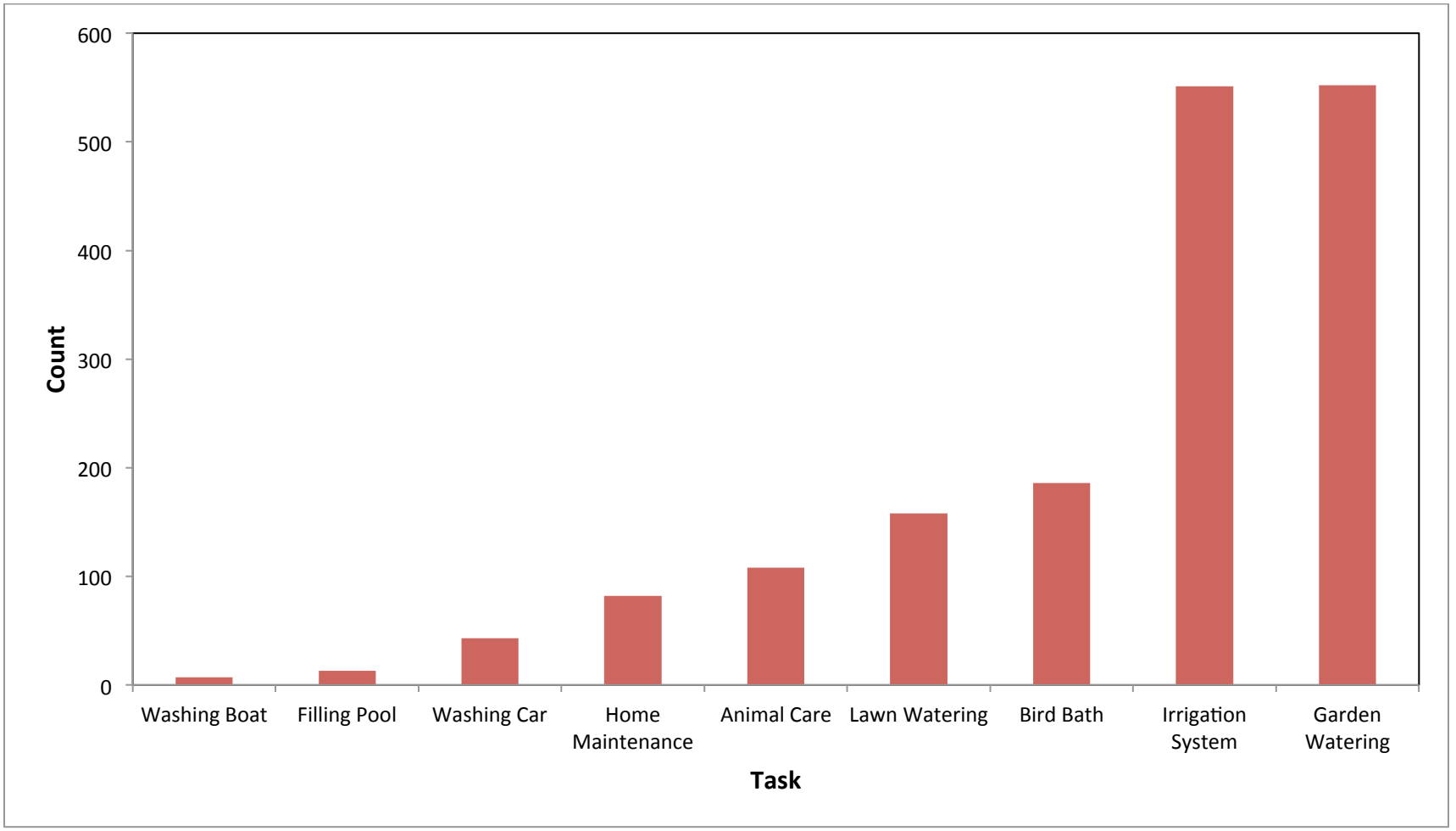


Figure 2. Number of uses per task over full nine-month study period by all participants.

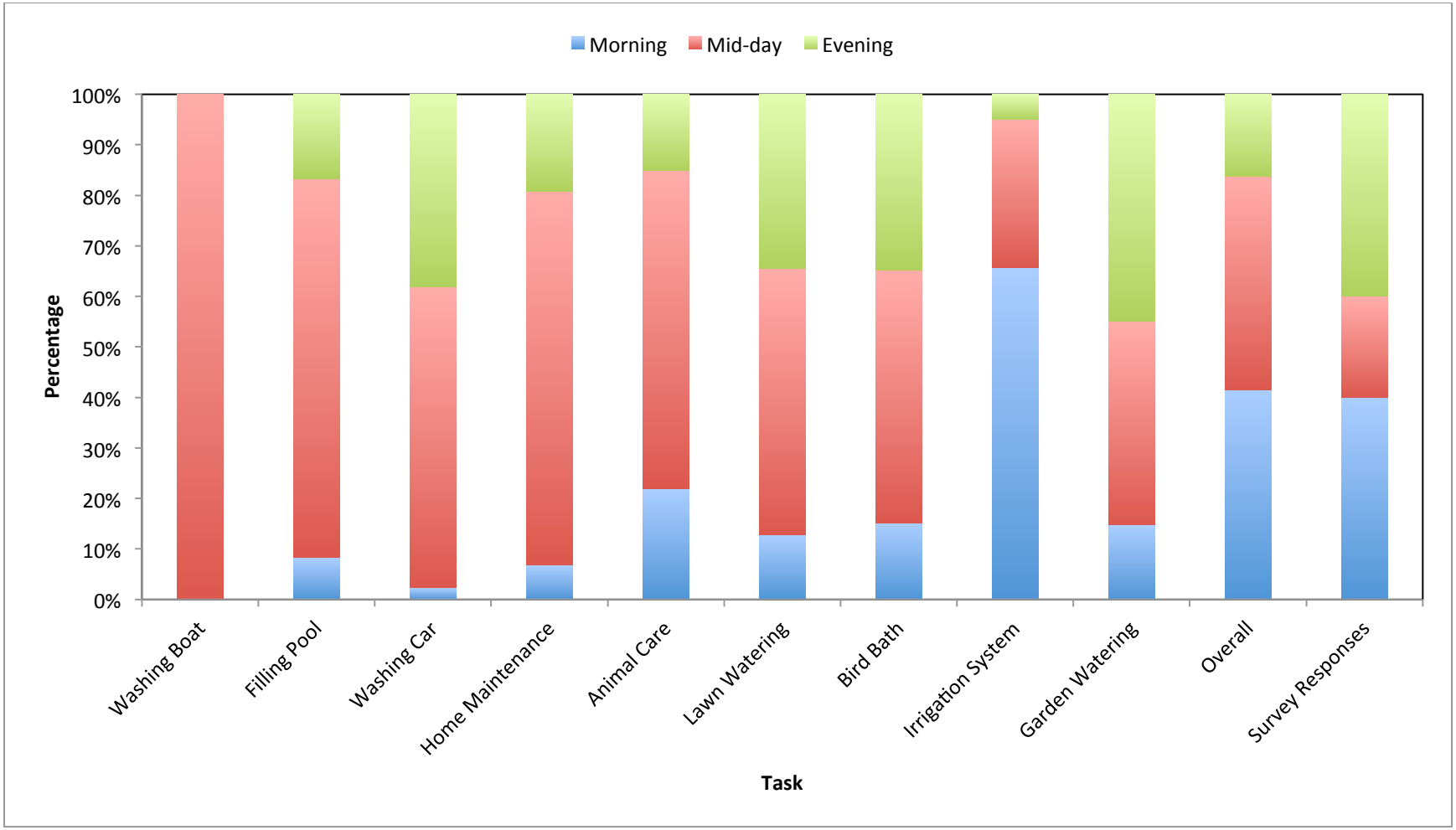


Figure 3. Task and percent of tasks that were performed during three times of day. Morning included any water use event between 12am and 9am, mid-day covered 9am to 5pm, and evening included 5pm to 11:59pm time of day.

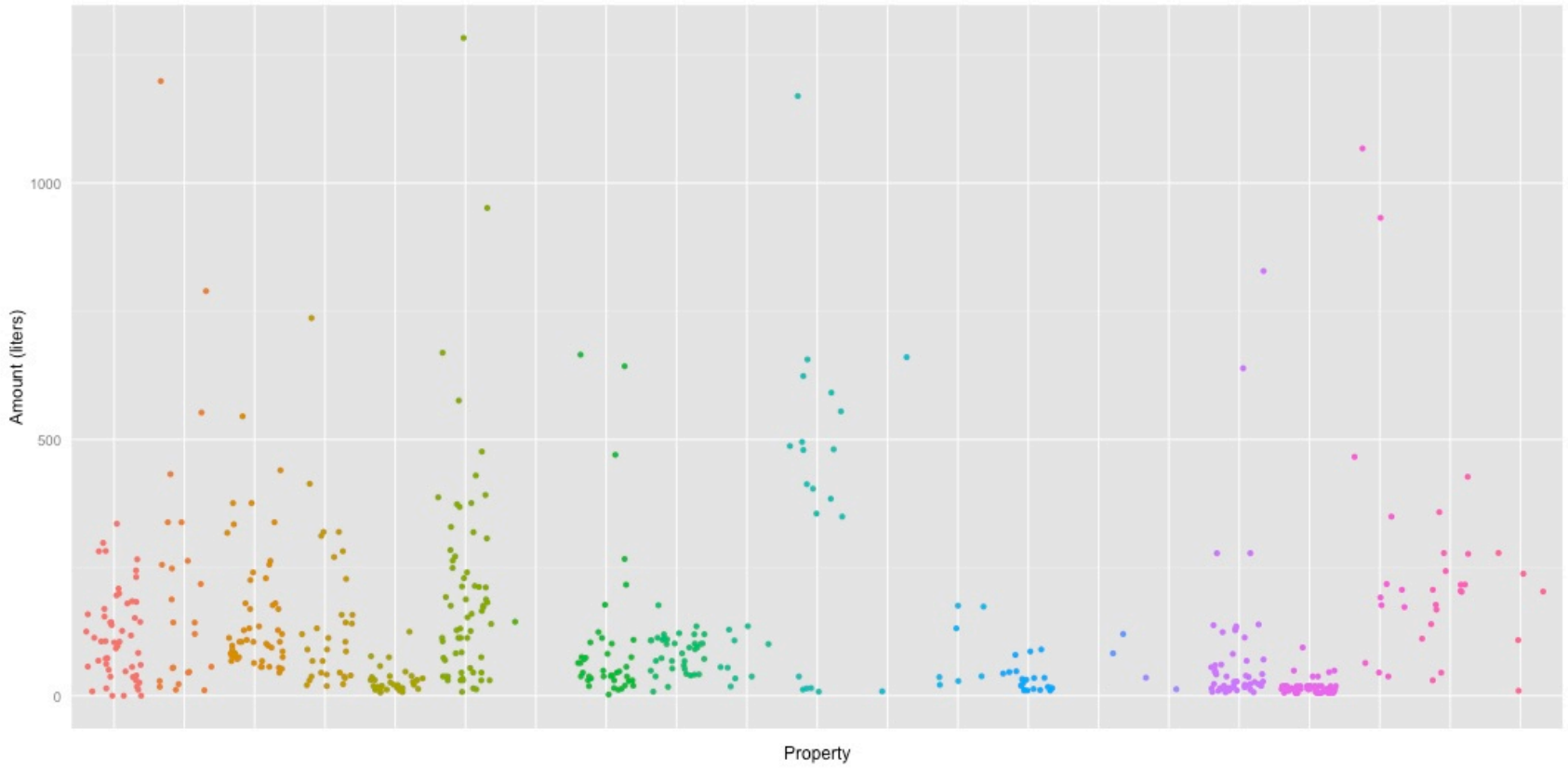


Figure 4. Amount used for garden watering for all participants that watered their garden during the study period. Individual points represent a garden watering event and colors correspond to individual study participants.

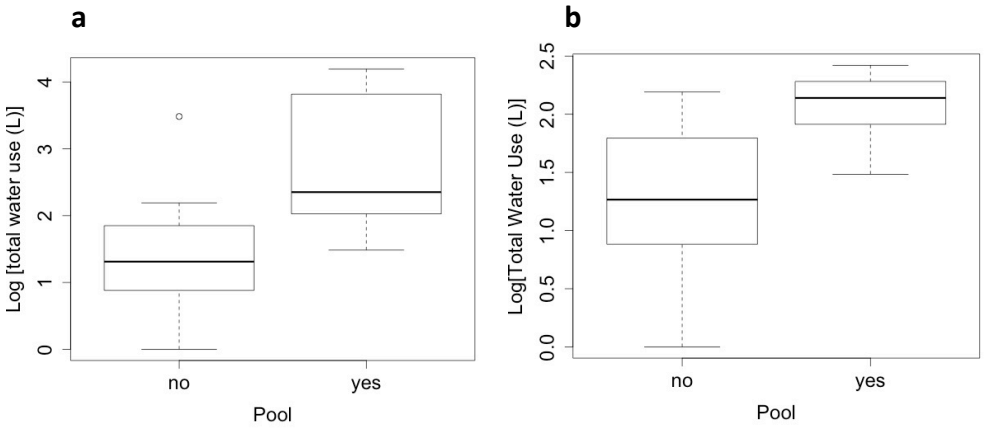


Figure 5. (a) Total water use for households with (n=8) and without (n=26) a pool (t-test, t= 3.6629, $p < 0.005$). **(b)** Boxplot showing relationship of total water use in liters and the presence of a pool. No significant relationship was found between the presence of a pool and total water use during the study period with participants running irrigation systems removed (t-test, t= 3.9636, $p < 0.003$).

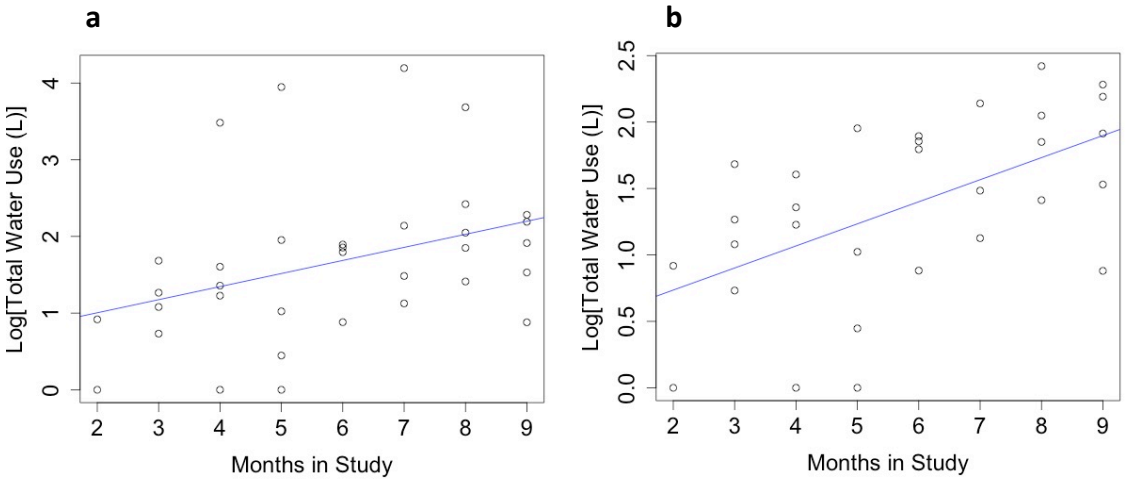


Figure 6. (a) Relationship between total water and the number of months participating in the study (n = 34, p = 0.0334)). **(b)** Regression showing relationship between total water use in liters and months in study with participants with irrigation systems excluded (p = 0.0013).

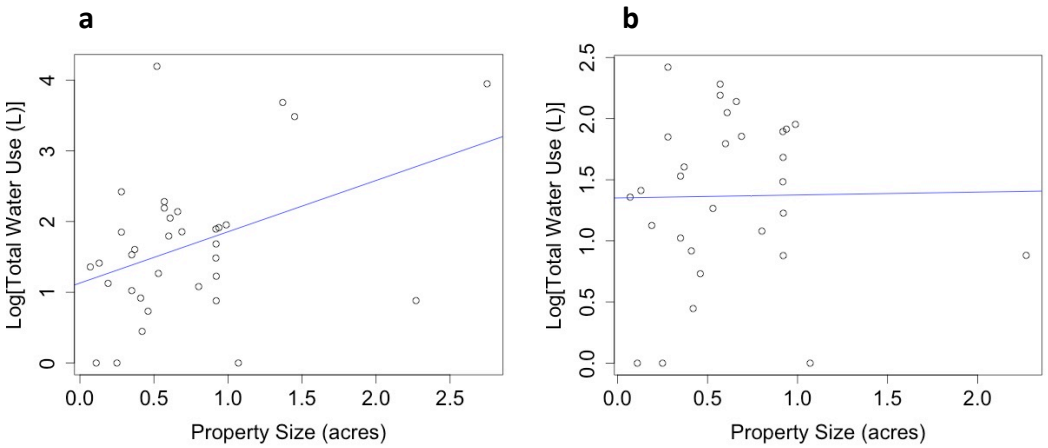


Figure 7. (a) Regression showing relationship between total water use in liters and property size in acres. Regression line is plotted in blue, but relationship is borderline not significant (p = 0.0517). **(b)** Regression showing relationship between total water use in liters and property size in acres. Regression line is plotted in blue, but relationship is borderline not significant (p = 0.937).

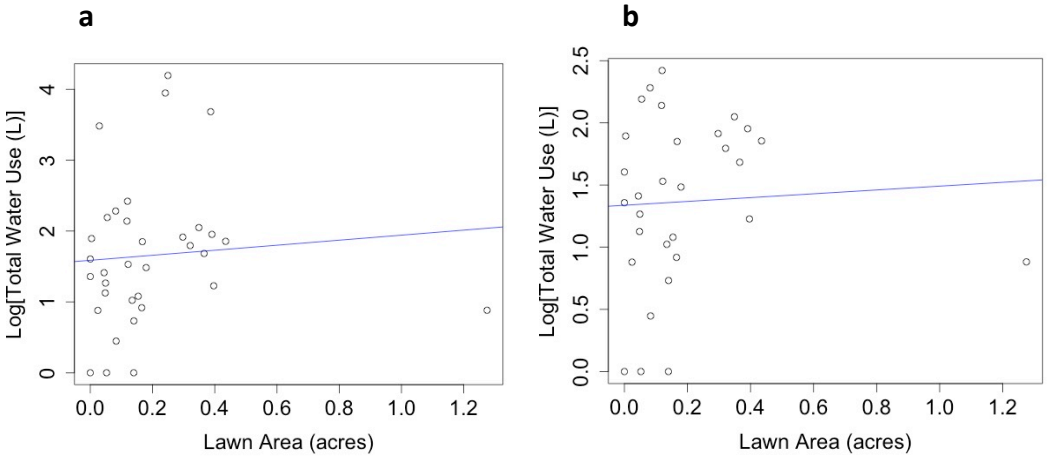


Figure 8. (a) Regression showing relationship between total water use in liters and lawn area in acres. Regression line is plotted in blue, but relationship is not significant (p = 0.652). **(b)** Regression showing relationship between total water use in liters and lawn area in acres. Regression line is plotted in blue, but relationship is not significant (p = 0.771).

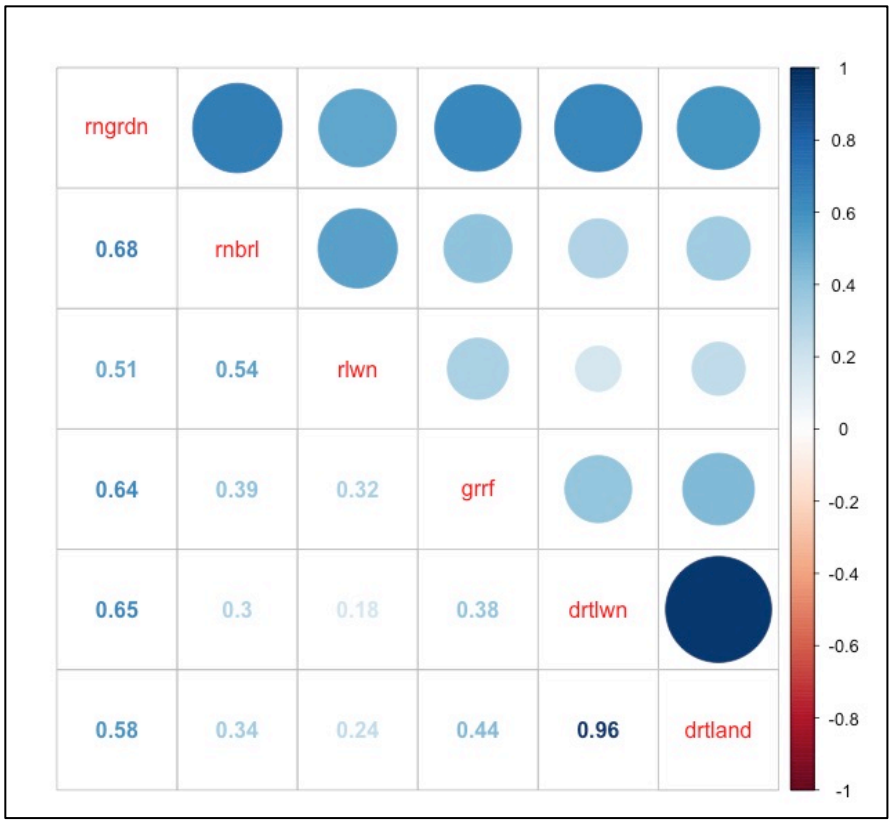


Figure 9. Correlation plot of responses to survey question 15 from Metering Survey indicating willingness to implement conservation practices (rngrdn: rain garden; rnbrl: rain barrel; rlwn: reduce lawn area; grrf: green roof; drtlwn: drought tolerant lawn; drtland: drought tolerant landscape).

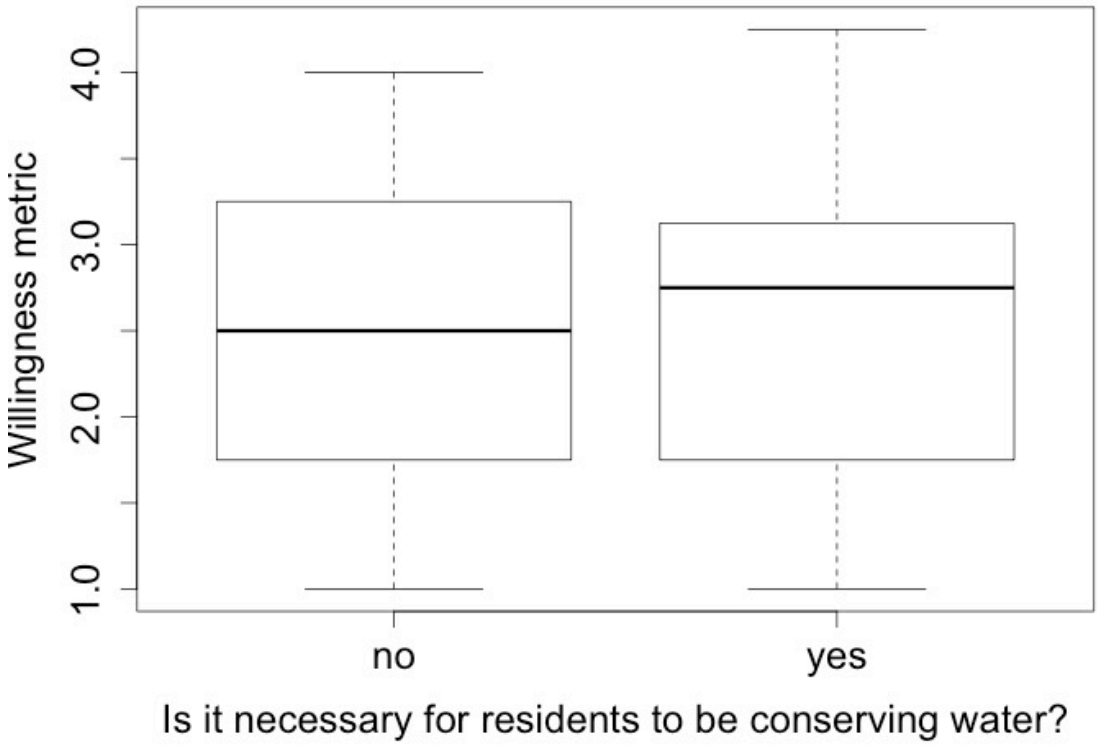


Figure 10. Comparison of willingness to implement conservation practices between participants that believed conservation was necessary (n = 9) and those that did not believe it was necessary (n = 3). The willingness metric was developed using survey responses addressing participant willingness to adopt conservation practices such as drought-tolerant lawns and rain barrels.

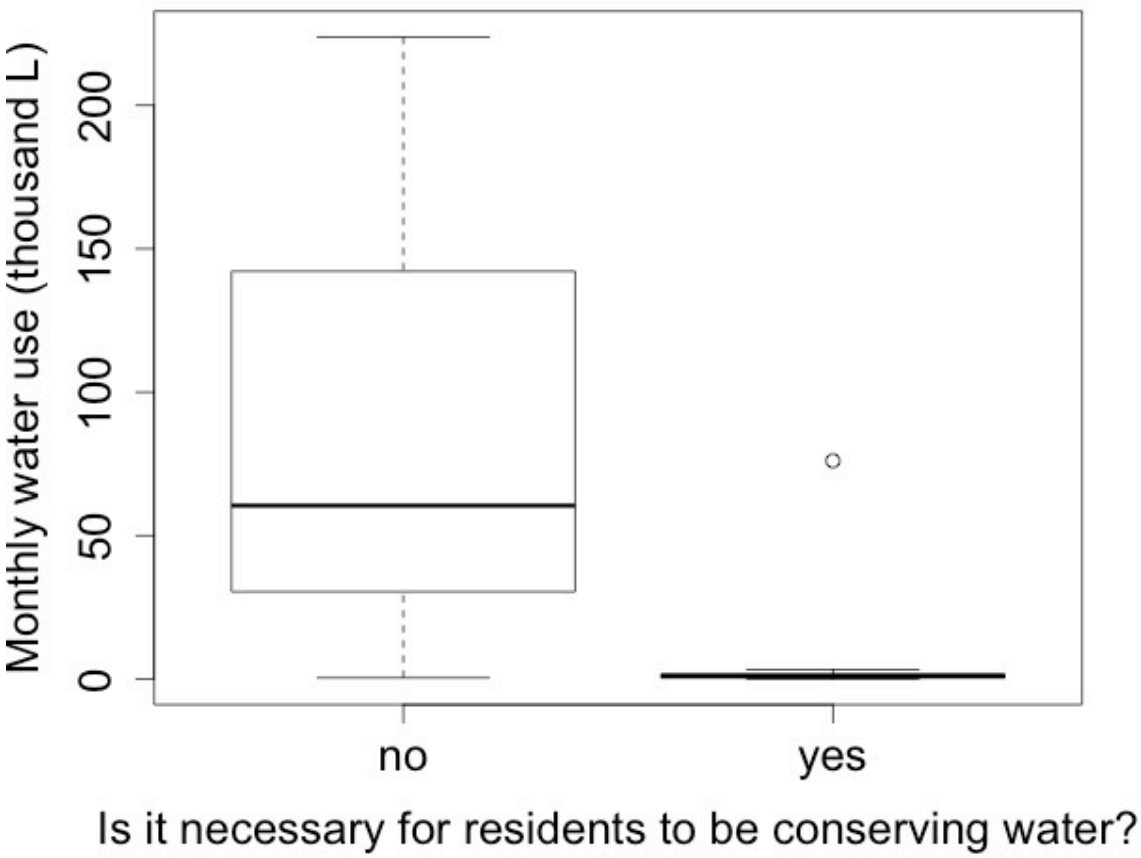


Figure 11. Comparison of standardized total water use between participants that believed conservation was necessary (n =15) and those that did not believe I was necessary (n = 3).

APPENDIX A

LANDSCAPE SURVEY

Ipswich River Watershed Landscape Survey

Please help us better understand outdoor water use and residents' attitudes about water conservation in the Ipswich River watershed. This survey is part of a three-year research study in the Ipswich River watershed conducted by the University of Massachusetts-Amherst and funded by the Center for Agriculture. It should be completed by an adult member of the household.

We appreciate you taking the time to complete this survey and value your responses.

For the following questions, please circle your response:

1) Do you own or rent your home? OWN RENT

2) What is the size of your property? less than 1/4 acre ¼ to 1 acre more than 1 acre

3) Do you have an irrigation system on your property? YES NO
   If YES, is it moisture-sensing? YES NO

4) Do you have a swimming pool on your property? YES NO
   How do you fill the pool? Purchased water Tap water

5) How much of your property is covered by the following:

Woods	more than half	less than half	none
Shrubs, meadow or unmown grass	more than half	less than half	none
Garden beds (flower or vegetable)	more than half	less than half	none
Lawn	more than half	less than half	none

6) Is there a pond, stream, or river on or bordering your property? YES NO

7) The tap water for your home comes from: PRIVATE WELL PUBLIC WATER SUPPLY

8) How many hours do you spend *weekly* on yard maintenance during the summer? ≤1 2-3 4-5 ≥6

9) On average, how many times per week do you water your lawn during summer months? 0 1 2-3 ≥4

10) What time of day do you usually water? BEFORE 9am MID-DAY (9am-5pm) EVENING (after 5pm)

11) Please rank how often you use your yard for the following activities :

1 = not at all, 2 = a little, 3 = sometimes, 4 = a lot, 5 = a great deal

Socializing and entertaining	1 2 3 4 5
Recreation	1 2 3 4 5
Appreciating nature/beauty	1 2 3 4 5
Watching or feeding wildlife	1 2 3 4 5
Other: _____	1 2 3 4 5

12) How much information do you obtain from the following sources about landscaping?

1 = none at all, 2 = a little, 3 = some, 4 = a lot, 5 = a great deal

Landscape company or Garden center	1 2 3 4 5
Family, friends or neighbors	1 2 3 4 5
Environmental organizations (e.g, Greenscapes)	1 2 3 4 5
UMass Home Lawn and Garden website	1 2 3 4 5
Books and magazines	1 2 3 4 5
Internet	1 2 3 4 5

13) How much water do you think is used indoors versus outdoors in an average household during the summer months (circle one)? More indoors About the same More outdoors

14) In your *opinion*, how effective are the following practices at reducing outdoor water use and would you be willing to practice them in the future?

1 = not very, 2 = a little, 3 = somewhat, 4 = very, 5 = extremely

		Would practice in future
Watering the lawn at dawn or dusk	1 2 3 4 5	Y N
Watering the lawn less often	1 2 3 4 5	Y N
Installing a moisture-sensing irrigation system	1 2 3 4 5	Y N
Using mulch in garden beds to reduce evaporation	1 2 3 4 5	Y N
Adding organic matter to the soil to increase water retention	1 2 3 4 5	Y N
Using a timer during watering	1 2 3 4 5	Y N
Checking soil moisture and only watering as needed	1 2 3 4 5	Y N

15) The following images show landscape features that conserve water on-site or in the river:

Rain garden — a shallow depression in the ground that collects stormwater, and can be planted with shrubs or flowers

Rain barrel — a container that stores water for later use

Reduced lawn area — shrubs, flowers and groundcovers replace lawn

Green roof – one planted with vegetation that absorbs some of the rain that falls on it

Drought-tolerant lawn— one planted with grasses that requires less water to stay green

Drought-tolerant landscape— one that uses plants that require less water

Please indicate if you have any of these features on your property and your willingness to implement them:

1 = not at all, 2 = a little, 3 = somewhat, 4 = very, 5 = extremely, N/A = not applicable

		I have this
Rain garden	1 2 3 4 5 N/A	□
Rain barrel or catchment system	1 2 3 4 5 N/A	□
Reduced lawn area	1 2 3 4 5 N/A	□
Green roof	1 2 3 4 5 N/A	□
Drought-tolerant lawn	1 2 3 4 5 N/A	□
Drought-tolerant landscape	1 2 3 4 5 N/A	□

16) How much would the following factors encourage you to install a rain garden on your property?

1 = not at all, 2 = a little, 3 = somewhat, 4 = a lot, 5 = a great deal	
Receiving technical assistance on how to construct one	1 2 3 4 5
Not having to pay for it	1 2 3 4 5
Reduction to my sewer and water bill	1 2 3 4 5
My property looked more interesting	1 2 3 4 5
Decreased flooding in my neighborhood/on my property	1 2 3 4 5
If a friend or neighbor installed one	1 2 3 4 5

17) Were there any outdoor water use restrictions in your town this past year? YES NO I don't know

18) How well do the following statements reflect your general opinion of the outdoor water use restrictions?

1 = not at all, 2 = a little, 3 = somewhat, 4 = a lot, 5 = a great deal	
They are an effective way to reduce outdoor water use	1 2 3 4 5
They do not affect me significantly	1 2 3 4 5
They are necessary	1 2 3 4 5
They are an inconvenience	1 2 3 4 5
I don't understand why we have them	1 2 3 4 5

19) How serious are the following environmental problems in your part of Massachusetts?

1 = not a all, 2 = a little, 3 = somewhat, 4 = very, 5 = extremely	
Availability of drinking water	1 2 3 4 5
Fewer fish in rivers and ponds	1 2 3 4 5
Climate change	1 2 3 4 5
Flooding	1 2 3 4 5
Poorly planned development	1 2 3 4 5
Too many environmental regulations	1 2 3 4 5
Other: _____	1 2 3 4 5

20) Would you consider replacing part of the lawn on your property with a meadow or groundcover? YES NO

Please indicate how important the following factors are in this decision:

1 = not at all, 2 = a little, 3 = somewhat, 4 = very, 5 = extremely	
Amount of time spent on maintenance	1 2 3 4 5
Lawn looks neater than meadow	1 2 3 4 5
To reduce water use	1 2 3 4 5
Lawn is a better fit for my neighborhood	1 2 3 4 5
Concern about ticks	1 2 3 4 5
Landscape changes are expensive	1 2 3 4 5
Lack of free time to implement changes	1 2 3 4 5
Lawn is used regularly for outdoor activities	1 2 3 4 5
Cost of landscape maintenance	1 2 3 4 5
Other: _____	1 2 3 4 5

21) Please indicate how much you agree with the following statement: I would reduce my outdoor water use if…

1 = not at all, 2 = little, 3 = somewhat, 4 = a lot, 5 = completely, N/A = not applicable		
…my water bill doubled (circle N/A if you have a private well)	1 2 3 4 5	N/A
…there were more restrictions on outdoor water use	1 2 3 4 5	N/A
…I would pay a $100 surcharge for excessive water use	1 2 3 4 5	N/A
…my town adopted regulations limiting irrigation use	1 2 3 4 5	N/A
…my property had less lawn	1 2 3 4 5	N/A
…the lawn on my property required little or no water	1 2 3 4 5	N/A

Please tell us a little about yourself.

22) Time at current residence:	0-4 yrs	5-9 yrs	10-14 yrs	15^{+} yrs
23) Age:	under 24	25-44	45-64	65 or over
24) Gender:	Male	Female		
25) Highest level of education:	High school	Some college	Bachelor's	Graduate
26) Household Income:	<$50,000	$50-100,000	$100-150,000	over $150,000
27) How many people live in your household?	1 2 3 4 5+			
28) Does anyone under 18 live in your household?		YES	NO	

Photographs: The next few pages show photographs of residential landscapes. Please rate how much you would like to have landscape features like those pictured in your own yard.

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Forest and lawn:

1) 1 2 3 4 5

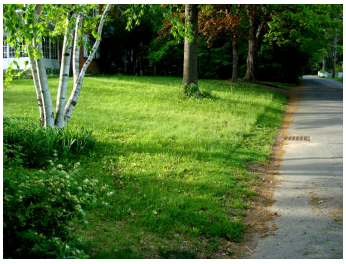
2) 1 2 3 4 5

Driveway type:

3) 1 2 3 4 5

4) 1 2 3 4 5

Taller grass height:



5) 1 2 3 4 5

6) 1 2 3 4 5

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Less lawn:

7) 1 2 3 4 5

8) 1 2 3 4 5

9) 1 2 3 4 5

10) 1 2 3 4 5

Rain gardens:

11) 1 2 3 4 5

12) 1 2 3 4 5

13) 1 2 3 4 5

14) 1 2 3 4 5

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Rain barrels:

15) 1 2 3 4 5

16) 1 2 3 4 5

Naturalized lawn:

17) 1 2 3 4 5

18) 1 2 3 4 5

Drought-tolerant:

19) 1 2 3 4 5

20) 1 2 3 4 5

21) For the photos you rated very high or very low, please use the margins next to the photos to add a word or two about why you did and didn't like the photos.

Thank you for your time!

6

APPENDIX B

METERING SURVEY

Ipswich River Watershed Landscape Survey

Please help us better understand outdoor water use and residents' perspectives on water conservation in the Ipswich River Watershed. This survey is part of a three-year research study in the Ipswich River Watershed conducted by the University of Massachusetts-Amherst and funded by the Center for Agriculture. It should be completed by an adult member of the household.

We appreciate you taking the time to complete this survey and value your responses.

For the following questions, please circle your response:

1. Do you own or rent your home? OWN RENT

2. What is the size of your property? less than 1/4 acre 1/4 to 1 acre more than 1 acre

3. Do you have an irrigation system on your property? YES NO
If YES, is it moisture-sensing? YES NO

4. Do you have a swimming pool on your property? YES NO
How do you fill the pool? Purchase water Tap water

5. How much of your property is covered by the following:

Woods	more than half	less than half	none
Shrubs, meadow, or unmown grass	more than half	less than half	none
Garden beds (flower or vegetable)	more than half	less than half	none
Lawn	more than half	less than half	none

6. Is there a pond, stream, or river on or boarding your property? YES NO

7. The tap water for your home comes from: PRIVATE WELL PUBLIC WATER SUPPLY

8. A watershed is an area of land where all water (above or below ground) drains to the same place, such as a river or stream. What watershed do you live in (check all that apply)?

□ Parker River
□ Ipswich River
□ Other (please specify):_____
□ Don't know

9. Does your tap water come from the watershed you indicated above?

□ Yes
□ No, it comes from _____(fill in).
□ Don't know

10. Estimate the number of gallons of water each of the following outdoor water use events typically require at your residence (**for a single event**). List additional outdoor uses as appropriate. If the event is not applicable to you, circle N/A.

Outdoor Use	Estimated Amount per Event (in Gallons)					
Washing the car	≤10	11-30	31-50	51-70	≥71	N/A
Watering the garden	≤10	11-30	31-50	51-70	≥71	N/A
Watering the lawn	≤10	11-30	31-50	51-70	≥71	N/A
Filling the pool	≤100	101-500	501-1000	1001-1500	≥1501	N/A
Other:						

11. Have you ever installed individual water meters on your outdoor water spigots? YES NO N/A

12. How many hours do you spend *weekly* on yard maintenance during the summer? ≤1 2-3 4-5 ≥6

13. On average, how many times per week do you water your lawn during summer months? 0 1 2-3 ≥4

14. What time of day do you usually water? BEFORE 9am MID-DAY (9am-5pm) EVENING (after 5pm)

15. Please rank how often you use your yard for the following activities:

1 = not at all; 2 = a little; 3 = sometimes; 4 = a lot; 5 = a great deal

Socializing and entertaining	1	2	3	4	5
Recreation	1	2	3	4	5
Appreciating nature/beauty	1	2	3	4	5
Watching or feeding wildlife	1	2	3	4	5
Other:_____	1	2	3	4	5

16. How much information do you obtain from the following sources about landscaping?

1 = not at all; 2 = a little; 3 = sometimes; 4 = a lot; 5 = a great deal

Landscape company or garden center	1	2	3	4	5
Family, friends, or neighbors	1	2	3	4	5
Environmental organizations (e.g. Greenscapes)	1	2	3	4	5
UMass Home Lawn and Garden website	1	2	3	4	5
Books and magazines	1	2	3	4	5
Internet	1	2	3	4	5

17. How much water do you think is used indoors versus outdoors in an average household during the summer months (circle one)?

More indoors About the same More outdoors

18. In your *opinion*, how effective are the following practices at reducing outdoor water use and would you be willing to practice them in the future?

1 = not at all; 2 = a little; 3 = sometimes; 4 = very; 5 = extremely

						Would practice in future?	
Watering the lawn at dawn or dusk	1	2	3	4	5	Y	N
Watering the lawn less often	1	2	3	4	5	Y	N
Installing a moisture-sensing irrigation system	1	2	3	4	5	Y	N
Using mulch in garden beds to reduce evaporation	1	2	3	4	5	Y	N
Adding organic matter to the soil to increase water retention	1	2	3	4	5	Y	N
Using a timer during watering	1	2	3	4	5	Y	N
Checking soil moisture and watering as needed	1	2	3	4	5	Y	N

19. The following images show landscape features that conserve water on-site or in the river:

Rain garden - a shallow depression in the ground that collects stormwater, and can be planted with shrubs and flowers

Rain barrel - a container that stores water for later use

Reduced lawn area - shrubs, flowers and groundcovers replace lawn

Green roof - one planted with vegetation that absorbs some of the rain that falls on it

Drought-tolerant lawn - one planted with grasses that requires less water to stay green

Drought-tolerant landscape - one that uses plants that require less water

Please indicate if you have any of these features on your property and your willingness to implement them:

	1=not at all; 2=a little; 3=sometimes; 4=very; 5=extremely						I have this
Rain garden	1	2	3	4	5	N/A	☐
Rain barrel or catchment system	1	2	3	4	5	N/A	☐
Reduced lawn area	1	2	3	4	5	N/A	☐
Green roof	1	2	3	4	5	N/A	☐
Drought-tolerant lawn	1	2	3	4	5	N/A	☐
Drought-tolerant landscape	1	2	3	4	5	N/A	☐

20. Please indicate which of the following landscape practices you have on your property and what motivated your decision to implement the practice. If a practice is not appropriate for your site, please select N/A.

1 = not at all; 2 = a little; 3 = some; 4 = a lot; 5 = a great deal

Practice	Y	N	N/A	Previous Owner Installed	Cost Savings	Environmental Consciousness	Other:
Rain garden	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Rain barrel or catchment system	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Reduced lawn area	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Green roof	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Drought-tolerant lawn	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Drought-tolerant landscape	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	
Other	□	□	□	Yes/No	1 2 3 4 5	1 2 3 4 5	

21. Which of the following factors would encourage you to install a rain garden and/or rain barrel on your property? If these practices are not appropriate for your site, please skip to the next question.

1 = not at all; 2 = a little; 3 = sometimes; 4 = a lot; 5 = a great deal

Factor	Rain Garden	Rain Barrel
Receiving technical assistance on how to construct one	1 2 3 4 5	1 2 3 4 5
Not having to pay for it	1 2 3 4 5	1 2 3 4 5
Reduction to my sewer and water bill	1 2 3 4 5	1 2 3 4 5
My property looked more interesting	1 2 3 4 5	1 2 3 4 5
Decreased flooding in my neighborhood/ on my property	1 2 3 4 5	1 2 3 4 5
If a friend or neighbor installed one	1 2 3 4 5	1 2 3 4 5
Increase stream water quality	1 2 3 4 5	1 2 3 4 5

22. Which of the following water saving measures do you and other members of your household engage in (check all that apply)?

□ Low flow shower heads

□ Limit shower times

□ Front loading washer

□ Checking for leaks/drips

□ Water saving toilet(s)

□ Other: _____

□ None

23. Were there any outdoor water use restrictions in your town this past year? YES NO Don't know

24. How well do the following statements reflect your general opinion of outdoor water use restrictions?

1=not at all; 2=a little; 3=sometimes; 4=a lot; 5=a great deal

They are an effective way to reduce outdoor water use	1	2	3	4	5
They do not affect me significantly	1	2	3	4	5
They are necessary	1	2	3	4	5
They are an inconvenience	1	2	3	4	5
I don't understand why we have them	1	2	3	4	5

25. How serious are the environmental problems in Massachusetts?

1=not at all; 2=a little; 3=sometimes; 4=very; 5=extremely

Availability of drinking water	1	2	3	4	5
Fewer fish in rivers and ponds	1	2	3	4	5
Climate change	1	2	3	4	5
Flooding	1	2	3	4	5
Poorly planned development	1	2	3	4	5
Too many environmental regulations	1	2	3	4	5
Other:_____	1	2	3	4	5

26. Would you consider replacing part of the lawn on your property with a meadow or groundcover? YES/NO
Please indicate how important the following factors are in this decision:

1 = not at all; 2 = a little; 3 = sometimes; 4 = very; 5 = extremely

Amount of time spent on maintenance	1	2	3	4	5
Lawn looks neater than meadow	1	2	3	4	5
To reduce water use	1	2	3	4	5
Lawn is a better fit for my neighborhood	1	2	3	4	5
Concern about ticks	1	2	3	4	5
Landscape changes are expensive	1	2	3	4	5
Lack of free time to implement changes	1	2	3	4	5
Lawn is regularly used for outdoor activities	1	2	3	4	5
Cost of landscape maintenance	1	2	3	4	5
Other:_____	1	2	3	4	5

27. Please indicate how much you agree with the following statement: I would reduce my outdoor water use if...

1 = not at all; 2 = a little; 3 = somewhat; 4 = a lot; 5 = completely; N/A = not applicable

...my water bill doubled (circle N/A if you have a private well	1	2	3	4	5	N/A
...there were more restrictions on outdoor water use	1	2	3	4	5	N/A
...I would pay a $100 surcharge for excessive water use	1	2	3	4	5	N/A
...my town adopted regulations limiting irrigation use	1	2	3	4	5	N/A
...my property had less lawn	1	2	3	4	5	N/A
...the lawn on my property required little or no water	1	2	3	4	5	N/A

Please tell us about yourself.

28. Time at current residence:	0-4 yrs	5-9 yrs	10-14 yrs	15+ yrs
29. Age:	under 24	25-44	45-64	65 or over
30. Gender:	Male	Female	_____	
31. Highest level of education:	High school	Some college	Bachelor's	Graduate
32. Household income:	<$50,000	$50-100,000	$100-150,000	over $150,000
33. How many people live in your household?	1	2	3 4	5+
34. Does anyone under 18 live in your household?		YES	NO	

35. Are you a member of a Home Owner's Association (HOA)? YES NO
If YES, does the HOA advise on landscaping practices? YES NO
Can you provide me with a copy of the HOA Handbook? YES NO

Photographs: The next few pages show photographs of residential landscapes. Please rate how much you would like to have landscape features like those pictured on your own yard.

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Forest and Lawn:

1. 

1 2 3 4 5

2. 

1 2 3 4 5

Driveway type:

3. 

1 2 3 4 5

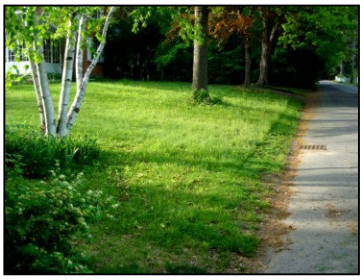
4. 

1 2 3 4 5

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Taller grass height:

5.



1 2 3 4 5

6.

1 2 3 4 5

Less lawn:

7.

1 2 3 4 5

8.

1 2 3 4 5

Less lawn:

9.

1 2 3 4 5

10.

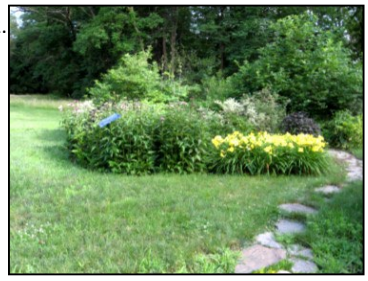
1 2 3 4 5

Rain gardens:

11.

1 2 3 4 5

12.



1 2 3 4 5

1 = not at all, 2 = somewhat, 3 = a little, 4 = a lot, 5 = a great deal

Rain gardens:

13. 

1 2 3 4 5

14. 

1 2 3 4 5

Rain barrels:

15. 

1 2 3 4 5

16. 

1 2 3 4 5

Naturalized lawn:

17. 

1 2 3 4 5

18. 

1 2 3 4 5

Drought-tolerant:

19. 

1 2 3 4 5

20. 

1 2 3 4 5

For the photos you rated very high or very low, please use the margins next to the photos to add a word or two about why you did or did not like the photos.

Thank you for your time!

APPENDIX C

POST SURVEY

Ipswich River Watershed Landscape Post-Study Survey

Thank you for participating in our outdoor water use study to help us better understand outdoor water use and perspectives on water conservation in the Ipswich River Watershed. The final task is for the same member of the household that completed the initial survey to complete this short follow-up survey. This survey will help us asses any changes during the study period and, therefore, the questions will be the same as those in the initial survey.

We appreciate you taking the time to complete this survey and value your responses.

For the following questions, please circle your response:

1. What is the size of your property? less than 1/4 acre 1/4 to 1 acre more than 1 acre

2. How much of your property is covered by the following:

Woods	more than half	less than half	none
Shrubs, meadow, or unmown grass	more than half	less than half	none
Garden beds (flower or vegetable)	more than half	less than half	none
Lawn	more than half	less than half	none

3. The tap water for your home comes from: PRIVATE WELL PUBLIC WATER SUPPLY

4. A watershed is an area of land where all water (above or below ground) drains to the same place, such as a river or stream. What watershed do you live in (check all that apply)?

□ Parker River
□ Ipswich River
□ Other (please specify):_____
□ Don't know

5. Does your tap water come from the watershed you indicated above?

□ Yes
□ No, it comes from _____ (fill in).
□ Don't know

6. Which of the following water saving measures do you and other members of your household engage in (check all that apply)?

□ Low flow shower heads
□ Limit shower times
□ Front loading washer
□ Checking for leaks/drips
□ Water saving toilet(s)
□ Other: _____
□ None

7. Were there any outdoor water use restrictions in your town this past year? YES NO Don't know

8. What time of day do you usually water? BEFORE 9am MID-DAY (9am-5pm) EVENING (after 5pm)

9. Estimate the number of gallons of water each of the following outdoor water use events typically require at your residence (**for a single event**). List additional outdoor uses as appropriate. If the event is not applicable to you, circle N/A.

Outdoor Use	Estimated Amount per Event (in Gallons)					
Washing the car	≤10	11-30	31-50	51-70	≥71	N/A
Watering the garden	≤10	11-30	31-50	51-70	≥71	N/A
Watering the lawn	≤10	11-30	31-50	51-70	≥71	N/A
Filling the pool	≤100	101-500	501-1000	1001-1500	≥1501	N/A
Other:						

10. How much water do you think is used indoors versus outdoors in an average household during the summer months (circle one)?

More indoors About the same More outdoors

11. In your *opinion*, how effective are the following practices at reducing outdoor water use and would you be willing to practice them in the future?

1 = not at all; 2 = a little; 3 = sometimes; 4 = very; 5 = extremely

						Would practice in future?	
Watering the lawn at dawn or dusk	1	2	3	4	5	Y	N
Watering the lawn less often	1	2	3	4	5	Y	N
Installing a moisture-sensing irrigation system	1	2	3	4	5	Y	N
Using mulch in garden beds to reduce evaporation	1	2	3	4	5	Y	N
Adding organic matter to the soil to increase water retention	1	2	3	4	5	Y	N
Using a timer during watering	1	2	3	4	5	Y	N
Checking soil moisture and watering as needed	1	2	3	4	5	Y	N

12. Which of the following factors would encourage you to install a rain garden and/or rain barrel on your property? If these practices are not appropriate for your site, please skip to the next question.

1 = not at all; 2 = a little; 3 = sometimes; 4 = a lot; 5 = a great deal

Factor	Rain Garden					Rain Barrel				
Receiving technical assistance on how to construct one	1	2	3	4	5	1	2	3	4	5
Not having to pay for it	1	2	3	4	5	1	2	3	4	5
Reduction to my sewer and water bill	1	2	3	4	5	1	2	3	4	5
My property looked more interesting	1	2	3	4	5	1	2	3	4	5
Decreased flooding in my neighborhood/ on my property	1	2	3	4	5	1	2	3	4	5
If a friend or neighbor installed one	1	2	3	4	5	1	2	3	4	5
Increase stream water quality	1	2	3	4	5	1	2	3	4	5

13. The following images show landscape features that conserve water on-site or in the river:

Rain garden - a shallow depression in the ground that collects stormwater, and can be planted with shrubs and flowers

Rain barrel - a container that stores water for later use

Reduced lawn area - shrubs, flowers and groundcovers replace lawn

Green roof - one planted with vegetation that absorbs some of the rain that falls on it

Drought-tolerant lawn - one planted with grasses that requires less water to stay green

Drought-tolerant landscape - one that uses plants that require less water

Please indicate if you have any of these features on your property and your willingness to implement them:

	1=not at all; 2=a little; 3=sometimes; 4=very; 5=extremely						I have this
Rain garden	1	2	3	4	5	N/A	☐
Rain barrel or catchment system	1	2	3	4	5	N/A	☐
Reduced lawn area	1	2	3	4	5	N/A	☐
Green roof	1	2	3	4	5	N/A	☐
Drought-tolerant lawn	1	2	3	4	5	N/A	☐
Drought-tolerant landscape	1	2	3	4	5	N/A	☐

14. How well do the following statements reflect your general opinion of outdoor water use restrictions?

	1 = not at all; 2 = a little; 3 = sometimes; 4 = a lot; 5 = a great deal				
They are an effective way to reduce outdoor water use	1	2	3	4	5
They do not affect me significantly	1	2	3	4	5
They are necessary	1	2	3	4	5
They are an inconvenience	1	2	3	4	5
I don't understand why we have them	1	2	3	4	5

15. How serious are the environmental problems in Massachusetts?

1 = not at all; 2 = a little; 3 = sometimes; 4 = very; 5 = extremely

Availability of drinking water	1	2	3	4	5
Fewer fish in rivers and ponds	1	2	3	4	5
Climate change	1	2	3	4	5
Flooding	1	2	3	4	5
Poorly planned development	1	2	3	4	5
Too many environmental regulations	1	2	3	4	5
Other:_____	1	2	3	4	5

16. Would you consider replacing part of the lawn on your property with a meadow or groundcover? YES/NO

Please indicate how important the following factors are in this decision:

1 = not at all; 2 = a little; 3 = sometimes; 4 = very; 5 = extremely

Amount of time spent on maintenance	1	2	3	4	5
Lawn looks neater than meadow	1	2	3	4	5
To reduce water use	1	2	3	4	5
Lawn is a better fit for my neighborhood	1	2	3	4	5
Concern about ticks	1	2	3	4	5
Landscape changes are expensive	1	2	3	4	5
Lack of free time to implement changes	1	2	3	4	5
Lawn is regularly used for outdoor activities	1	2	3	4	5
Cost of landscape maintenance	1	2	3	4	5
Other:_____	1	2	3	4	5

17. Please indicate how much you agree with the following statement: I would reduce my outdoor water use if...

1 = not at all; 2 = a little; 3 = somewhat; 4 = a lot; 5 = completely; N/A = not applicable

...my water bill doubled (circle N/A if you have a private well	1	2	3	4	5	N/A
...there were more restrictions on outdoor water use	1	2	3	4	5	N/A
...I would pay a $100 surcharge for excessive water use	1	2	3	4	5	N/A
...my town adopted regulations limiting irrigation use	1	2	3	4	5	N/A
...my property had less lawn	1	2	3	4	5	N/A
...the lawn on my property required little or no water	1	2	3	4	5	N/A

Please return survey to Emily Argo (413) 345-0107, wateruse@umass.edu.
University of Massachusetts Amherst
Holdswroth Hall
160 Holdsworth Way
Amherst, MA 01003

Thank you for your time!

APPENDIX D

INTERVIEW SCRIPT

Thanks for taking the time to chat with me about your outdoor water use in a little more detail. When you first got started with our study you signed a consent form that explained the interview process, so I wanted to go over this before we get started. I will be recording the interview with this tape recorded and will be keeping all of your responses confidential and will not be storing the recording with your names associated with it, I will just be using a code similar to the one your water use logs. I expect it will take us about an hour to complete the interview. **Do you have any questions about anything I've said so far?**

Ok, great. Before we get going I want to give you a road map of what we are going to cover and some context for the questions. I am interested in learning more details about how you make decisions to use water outdoors in different areas of your property, what if any changes you would consider making, your thoughts on watering restrictions and what your experience has been like participating in this research. The goal of these interviews and study as a whole is to get a better understanding of how residents in the suburban Boston use water outdoors and what influences your decision making process. I am also interested learning about the kinds of changes you would be interested in implementing. If you are satisfied with your current landscape design and water use, I want to hear about that too.

We have probably touched on some of these topics on occasion before this point but I would like to get some more detailed information from you.

Do you have any questions about what we are covering?

Great, I'm going to turn on the tape recorder and we can get started.

<u>Section 1 – Decision to water</u>
Lets start off by discussing how you think about your outdoor space. **Could you describe for me how you see your property in terms of outdoor watering – what are the different areas and how do you treat them differently?** (examples: garden, lawn, grass, forest, etc.)

Lets focus on the lawn, **are there areas of your lawn that you water differently?**

If yes:
What about these areas makes you water differently?

If they use an irrigation system:
At the beginning of the study you provided me with information about the timing and frequency of your irrigation system. I'd like to take a few steps back and learn from you **how you decided upon the schedule you currently use?**

If they do not address in responses above:
Why did you select a certain time of day to water?
How do you decide how long to water for?

You also have a garden area on your property, **what types of plants do you have?**

How do you water the garden? (ex. from a hose, sprinkler, drip irrigation, watering can, set a timer, etc.)
What makes you decide its time to water?
How does watering vary between plants?

If they say they water when the plants were looking dry or wilted etc.:
What characteristics tell you the plant meets this definition?

If they have a pool:
When do you usually fill the pool?
When do you decide you need to add more water to the pool?

Is anyone else responsible for watering?
If yes:
How do you think your opinions compare?

Section 2 – Watering Restrictions
Restrictions are used every summer here in YOUR TOWN (input what their actual restrictions are here). I'll preface my questions by saying that whether or not you follow restrictions is not something I am evaluating, some people comply to the letter others are more lenient in following the restrictions. Your responses and water use are completely confidential, I asking because I am very interested in learning how people respond or react to restrictions.

Modify questions depending on restriction level
When you see a new or upgraded restriction has been put in place, **how do you modify water use at your property?**

If they do not address in response:
How does the frequency with which you water change?
How does the time of day you water change?

Section 3 – Practice Implementation
Great, so now we've talked about what parts of your lawn get watered when, and how that changes if there are restrictions in place. Now I'd like to turn to hearing your perspectives on modifications to your property. I am not suggesting you should or need to make any changes, rather, I know people often have ideas in the back of their head about things they would like to do differently, even if they don't have the

opportunity to actually do them. So here I'm interested in gathering more detailed information about your interests and motivations for water conservation that could be instructive for future outreach efforts.

How open are you to changing how you water your lawn?
Would you be willing to change the appearance of your outdoor space?
What types of things could you do to use less water?
Are there certain things you are more open to changing that others?
What makes these things more or less appealing to you?

Section 3a – If they have conservation practices
Since you marked on your survey/I see you have (insert particular practices), I would like to get your opinion about this practice. **How has your water use behavior changed since installing conservation practices or changing your landscaping?**
Would you recommend these practices or changes to a friend?
What makes you more or less likely to suggest the practice?
What changes have you seen on your property since you installed the rain garden?
How did you come to the decision to install a rain barrel?
What is it about your lawn/landscaping that makes it drought-tolerant?

Section 4 – Need for conservation
There has been a lot in the media attention about water conservation recently given the drought and subsequent restrictions and debates in California. However, for these next questions please consider your responses in the context of where we are now, suburban Boston.

Is water availability an issue in suburban Boston?
Why do you think it is or is not an issue?
Is it necessary for residents to be conserving water?

Section 5 – Discussing conservation
Since water is very much in the news right now and there are active restrictions in town I'm curious how much you discuss water conservation or use with your neighbors, friends and family.

Is this a topic that comes up in conversation?

If yes:
What typically initiates these conversations?
Have you changed how you use water following one of these conversations or researched a particular practice or topic following the conversation?

If no:
What do you think makes you less inclined to discuss this topic with others?

Section 6 – Study Experience

To wrap things up, I would like to get some feedback form you as a participant in our study since you've completed a survey, recorded water use, and are now participating in this interview - a considerable amount of work.

What has been working well throughout this process?
What hasn't been working so well?
Did knowing your water use change how you used water? If so, in what ways?
Do you have any suggestions for us?

Final Question: Is there anything I haven't addressed in the interview that you would like to share?

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