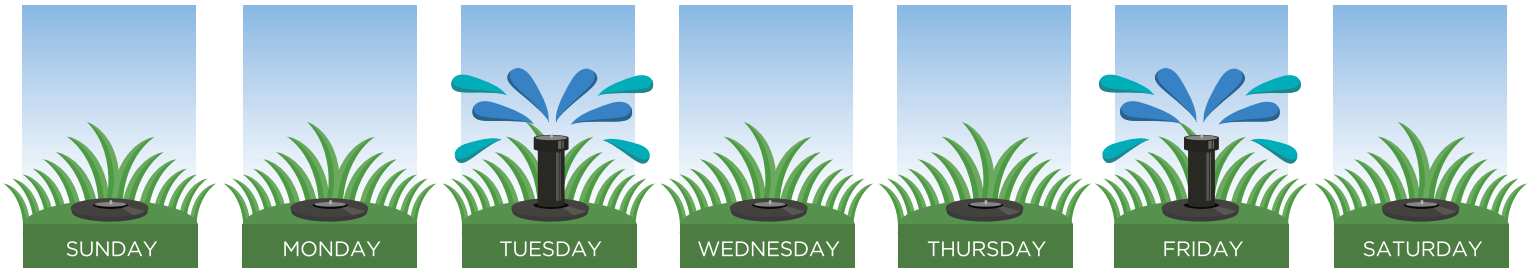
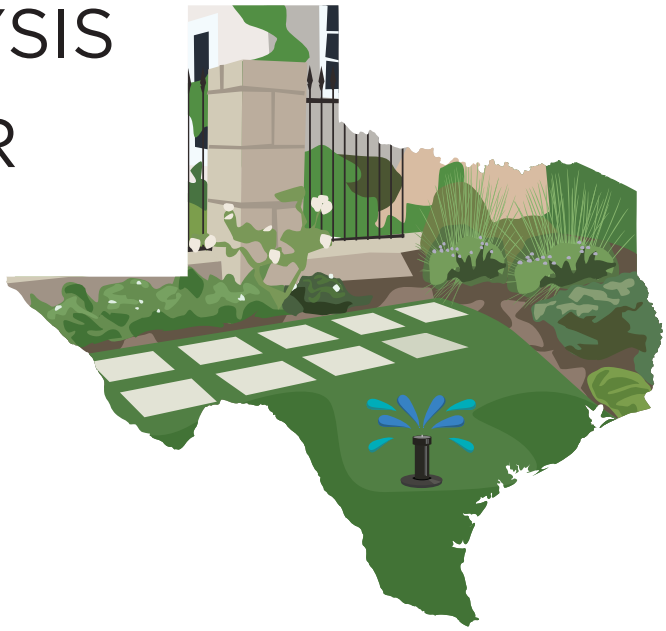
March 2018

WATER CONSERVATION BY THE YARD:



A STATEWIDE ANALYSIS OF OUTDOOR WATER SAVINGS POTENTIAL



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Texas Living Waters Project

Acknowledgements:

Water Conservation by the Yard: A Statewide Analysis of Outdoor Water Savings Potential is a joint publication of the Sierra Club, Lone Star Chapter and National Wildlife Federation.

Water Conservation by the Yard was researched and written by Meghan Bock and Jonathan Kleinman of Aiqueous in collaboration with Jennifer Walker, Ruthie Redmond and Myron Hess.

This publication was produced as an activity of the Texas Living Waters Project. The Texas Living Waters Project is a collaborative effort of the National Wildlife Federation and the Sierra Club, Lone Star Chapter and Galveston Bay Foundation.

The goals of the Texas Living Waters Project include:

1) Ensure adequate water for both people and the environment,
2) Reduce future demand for water and foster efficient and sustainable use of current water supplies,
3) Educate the public and decision makers about the impact of wasteful water use and the opportunities for water conservation, and
4) Involve citizens in the decision-making process for water management.

This report was funded through the generous support of The Cynthia and George Mitchell Foundation.

Thank you to Carole Baker and the Texas Water Foundation for your assistance in producing this update and expansion to *Water Conservation by the Yard*.

You can learn more about the Texas Living Waters Project at www.texaslivingwaters.org.

Texas Living Waters Project

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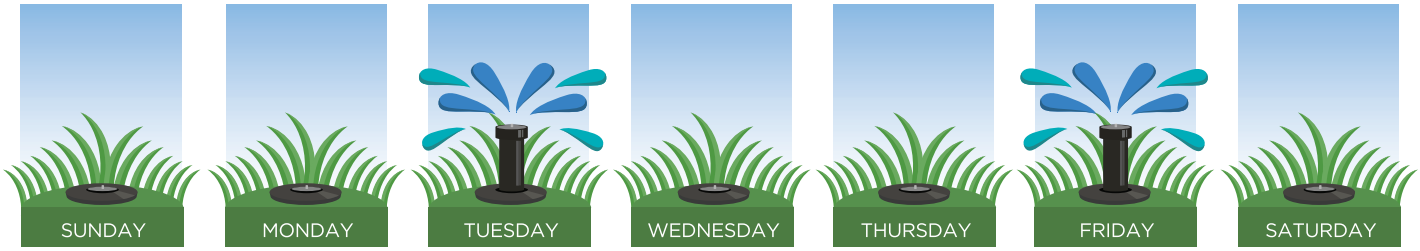
EXECUTIVE SUMMARY

There is a lot of water to be saved from implementing more efficient landscape irrigation practices. Landscape irrigation is estimated to be the single, largest component of municipal water use, and municipal water use is the second largest use of water in Texas (Cabrera et al., 2013). Studies show that homeowners have a tendency to overwater landscapes by as much as two to three times the amount needed (Haley et al, 2007).



In 2012, the TWDB released a report on outdoor water usage patterns in single-family households across Texas (Hermitte and Mace, 2012). TWDB's analysis showed that outdoor watering accounts for about 31 percent of single-family residential water consumption statewide. By outdoor use, we are referring to the water used to irrigate lawns, gardens, and plants, which represents 80 to 90 percent of total outdoor water consumption (Hermitte and Mace, 2012). Single-family households typically dedicate a greater share of their total water usage to outdoor purposes, but other municipal sectors, such as multi-family residential and institutional, commercial, and industrial (ICI), also have high outdoor watering demands. Moreover, outdoor water can represent a much higher percentage during our hot, dry summers. To help curb excessive outdoor water use, cities can for instance encourage residents to convert turf grass to native landscaping, introduce conservation rate structuring, and establish limits on the number of days residents can irrigate their lawns.

The latter approach, referred to as outdoor watering restrictions, is often the first line of defense for many cities during periods of drought because restrictions offer an immediate solution for stretching existing water supplies. Although outdoor watering restrictions can yield impressive savings in times of emergency, this straight-forward, minimal cost strategy can also drive long-term reductions in municipal per capita water usage on an ongoing basis if combined with robust enforcement and education efforts. Several cities across Texas — including Dallas, Austin, Frisco, Fort Worth, and the Woodlands — already utilize permanent outdoor watering restrictions as a core component of their water conservation efforts.

Even with outdoor watering limited to no more than twice per week, evidence shows Texas lawns will continue to thrive. In fact, the City of Austin has now moved to a no more than once per week watering schedule on a permanent basis, which has resulted in further savings while still allowing landscapes to do well. In order to stretch water supplies and protect rivers and bays, no more than twice per week landscape watering restrictions should be viewed as the maximum allowable watering frequency, with individual utilities looking carefully to determine if landscape watering should be allowed less frequently.

In addition, reducing water withdrawals for landscape watering will leave more water flowing in Texas rivers and into Texas bays.

This approach would greatly reduce overall municipal water use, and by reducing peak water demand, reduce capital expenditures otherwise required for expanding water treatment capacity and transmission lines. In addition, reducing water withdrawals for landscape watering will leave more water flowing in Texas rivers and into Texas bays. Adequate river flows and freshwater inflows

to bays are essential for maintaining good water quality and for supporting healthy populations of fish and wildlife that are a key component of the natural heritage of all Texans.

To illustrate the water savings potential resulting from no more than twice per week watering restrictions, we performed a statewide analysis of residential outdoor watering and, based on that analysis, estimated a range of water savings using data collected from the efforts of utilities in multiple states. Our approach uses municipal-level data and extrapolates it to the regional and statewide scale. Presenting our findings based on regional water planning areas allows us to compare regional savings to current and future municipal needs and demands, as set forth in the 2017 State Water Plan.

Based on regional differences in outdoor use and on varying levels of education and enforcement effort, we identified a potential savings range of 2 percent to 11 percent of total municipal water usage for Texas' 16 planning regions. Total municipal usage reflects total water consumption by single-family and multi-family residential, commercial, industrial, and institutional users. If no more than twice per week watering restrictions were implemented in each region with a high level of education and enforcement effort, 460,000 acre-feet of water per year could be conserved relative to the projected 2020 municipal demand levels across the entire state **(Table 1)**. By 2070, with projected population growth rates and a high level of effort, statewide municipal water savings could exceed 750,000 acre-feet per year. In the coming decades, water savings from these measures alone would be enough to satisfy a significant portion of projected municipal water needs.

There is a range of savings possible through implementing no more than twice per week watering restrictions. A higher level of effort will yield bigger savings. For example, a comprehensive education program will ensure more customers are aware of the watering restrictions and offer information on how to maintain a healthy landscape while complying with the watering restrictions. An enforcement program will help increase program compliance and water savings. This could be combined with a reporting mechanism that allows community members to report instances of water waste. To help lock in and increase these water savings, Texas cities can complement outdoor watering restrictions with additional conservation measures over the long-term. These strategies include:

- Encouraging the installation of drip irrigation and evapotranspiration-based (ET-based) irrigation controllers;
- Promoting water smart landscaping, establishing top soil requirements in new development, and limiting irrigated landscape area; and
- Providing tools and opportunities to educate communities on efficient landscaping and irrigation practices.
- Provide free or reduced-cost irrigation system audits or check-ups

TABLE 1: PROJECTED MUNICIPAL SAVINGS FROM OUTDOOR WATER RESTRICTIONS BASED ON PROJECTED FUTURE MUNICIPAL DEMANDS & NEEDS

	2020 Planning Decade		2040 Planning Decade		2070 Planning Decade	
STATEWIDE	Municipal Demand (acre-feet/year)	Municipal Need (acre-feet/year)	Municipal Demand (acre-feet/year)	Municipal Need (acre-feet/year)	Municipal Demand (acre-feet/year)	Municipal Need (acre-feet/year)
	5,199,942	510,750	5,791,143	1,575,086	8,432,718	3,413,130
	Water Savings (acre-feet/year)		Water Savings (acre-feet/year)		Water Savings (acre-feet/year)	
	222,163 (low effort) to 464,066 (high effort)		276,471 (low effort) to 573,957 (high effort)		367,981 (low effort) to 759,069 (high effort)	

Table 1: Summary of projected statewide water savings from twice per week outdoor watering restrictions by planning decade (2020, 2040, and 2070). The range of potential savings is based on the level of effort (low and high) exercised in educating and enforcing outdoor watering restrictions. Projected municipal demands and needs are taken from 2017 State Water Plan. Water needs refers to amount of project demand not expected to be met from current supply sources.

There is no doubt water conservation must play an integral role in ensuring Texas' future water needs are adequately met. Over the next 50 years, the 2017 State Water Plan estimates over $60 billion of investment will be required to meet the state's future water demands. In almost all instances, water conservation represents the most cost-effective water management strategy recommended in the Plan and the option with the least amount of adverse environmental impact, especially compared to developing new groundwater or surface water supplies. Water conservation enables cities to stretch existing water supplies to meet the needs of more people and businesses. Moreover, since that supply and the infrastructure to deliver it has already been developed, conserving that water is far less expensive than building new capital projects, such as major reservoirs or desalination plants.

As this report demonstrates, effectively implemented outdoor watering restrictions can contribute immensely to meeting statewide municipal water needs and can alone achieve much of the projected conservation savings included in the 2017 State Water Plan. By acting now to recognize and capture the full potential of outdoor watering restrictions, Texas communities can achieve these long-term conservation savings and take a major step towards meeting the state's projected municipal water needs.

As this report demonstrates, effectively implemented outdoor watering restrictions can contribute immensely to meeting statewide municipal water needs and can alone achieve much of the projected conservation savings included in the 2017 State Water Plan. By acting now to recognize and capture the full potential of outdoor watering restrictions, Texas communities can achieve these long-term conservation savings and take a major step towards meeting the state's projected municipal water needs.

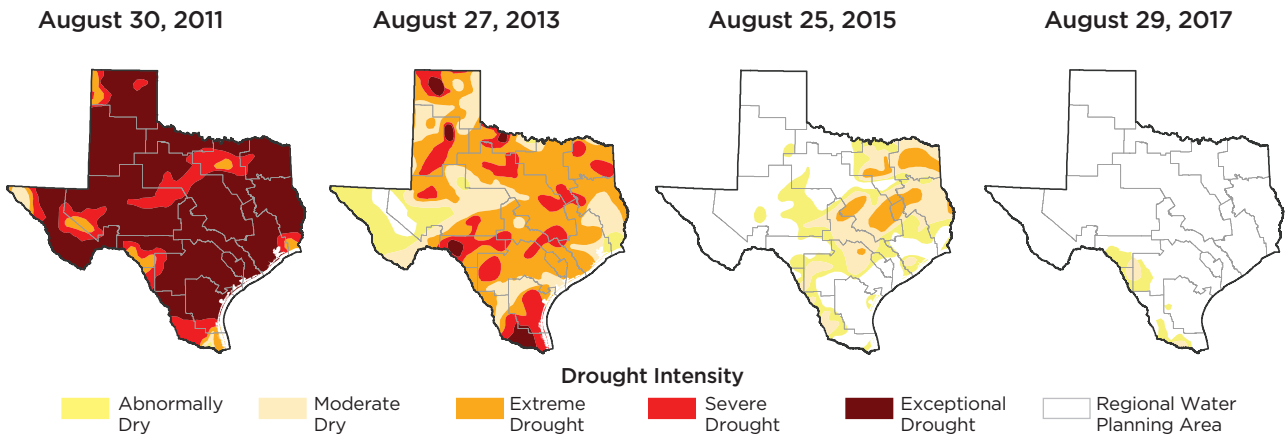
INTRODUCTION

In 2015, the Sierra Club, Lone Star Chapter and the National Wildlife Federation jointly published the original *Water Conservation by the Yard: Estimating Savings from Outdoor Watering Restrictions*, which focused only on conservation opportunities in water planning regions C and H. The report estimated the water savings from no more than twice per week watering restrictions in those two regions. As the original report highlighted, outdoor water use represents a significant opportunity for water conservation because landscapes are often overwatered.

Reducing excessive outdoor water use through the implementation of watering ordinances offers one of the most cost-effective water supply strategies available to municipalities. More cities have started to recognize the value of mandatory, year-round watering restrictions as an ongoing conservation measure, even when drought conditions have improved.

The state of Texas is certainly no stranger to drought. It was not too long ago that the state was fully immersed in one of the most severe droughts on record. During these periods of water crisis, limitations on outdoor watering, which represents the largest category of discretionary household use, becomes a utility's first line of defense in reducing overall water use. As drought conditions begin to dissipate, however, cities often rescind outdoor restrictions even though savings from these watering ordinances can be secured on an ongoing basis. The original *Water Conservation by the Yard: Estimating Savings from Outdoor Watering Restrictions* argued that outdoor watering restrictions should remain in place on a full-time basis because wasteful landscape irrigation remains a problem through periods of both drought and non-drought.

Since the original report was published, as illustrated in the maps below, Texas fully transitioned out of a severe drought. Following the impacts of the devastating hurricane that unleashed over 50 inches of rain and as much as 31 trillion gallons of water along the Texas Gulf Coast in late summer of 2017, it can be difficult to focus on water conservation. However, for much of the state, abnormally dry, and even drought-level conditions, had already returned by the end of the year. As the state recovers from Hurricane Harvey, it appears increasingly likely that increasing severe fluctuations between intense rainfall and drought will be the new norm for the state. It is critical, then, for water conservation to remain on the minds of both the public and decision-makers because the next drought is just around the corner.



Proactive, ongoing water conservation measures to ensure long-term water demand reduction will be key to ensuring a good water future for Texas, regardless of whether we are in a drought at any particular time.

As demonstrated in our earlier study on savings from outdoor watering restrictions in planning regions C and H, ordinances limiting the frequency of landscape watering can produce large savings. In this report, we provide savings calculations for all 16 water planning regions. The purpose of this expanded study is to examine the full water savings potential on a statewide scale and to consider more carefully how heightened education and enforcement can affect the savings achieved. In our analysis we focus on the water savings from no more than twice per week watering restrictions, which we believe is the minimal standard that Texas cities should adopt. In fact, some Texas communities have gone further to curb excessive outdoor water use by limiting outdoor irrigation to no more than once per week, and their efforts have yielded compelling results.

Using no more than twice per week watering restrictions as a benchmark, we estimate future municipal water savings according to updated municipal demand projections through 2070, as set out in the 2017 State Water Plan. We then compare these estimated future municipal water savings to projected municipal needs. We complement this quantitative analysis by also highlighting strategies for designing and implementing effective watering ordinances. As Texas looks ahead to the next 50 years, the results of our analysis underscore the integral role conservation measures should play in securing a more resilient water future.

Proactive, ongoing water conservation measures to ensure long-term water demand reduction will be key to ensuring a good water future for Texas, regardless of whether we are in a drought at any particular time.

OUTDOOR WATERING IN TEXAS

Landscape irrigation is estimated to be the single, largest component of municipal water use, and municipal water use is the second largest use of water in Texas (Cabrera et al., 2013).

Municipal water use is comprised of three main categories: single-family residential; multi-family residential; and institutional, commercial, and industrial (ICI). Each of these municipal use categories contributes to total outdoor watering demands to varying degrees. Landscape water use as a percentage of total water use is greatest among single-family households, with less, but still substantial, percentages for multi-family and ICI uses. Numerous factors influence outdoor watering demands at the municipal scale, including the size of each customer class, building characteristics, size of irrigated land, density, etc. For a community with a greater mix of water user types (i.e., diversified service base), **Figure 1** illustrates a fairly typical distribution of municipal water consumption by sector and end use category (indoor or outdoor).

Outdoor water consumption in communities with a diversified service base is more evenly distributed across each sector — however, single-family residences are still the largest outdoor water users. In communities with a predominant share of single-family residential users (i.e., homogenous service base), outdoor water consumption by single-family residences accounts for an even larger share of total municipal usage, as shown in **Figure 2**.

FIGURE 1: DISTRIBUTION OF MUNICIPAL WATER CONSUMPTION BY USE CATEGORY — EXAMPLE OF A COMMUNITY WITH A DIVERSIFIED SERVICE BASE

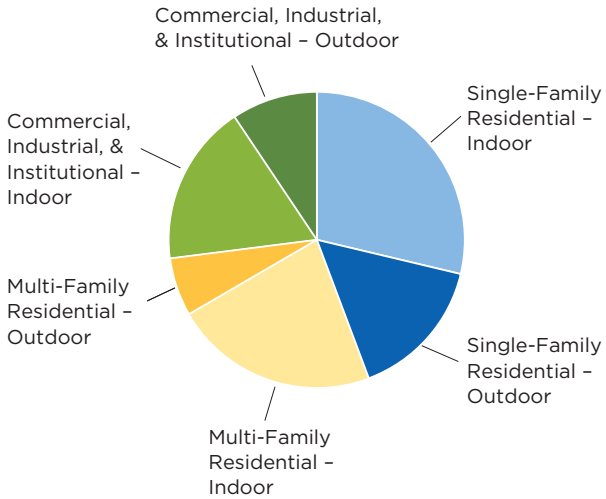


Figure 1: Example distribution of municipal water consumption by use category (single-family; multi-family; commercial, institutional, and industrial) and by end use category (indoor or outdoor) for a community with a mixture of single-family, multi-family, and ICI customers. This information is based on the City of Austin's 2010 historical water consumption data, which is prior to the city's adoption of year-round twice per week watering restrictions (City of Austin, 2017).

Outdoor water use represents a substantial portion of residential water consumption in Texas, ranging from 21 percent in wetter areas to 41 percent in drier areas. In total, single family households in Texas currently use as much as 590,000 acre-feet of water each year for landscape irrigation.

FIGURE 2: DISTRIBUTION OF MUNICIPAL WATER CONSUMPTION BY SECTOR — EXAMPLE OF A COMMUNITY WITH A HOMOGENEOUS SERVICE BASE

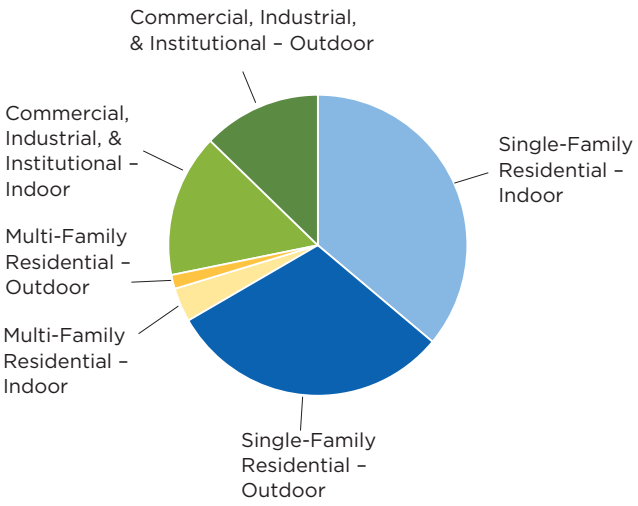


Figure 2: Example distribution of municipal water consumption by use category (single-family; multi-family; commercial, institutional, and industrial) and by end use category (indoor or outdoor) for a community with a service base dominated by single-family homes. This information is based on municipal water usage for the City of Frisco (TWDB, 2012 through 2015). Percent outdoor water use for single-family households was obtained from the TWDB (Hermitte and Mace, 2012). Percent outdoor water use for multi-family and ICI customers was extrapolated from the City of Austin's historical water consumption data (City of Austin, 2017).

To better understand statewide outdoor water usage, we first focus on single-family households because of the high percentage of total municipal outdoor watering demands coming from this municipal water use category. Moreover, available data on single-family household outdoor use allows us to assess usage on a more localized level. Building on the analysis of single-family outdoor water usage, we next compute the savings available from total municipal water usage by incorporating multi-family and ICI categories into the saving estimations.

Single-Family Outdoor Watering in Texas

Outdoor water use represents a substantial portion of residential water consumption in Texas, ranging from 21 percent in wetter areas to 41 percent in drier areas. In total, single family households in Texas currently use as much as 590,000 acre-feet of water each year for landscape irrigation.

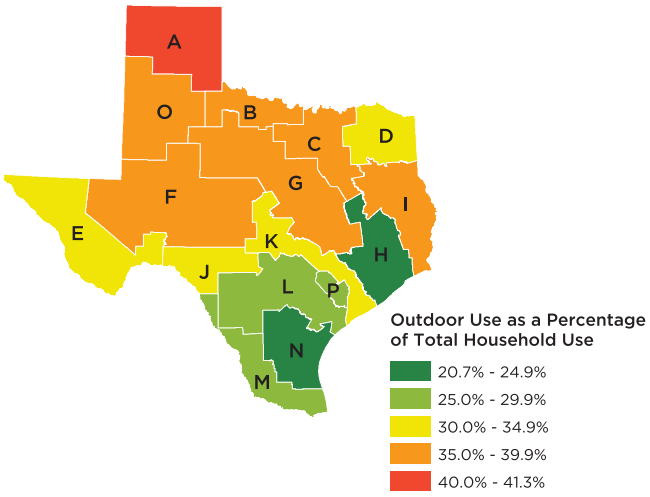
In 2012 the TWDB prepared a report on outdoor water usage patterns in single-family households across Texas.[1] The analysis showed that outdoor watering accounts for about 31 percent of single-family residential water consumption statewide. The study also found that patterns in outdoor water usage roughly mirrored the east-west precipitation gradient with drier areas using a larger proportion of water for outdoor purposes than wetter areas, although significant variability was noted.

Data presented in TWDB's report forms the basis of our analysis of statewide outdoor water use by single-family households in Texas. We start by determining total outdoor water use as a percentage of total usage for each region, and from these data, we estimate the total volume of single-family outdoor water use, both in regional water planning areas and statewide. Outdoor water use can vary substantially from region to region depending on climate, household characteristics, landscaping preferences, etc. To better capture these regional variations, we also calculate daily household outdoor use within each region.

1 The study, titled The Grass is Always Greener… Outdoor Residential Water Use in Texas, focused on residential outdoor consumption for 259 Texas cities from 2004 to 2008 and 17 Texas cities from 2004 through 2011 (Hermitte and Mace, 2012)

Determining Single-Family Outdoor Water Use by Region

MAP 1: OUTDOOR WATER USE AS A PERCENTAGE OF TOTAL HOUSEHOLD USE



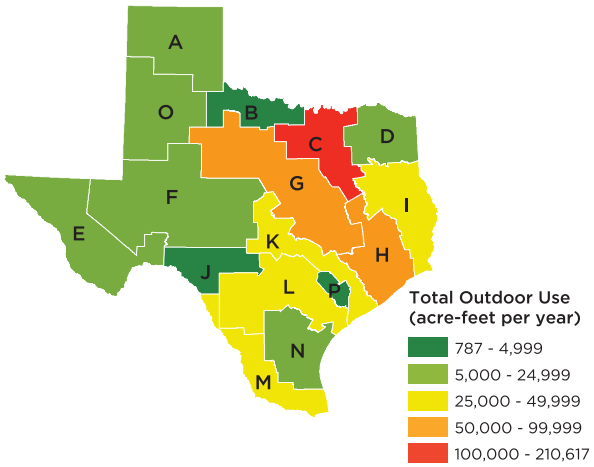
Map 1: Outdoor water use as a percentage of total household use per planning region, based on utility records from 2004 to 2008 (Hermitte and Mace, 2012).

Using municipal-level data cited in TWDB's report, we computed a weighted percentage of outdoor water use for each region. We began by assigning each city from the TWDB report to its respective region and then calculating the weighted average for the region based on the number of single-family residential connections. Outdoor water use is extremely prevalent in single-family households, so by weighting these percentages, we can describe the relationship between percent outdoor water use and the number of single-family connections in a more meaningful way. For instance, cities with higher concentrations of single-family households represent a larger share of total outdoor water usage region-wide, so a weighted average allows us to better account for the relative impact of these cities on total outdoor water usage.

Our results show that single-family households in Region A use the largest share (41.3 percent) of their total consumption for outdoor purposes. Conversely, single-family households in Regions H and N use the smallest share (20.7 percent and 23.4 percent, respectively) for outdoor water use.

For the most part, the outdoor water use characteristics illustrated in **Map 1** reflect the east-west precipitation gradient from wetter to drier regions of the state. However, in Regions like D and I, which are in a wetter part of the state, outdoor usage accounts for a larger share of total usage compared to surrounding regions. Rainfall is not the only factor contributing to these usage patterns — other factors such as land use, housing characteristics, and behavioral differences between urban and rural residential users can also influence outdoor use.

MAP 2: TOTAL ANNUAL SINGLE-FAMILY RESIDENTIAL OUTDOOR WATER USE



Map 2: Total single-family residential outdoor water use per region, based on utility records from 2004 to 2008 (Hermitte and Mace, 2012) and utility water use estimates (TWDB, 2012 through 2015).

Next, we estimated the total annual volume of outdoor water use for single-family residences in each region. We arrived at these estimations by applying the percentages of outdoor use to average single-family household demand within the region from 2012 to 2015. This information was obtained from annual water use surveys collected by the TWDB for all Texas public water systems. We chose to average single family residential consumption over this four-year period to account for the fluctuations in demand that occur as a result of years with more or less rainfall.

Our results indicate Region C uses more water outdoors by far than any other region —

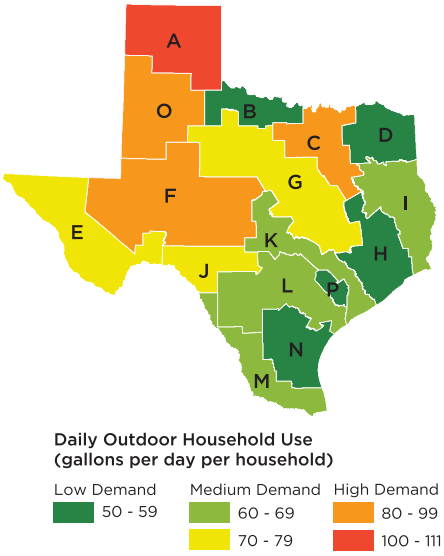
approximately 210,000 acre-feet annually — which accounts for 35 percent of total single-family outdoor consumption statewide. Although Regions H, G, and L round out the top four regions in terms of total outdoor water use, these regions use a combined volume of 189,000 acre-feet, which is less than Region C alone. Regions with the lowest volumes of outdoor water use include Regions B, J, and P. **Map 2** illustrates the variation in total outdoor consumption, by volume, across the state.

Demographic trends, rather than regional climate variations, tend to be the primary drivers influencing these patterns in total outdoor water use. More populated regions, such as C, H, G, K, and L, consume the highest volumes of outdoor water because these regions are also the population centers of Texas and therefore have a larger concentration of single-family households, which typically use more water outdoors than other sectors such as the multi-family sector and the institutional, commercial, and industrial sector. Region A, on the other hand, has the highest outdoor water use as a percentage of total household water use, but it is less densely populated, so the region's overall outdoor water use is much lower.

Statewide, average annual outdoor water use is approximately 590,000 acre-feet. This value is equivalent to the combined annual total municipal water usage of Regions A, B, D, E, and K. In other words, the amount of water we use for municipal outdoor water use as a state could meet the full municipal water use of five of the water planning regions.

Another useful metric for evaluating outdoor water use is daily outdoor use by household, which captures both regional variations in climate as well as differences in housing characteristics and cultural norms associated with lawns. Even though Regions C, G, and H have the highest outdoor water use on a regional basis, that does not necessarily indicate excessive amounts of outdoor water use because of differences in numbers of households. To better understand these regional differences, we calculated outdoor water use on a per household basis. **Map 3** shows these per household usage patterns by region.

MAP 3: DAILY OUTDOOR HOUSEHOLD USE

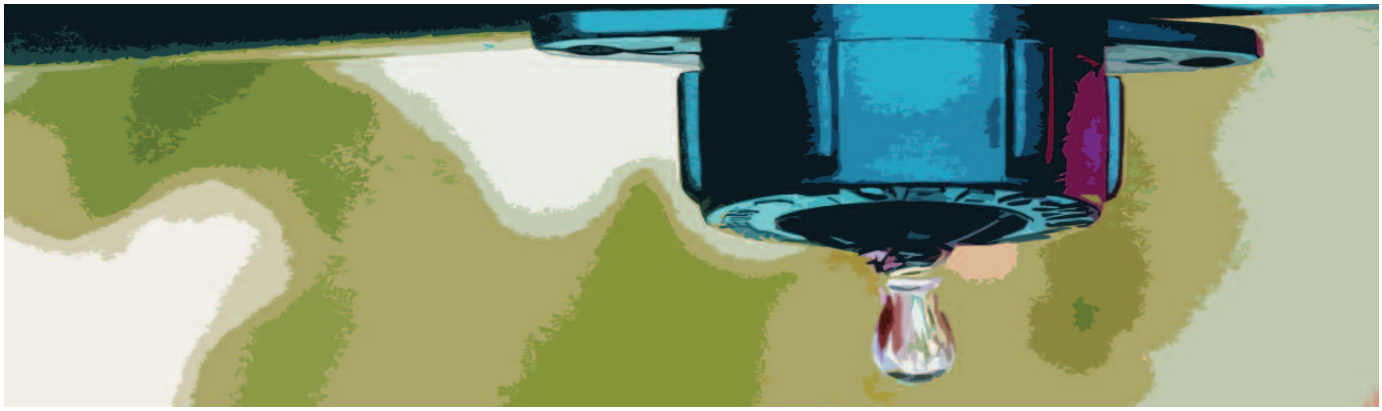


Map 3: Daily outdoor household use per region, based on utility records from 2004 to 2008 (Hermitte and Mace, 2012) and utility water use estimates (TWDB, 2012 through 2015).

The map of daily household outdoor usage generally tracks the east to west precipitation gradient more clearly than percentage outdoor water use. Regions on the eastern edge of Texas and along the Gulf Coast receive more rainfall and experience higher humidity, which lead to lower rates of evapotranspiration. Due to the effects of climate, for similar types of landscape plants, outdoor watering requirements are often much lower in these regions compared to regions to the west, which receive less rainfall. Household outdoor water use is also highly correlated with a number of other factors, such as age of housing stock, lot size, and assessed value.

Given how much water is used in the state of Texas for landscape irrigation, there is a significant opportunity to achieve water savings through conservation measures. The TWDB projects the state's population to nearly double by 2070, meaning outdoor water use will likely follow a similar trajectory unless action is taken now. Curbing outdoor water use through more efficient landscape irrigation practices can yield substantial water savings, while still maintaining healthy landscapes. In the next section, we highlight the savings potential tied to the implementation of outdoor watering restrictions.

APPROACH FOR COMPUTING SAVINGS FROM OUTDOOR WATERING RESTRICTIONS



As our findings indicate, the scale of outdoor water use statewide is massive. A significant percentage of highly treated, potable water — not to mention the expensive infrastructure required to deliver that water — is devoted to watering landscapes. Given the ability of landscapes to survive and thrive with lower watering amounts and frequencies, watering restrictions can reduce total municipal water usage by as much as 11 percent, even without large-scale changes in the types of residential landscapes. Now more than ever, Texas cities should employ watering restrictions as an ongoing conservation strategy, not just as a temporary drought-management response.

The push towards permanent, outdoor watering restrictions also comes in line with demographic and housing trends in recent decades. Texas is home to the fastest growing cities in the nation, and with this demographic growth comes burgeoning housing markets across many parts of the state. The abundance of new housing stock is rapidly shaping municipal water demands, especially in the single-family sector where in-ground irrigation systems and turf grass have become increasingly prevalent (Aquacraft, 2011b). Because these housing preferences drive higher outdoor water usage, the need to curb excessive outdoor water use has become ever more salient.

Communities can implement a variety of measures to achieve outdoor water savings, from promoting drought-tolerant plant species, to transitioning to conservation-driven water rate structures, to adopting ordinances that reduce inefficient or inappropriate watering practices. To leverage the greatest water savings, cities can focus their efforts on all municipal sectors and tailor these measures to the unique characteristics of their service base. When it comes to outdoor watering restrictions, the largest portion of these outdoor water savings will come from single-family households. However, the multi-family and ICI sectors represent a sizeable chunk of total municipal outdoor water usage, and as such, substantial savings are also achievable through restrictions on outdoor watering for these sectors.

Our analysis of the potential water savings from no more than twice per week watering restrictions focuses on both single-family residential savings (as a percentage of total single-family consumption), as well as on total municipal savings, which reflect the combined savings from single-family, multi-family, and ICI (as a percentage of total municipal use). These two perspectives allow us to provide useful information for understanding the full scale of achievable municipal-wide savings, while also highlighting the critical savings available from the single-family residential sector.

Texas is home to the fastest growing cities in the nation, and with this demographic growth comes burgeoning housing markets across many parts of the state. The abundance of new housing stock is rapidly shaping municipal water demands, especially in the single-family sector where in-ground irrigation systems and turf grass have become increasingly prevalent. Because these housing preferences drive higher outdoor water usage, the need to curb excessive outdoor water use has become ever more salient.

How Much Water can be Saved?

Outdoor watering restrictions have been a component of drought management planning for well over a decade. In times of drought, cities enact irrigation restrictions as an emergency response to rapidly declining water supplies, but once drought conditions subside, these restrictions are typically withdrawn. In periods between droughts, however, permanent, year-round outdoor watering restrictions can strengthen long-term water supplies by ensuring ongoing outdoor water savings.

The state of Texas is especially susceptible to drought — since its first recorded drought in 1870, the state has experienced prolonged, severe drought at least once every decade. In fact, the most recent drought punctuated by 2011 — now the state's worst short-term drought on record — persisted for over three years and was preceded by a series of back-to-back droughts in the early 2000s (Henry, 2011). Outdoor watering restrictions were widely implemented across the state during the peak of the 2011 drought, but only a handful of cities kept the restrictions in place after the drought dissipated, including Fort Worth, Austin, and Dallas. Even in non-drought periods, these cities continue to see reductions in outdoor water use.

In Texas and beyond, more communities have started to recognize the benefits of implementing watering restrictions as a permanent conservation strategy versus as just an emergency response to water shortages. Unfortunately, records of specific, quantified water savings projections associated with this measure have not been readily available, largely because the data are not routinely collected. For cities that do track their water savings, it can be difficult to tease out other factors that may affect outdoor water use patterns.

To gain more insight into the range of potential savings from watering restrictions, we performed an extensive literature review and reached out directly to several cities. In **Table 2** (page 15), we present the reported watering savings from no more than twice per week watering restrictions, as implemented under two different contexts: as a temporary mechanism for drought management and as an ongoing conservation strategy. The watering day limitations are typically paired with time-of-day restrictions (e.g., no watering between 10 am and 6 pm, when evaporative loss is especially high) and prohibitions against wasting water (e.g., no runoff or no watering impervious cover).

Water utilities report a wide range of savings from watering restrictions, which, to some extent, appears to reflect their underlying service base, but also level of implementation effort. The lower percentage savings generally are reported by utilities serving a mixture of single-family; multi-family; institutional, commercial, and industrial sectors (data from Dallas, Fort Worth, Austin, and Tarrant Regional Water District). Alternatively, percentage savings rates in the double digits (11 to 16 percent) generally come from utilities serving primarily single-family homes (data from Ococee, Winter Park, Deland, and The Woodlands). All other things being equal, the difference makes sense because single-family residences generally use a higher percentage of water outdoors as compared to other municipal use categories. When outdoor usage is curtailed, the largest portion of the savings likely will come from single-family homes, so utilities with a higher percentage of those homes are expected to see greater savings.

The level of effort that cities dedicate to implementing a watering restriction is also a key factor. The results of our review indicate that it is possible the persistence of these savings can diminish over time as drought conditions subside, particularly for measures initiated in response to drought but kept in effect without a robust education and enforcement mechanism. For instance, the City of Fort Worth reports seeing its savings from outdoor watering restrictions drop from 9 percent in 2013 — when the city first implemented permanent restrictions — to 1 percent in 2016.

TABLE 2: EXAMPLES OF SAVINGS FROM OUTDOOR WATERING RESTRICTIONS				
Source	**Type of Restriction**	**Year(s)**	**Annual Percent Water Savings**	**Category of Use**
Fort Worth	Drought	2011	8%	Total municipal use
	Permanent	2013 - 2016	1% - 9%	Total municipal use
Tarrant Regional Water District	Drought	2011	8%	Total municipal use
	Permanent	Projected	4%	Total municipal use
Dallas	Permanent	2012	7%	Total municipal use
Austin	Permanent	2009	7%	Total municipal use
St. Johns River Water Management District	Permanent	2006 - 2012	11%	Total municipal use
Stuart, FL	Permanent	2010	15.5%	Total municipal use
The Woodlands	Permanent	2012 - 2013	13%	Total single-family use
Ococee, FL	Permanent	Early 2000s	11.6% - 12.8%	Total single-family use
Winter Park, FL	Permanent	Early 2000s	15%	Total single-family use
DeLand, FL	Permanent	Early 2000s	11%	Total single-family use
Sanford, FL	Permanent	Early 2000s	3%	Total single-family use
Virginia (18 municipalities)	Drought	2002	3.6% - 22.1%	Total single-family use
Los Angeles, CA	Drought	2009	4% - 23%	Total single-family use

Table 2: Savings from no more than twice per week watering restrictions reported by water providers across the country. Savings are identified by type of restriction (drought-related or permanent), year(s), percent savings, and use category (total municipal use or single-family use) against which estimated savings are calculated.

The Impact of Education and Enforcement on Water Savings

Service base composition plays a factor in the broad range of savings observed in these communities, but level of implementation effort is an even stronger indicator of the captured savings. We observe this connection in data from Virginia, Los Angeles, and Sanford, FL, which reported percentage savings on both the lower and higher ends of the spectrum (3 to 23 percent). Specifically, the study of 18 municipalities in Virginia examined the effectiveness of heightened education and enforcement during a 2002 drought (Halich and Stephenson, 2009). The most aggressive efforts resulted in as much as 22.1 percent water savings compared to a modest 4 percent savings when levels of education and enforcement were both low.

In developing our estimates of potential savings, we included data on savings from both permanent and drought-related restrictions. The assumption is that the practice being implemented is the same for each, which leads us to assume permanent and drought-related restrictions should yield similar savings opportunities. However, that is not always the case, as our review of savings estimates reveals. For outdoor watering restrictions to be effective, robust implementation mechanisms must be established. Drought-related restrictions see higher water savings because educational and enforcement efforts are typically more aggressive during drought. As the Virginia study demonstrates, heightened implementation efforts translate to a much higher savings potential. When drought conditions recede, however, it is not uncommon for enforcement and education mechanisms to drop off as available water supplies return to previous levels and the sense of urgency begins to diminish. Lax education and enforcement may often result in water users who are not mindful of the importance of avoiding wasteful water use. Maintaining elevated levels of education and enforcement, consistent with those evidenced during periods of drought, can help ensure restrictions remain just as effective in periods of non-drought.

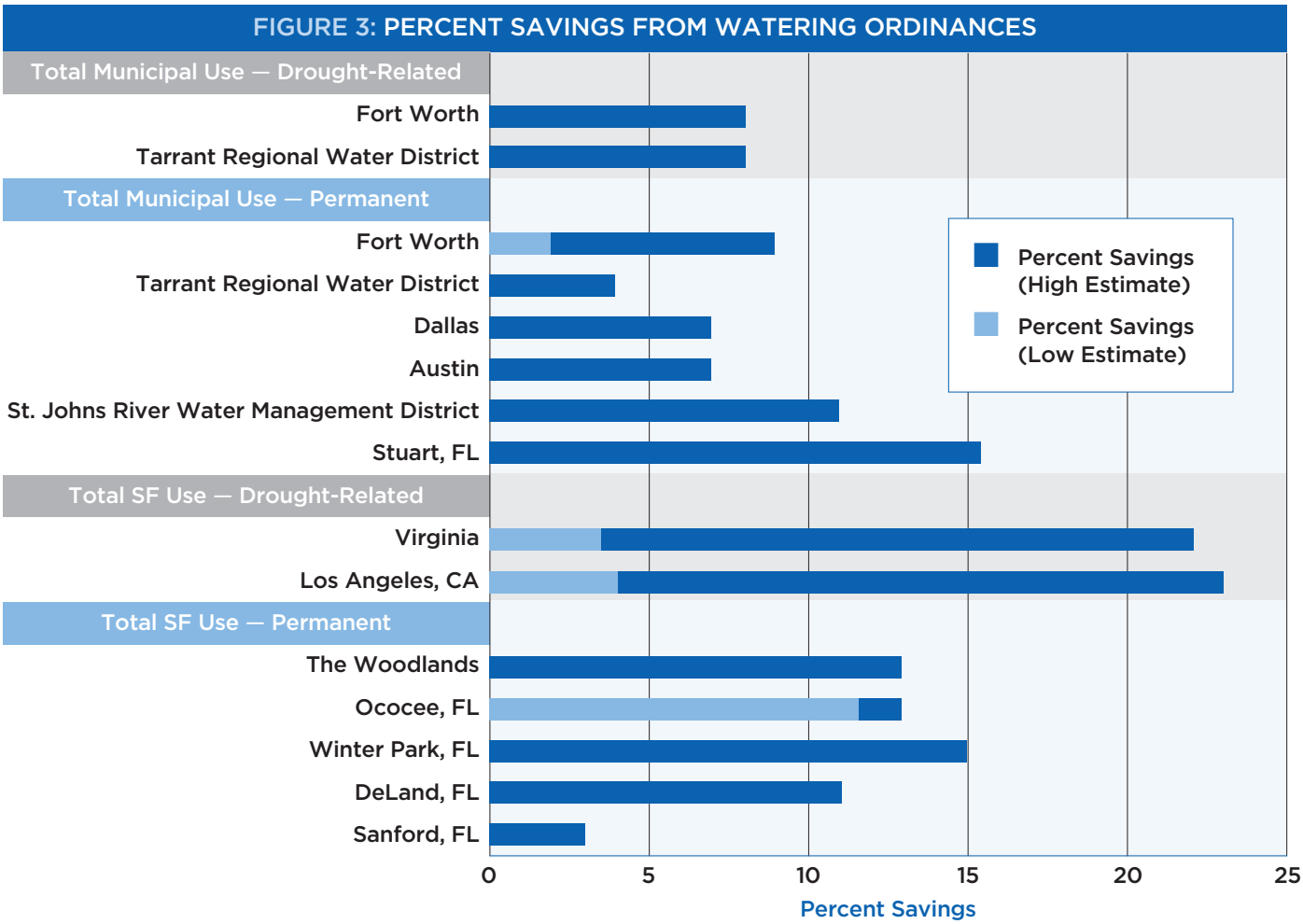


Figure 3: Water conservation savings for landscape watering restrictions, as reported by water suppliers throughout the U.S. The top 2 bars represent annual savings as a percentage of total municipal use (i.e., single-family; multi-family; commercial, institutional, and industrial) for restrictions implemented during a drought. The next 6 bars represent annual savings as a percentage of total municipal use for permanent restrictions. The following 2 bars represent annual savings as a percentage of overall use by single-family homes for restrictions implemented during a drought. The bottom 5 bars represent annual savings as a percentage of overall use by single-family homes for permanent restrictions. When data were reported as a range of savings, the lower savings percentage is indicated in light green.

A broad range of savings comes as no surprise, given the unique context in which outdoor watering restrictions are implemented — including level of education and enforcement effort, the service base composition, regional climate, etc. Because of this complexity, savings observed in one place may not be as easily replicable in another. The challenge of determining precise savings estimations is made more difficult by the fact that the savings reported in **Figure 3** may reflect the combined impact of multiple efforts to reduce outdoor demands such as rebate programs, conservation education initiatives, and shifts in pricing. Nonetheless, water suppliers commonly underscore watering restrictions as the greatest contributor to these savings. To account for these variations, we developed matrices of potential savings for single-family water use and total municipal water use.

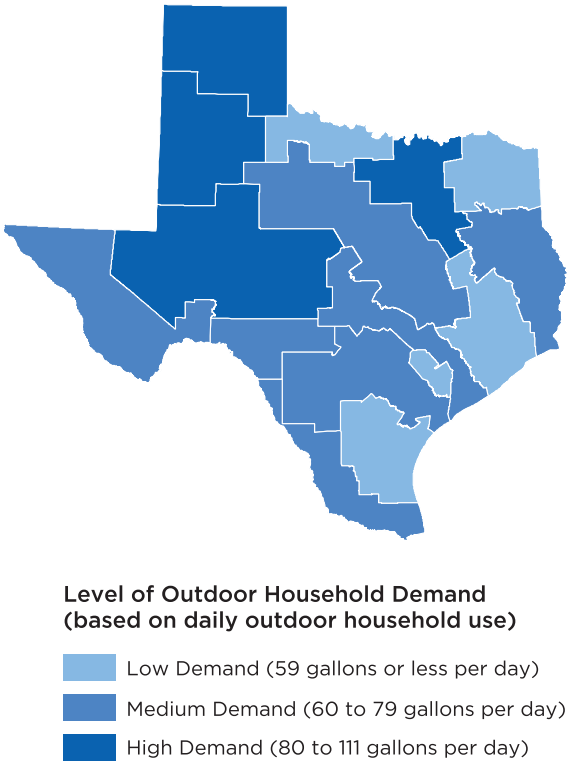
Estimating Savings Potential

In order to incorporate the effect of these factors into our analysis, we developed a range of potential savings for outdoor water restrictions, both for single-family use (i.e., the water savings from single-family households alone) and for total municipal use (i.e., the combined water savings from all municipal sectors). We determined these

ranges using two parameters: initial level of household outdoor use (lower, medium, or higher demand) and level of effort employed to implement the measures (low or high effort).

This format allows the flexibility to assign water savings estimates that better align with the climate and outdoor water use behaviors characteristic of each region and with the implementation strategy. Using daily outdoor household demand presented in the previous section, we categorized each region by level of demand: lower (59 gallons or less per day per household), medium (60 to 79 gallons per day per household), and higher (80 gallons or more per day per household). **Map 4** depicts these levels of demand by region.

MAP 4: LEVEL OF OUTDOOR HOUSEHOLD DEMAND (BASED ON DAILY OUTDOOR HOUSEHOLD USE)



Map 4: Level of Outdoor Household Demand: Low, Medium, and High. [based on utility records from 2004 to 2008 (Hermitte and Mace, 2012) and utility water use estimates (TWDB, 2012 through 2015)].

We also used level of implementation effort (low or high) as a parameter for demonstrating the breadth of potential savings that can be achieved from outdoor watering restrictions. Our research indicates that the robustness of education and enforcement efforts during implementation greatly influences the effectiveness of these restrictions.

Tables 3 and **4** illustrate the estimated percentage savings for single-family and total municipal usage based on different combinations of levels of outdoor water demand and of implementation effort: Low Demand-Low Effort, Low Demand-High Effort, Medium Demand-Low Effort, Medium Demand-High Effort, High Demand-Low Effort, and High Demand-High Effort.

TABLE 3: SAVINGS ESTIMATE MATRIX — TOTAL SINGLE-FAMILY USAGE

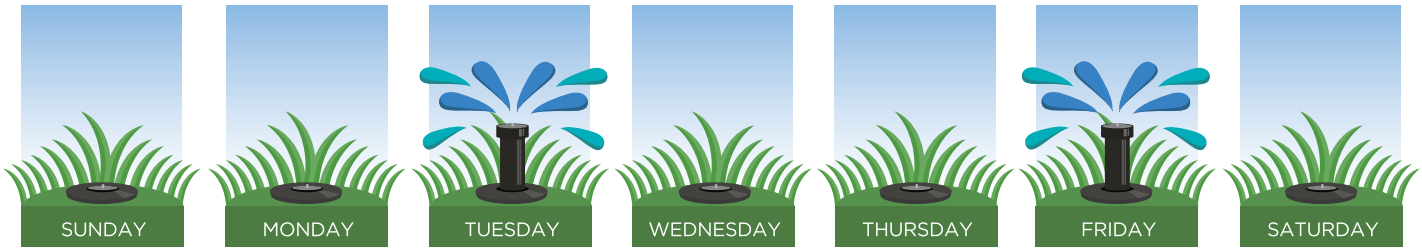
Outdoor Household Demand	Level of Effort/Education	
	Low	High
Low	3.5%	12.2%
Medium	5.8%	14.5%
High	12.2%	22.2%

Table 3: Estimated percent savings in single-family household water consumption by level of implementation effort (low and high) and household outdoor demand (low, medium, and high).

TABLE 4: SAVINGS ESTIMATE MATRIX — TOTAL MUNICIPAL USAGE (INCLUDES SINGLE-FAMILY, MULTI-FAMILY, ICI)

Outdoor Household Demand	Level of Effort/Education	
	Low	High
Low	2.0%	7.0%
Medium	3.5%	8.5%
High	7.0%	11.0%

Table 4: Estimated percent savings in total municipal water consumption by level of implementation effort (low and high) and household outdoor demand (low, medium, and high).



We determined these savings estimates by compiling two separate datasets of savings from no more than twice per week landscape watering restrictions (single-family residential savings and total municipal savings) and computing the 10th, 25th, 50th, 75th, and 90th percentiles of each dataset. These percentiles were chosen because they reflect the range of savings potential expected from outdoor watering restrictions. A primary assumption, based on our review of the data, is that high levels of enforcement and education in regions with lower household outdoor use will generate the same amount of savings as low levels of enforcement and education in regions with high household use. We also assumed that the range of potential savings for the low, medium, and high outdoor demand classifications would overlap. Using best professional judgment, we applied these percentiles to the three outdoor demand categories (low, medium, and high) in each matrix, starting with low level of implementation effort (10th, 25th, 50th percentiles) followed by high level of implementation effort (50th, 75th, and 90th percentiles).

The underlying logic supporting these savings percentages is that outdoor watering restrictions yield fewer savings in areas where there is less demand for outdoor water. The potential to save water increases in areas with greater outdoor watering demands because there is greater capacity to cut down on inefficient outdoor water usage. A second component of our logic is that when robust complementary programs are in place to enforce watering restrictions and educate residents about the value of conserving water and about proper landscape watering needs, these savings can be greatly improved.

In the next section, we apply these savings percentages to each region's annual single-family and total municipal usage to determine a volume of potential savings from no more than twice per week watering restrictions.

Our research indicates that passing an ordinance limiting outdoor watering should be combined with education and enforcement programs in order to increase the effectiveness of the restrictions.

PROJECTED STATEWIDE WATER SAVINGS FROM WATERING ORDINANCES

Anticipated water savings from no more than twice per week watering restrictions across the full range of municipal use categories are 460,000 acre-feet per year statewide by 2020, with high levels of education and enforcement efforts. This volume of water is equal to the combined annual municipal demands of Regions A, B, F, N, and O during this same time.

Savings Solely from Single-Family Residential Use

We developed savings projections by applying the savings percentages presented in the previous section to each region's current single-family residential demand (based on average annual demand from 2012 and 2015). We calculated an estimated savings range of 7.5 to 16.6 percent of average annual single-family residential demand across the entire state, as shown in **Table 5**. The percentage ranges vary from region to region based on levels of single-family residential demand within the region.

Some of these potential savings, however, are already being realized as municipalities such as Dallas, Fort Worth (including its wholesale customers), Frisco, The Woodlands, College Station, and Lubbock have adopted ordinances limiting residential watering to a maximum of two days per week year-round, while Austin has gone even further by implementing no more than once per week watering restrictions.

Savings from Total Municipal Use

To calculate percentage savings from total municipal use from no more than twice per week watering restrictions, we applied our municipal savings estimate matrix to current municipal demand. As for single-family residential savings, we obtained municipal demand data from TWDB's annual water use surveys and determined average municipal demand from 2012 to 2015. We characterized outdoor municipal demand as low, medium, or high using the single-family household

TABLE 5: ESTIMATED PERCENTAGE SAVINGS BASED ON CURRENT SINGLE-FAMILY RESIDENTIAL DEMAND

Region	Outdoor Household Demand (low, medium, or high)	Current Single-Family Residential Demand (acre-feet/year)	Percent Water Savings	
			LOW Education/ Enforcement	HIGH Education/ Enforcement
A	High	35,381	12.2%	22.2%
B	Low	11,735	3.5%	12.2%
C	High	536,554	12.2%	22.2%
D	Low	47,994	3.5%	12.2%
E	Medium	66,155	5.8%	14.5%
F	High	48,814	12.2%	22.2%
G	Medium	164,831	5.8%	14.5%
H	Low	392,373	3.5%	12.2%
I	Medium	68,603	5.8%	14.5%
J	Medium	8,603	5.8%	14.5%
K	Medium	83,497	5.8%	14.5%
L	Medium	175,898	5.8%	14.5%
M	Medium	129,887	5.8%	14.5%
N	Low	35,973	3.5%	12.2%
O	High	36,487	12.2%	22.2%
P	Low	2,722	3.5%	12.2%
TOTAL		1,845,509	AVG 7.5%	AVG 16.6%

Table 5: Estimate of water savings percentages for single-family residences within planning regions by level of implementation effort in the form of education and enforcement (low or high). Current single-family residential demand reflects average usage from 2012 to 2015 obtained from the TWDB's Water Use Survey (TWDB, 2012 to 2015). The percent water savings from no more than twice-per-week watering restrictions were identified in the prior section of this study.

TABLE 6: ESTIMATED PERCENTAGE SAVINGS BASED ON CURRENT TOTAL MUNICIPAL DEMAND

Region	Outdoor Municipal Demand (low, medium, or high)	Current Total Municipal Demand (acre-feet/year)	Percent Water Savings	
			LOW Education/ Enforcement	HIGH Education/ Enforcement
A	High	77,393	7.0%	11.0%
B	Low	22,639	2.0%	7.0%
C	High	1,221,274	7.0%	11.0%
D	Low	122,209	2.0%	7.0%
E	Medium	130,734	3.5%	8.5%
F	High	112,773	7.0%	11.0%
G	Medium	343,083	3.5%	8.5%
H	Low	980,056	2.0%	7.0%
I	Medium	187,938	3.5%	8.5%
J	Medium	23,678	3.5%	8.5%
K	Medium	234,892	3.5%	8.5%
L	Medium	408,966	3.5%	8.5%
M	Medium	246,359	3.5%	8.5%
N	Low	88,846	2.0%	7.0%
O	High	82,772	7.0%	11.0%
P	Low	6,716	2.0%	7.0%
TOTAL		4,290,328	AVG 4.3%	AVG 8.9%

Table 6: Estimate of water savings percentages for total municipal use by level of effort in the form of education and enforcement (low or high). Current municipal demand reflects average municipal demand from 2012 to 2015 obtained from the TWDB's Water Use Survey (TWDB, 2012 to 2015). The percent water savings from no more than twice-per-week watering restrictions were identified in the prior section of this study.

classification of each region. Our savings estimates presented here reflect the anticipated outdoor savings in not only the single-family residential sector, but also the multi-family sector and the industrial, commercial, and institutional (ICI) sector. All of these sectors use water for landscape watering.

Based on anticipated population growth and increasing municipal water demands over the coming decades, we expect the potential municipal savings from outdoor watering restrictions to follow a similar trend. To demonstrate this, we applied the same savings percentages to the projected municipal demand in 2020, 2040, and 2070. Our estimations show that potential savings in 2020 could be more than 460,000 acre-feet per year statewide, with high levels of implementation effort. By 2070, these annual municipal savings would increase to almost 760,000 acre-feet. **Table 7** shows projected municipal savings based on projected total municipal demands for the 2020, 2040, and 2070 planning decades.

As part of the regional water planning process, planning groups estimate projected "Municipal Needs" (as shown in **Table 8**), which represents the difference between municipal demand and available supply from existing water sources. Regional planning groups recommend water management strategies that can be used to meet those projected water needs, and these recommendations are presented in State Water Plan. As shown in **Table 8**, a comparison of the projected municipal needs in 2020 to the potential savings from outdoor watering restrictions indicates that watering ordinances could satisfy much of the projected municipal need in most regions in the near-term. A similar comparison based on 2070 projections indicates that watering ordinances could satisfy a significant percentage of needs even for the 2070 timeframe. It is likely that, particularly by 2070, new technologies for more efficient landscape watering and new varieties of drought-tolerant plants can reduce demands for outdoor watering even further.

To meet these projected municipal needs, regional water planning groups have recommended a broad range of water management strategies and capital infrastructure projects as part of the 2017 state water planning process. Results from our analysis show that outdoor watering ordinances can potentially generate enough savings to fulfill much of these projected municipal water needs. However, the savings from water conservation primarily benefit the water supply of the community that the savings are realized in or communities that use that same water supply (such as a shared reservoir) and the distribution of savings may not match the distribution of needs within the region. Water conservation savings are generally not transferable across regions. In Regions B and D, for instance, savings from restrictions only represent 28 percent and 42 percent of future municipal needs, respectively, based on 2020 projections. Meanwhile, projected water savings in Regions I, K, and N are large

TABLE 7: PROJECTED MUNICIPAL SAVINGS BASED ON 2017 STATE WATER PLAN MUNICIPAL DEMANDS									
Region	2020 Planning Decade			2040 Planning Decade			2070 Planning Decade		
	Municipal Demand (acre-feet/year)	Water Savings (acre-feet/year)		Municipal Demand (acre-feet/year)	Water Savings (acre-feet/year)		Municipal Demand (acre-feet/year)	Water Savings (acre-feet/year)	
		LOW	HIGH		LOW	HIGH		LOW	HIGH
A	91,637	6,415	10,080	98,792	7,440	11,691	133,572	9,350	14,693
B	32,563	651	2,279	32,784	656	2,296	33,827	677	2,368
C	1,481,530	103,707	162,968	1,675,385	132,631	208,419	2,594,833	181,638	285,432
D	134,310	2,686	9,402	142,631	3,051	10,678	208,132	4,163	14,569
E	141,818	4,964	12,055	156,499	5,971	14,501	215,923	7,557	18,353
F	141,454	9,902	15,560	151,070	11,229	17,646	193,585	13,551	21,294
G	403,094	14,108	34,263	450,798	17,615	42,779	693,829	24,284	58,975
H	1,257,276	25,146	88,009	1,377,892	29,838	104,432	1,893,397	37,868	132,538
I	188,646	6,603	16,035	196,302	7,145	17,353	239,607	8,386	20,367
J	25,567	895	2,173	26,874	978	2,376	31,315	1,096	2,662
K	306,560	10,730	26,058	359,194	14,412	35,000	558,949	19,563	47,511
L	469,065	16,417	39,871	526,806	20,385	49,506	754,306	26,401	64,116
M	311,591	10,906	26,485	368,997	14,966	36,347	612,127	21,424	52,031
N	112,081	2,242	7,846	117,701	2,421	8,475	128,510	2,570	8,996
O	94,753	6,633	10,423	101,434	7,575	11,903	132,718	9,290	14,599
P	7,997	160	560	7,984	159	556	8,088	162	566
TOTAL	**5,199,942**	222,163	464,066	**5,791,143**	276,471	573,957	**8,432,718**	367,981	759,069

Table 7: Projected annual municipal savings from outdoor watering restrictions in 2020, 2040, 2070. Estimated savings are calculated based on projected future municipal demands, as presented in the 2017 State Water Plan (TWDB, 2017).

enough on a regional basis to satisfy 2020 regional municipal needs several times over. Although the dynamics driving projected future municipal demands, supplies, and needs must be evaluated on an individual water supplier basis, this comparison of water savings and future municipal water needs underscores the importance of outdoor watering restrictions.

Savings from watering restrictions will only accrue to the degree that ordinances are adopted, followed, and enforced. Education and enforcement are key to realizing these water savings. Without effective mechanisms in place, it is difficult to ensure that restrictions are consistently enforced and residents understand the importance of reducing their outdoor water usage. Successful watering ordinances specify watering days by address or according to the garbage collection day, providing a clear mechanism for assessing compliance. Additionally, to strengthen adherence to the ordinance, fines can be imposed when residents do not follow their watering schedules.

Above all, cities must communicate a message that is clear, consistent, and compelling. We all know that old habits die hard and altering watering behavior requires campaigns to re-educate the public. Ordinances, by themselves, only set the foundation for outdoor water savings. The greatest outdoor water conservation savings are achieved when homeowners are educated not only about proper irrigation practices, but also on irrigation system maintenance and sound landscape management practices. The best way to transform outdoor water use habits is by developing robust educational campaigns and providing easy access to online information, resources, and tools. Public

TABLE 8: PROJECTED MUNICIPAL SAVINGS AS A PERCENTAGE OF 2017 STATE WATER PLAN MUNICIPAL NEEDS									
Region	2020 Planning Decade			2040 Planning Decade			2070 Planning Decade		
	Municipal Needs (acre-feet/year)	Water Savings as a Percent of Needs		Municipal Needs (acre-feet/year)	Water Savings as a Percent of Needs		Municipal Needs (acre-feet/year)	Water Savings as a Percent of Needs	
		LOW	HIGH		LOW	HIGH		LOW	HIGH
A	10,074	64%	100%	38,521	19%	30%	81,559	11%	18%
B	8,060	8%	28%	9,092	7%	25%	10,848	6%	22%
C	106,718	97%	> 100%	539,183	25%	39%	1,227,956	15%	23%
D	22,341	12%	42%	29,850	10%	36%	51,390	8%	28%
E	5,623	88%	> 100%	14,734	41%	98%	58,011	13%	32%
F	36,262	27%	43%	56,120	20%	31%	88,349	15%	24%
G	32,314	44%	106%	102,132	17%	42%	259,402	9%	23%
H	141,908	18%	62%	420,866	7%	25%	760,957	5%	17%
I	121	> 100%	> 100%	1,476	> 100%	> 100%	13,629	62%	> 100%
J	3,462	26%	63%	3,925	25%	61%	4,228	26%	63%
K	7,881	> 100%	> 100%	45,883	31%	76%	182,173	11%	26%
L	72,636	23%	55%	148,627	14%	33%	304,164	9%	21%
M	48,534	22%	55%	132,173	11%	27%	312,410	7%	17%
N	1,583	> 100%	> 100%	1,567	> 100%	> 100%	1,683	> 100%	> 100%
O	13,233	50%	79%	30,937	24%	38%	56,371	16%	26%
P	0	-	-	0	-	-	0	-	-
TOTAL	**510,750**	**43%**	**91%**	**1,575,086**	**18%**	**36%**	**3,413,130**	**11%**	**22%**

Table 8: A comparison of projected municipal needs in 2020, 2040, and 2070, as defined in the 2017 State Water Plan (TWDB, 2017) and the estimated savings from implementation of no more than twice per week watering restrictions by regional planning areas. Estimated savings are divided by projected municipal needs to demonstrate the extent to which potential savings from watering restrictions could satisfy these municipal needs. There are no projected municipal needs for Region P.

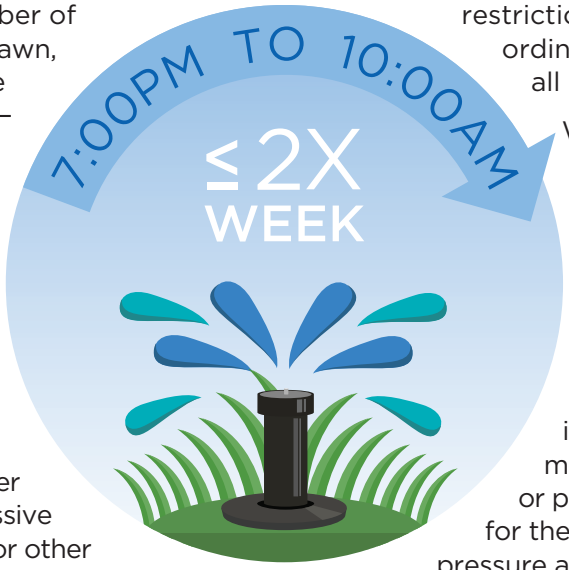
awareness and education are essential to reinforcing homeowners' understanding of water use behaviors and the importance of conserving water (Quesnel and Ajami 2017).

Reductions in outdoor usage from watering restrictions serve to not only extend available water supplies, but also drive down peak summer demands. The system capacity required for treating and conveying water is determined by summer "peak" water use, which is driven, in large part, by outdoor watering. When water resources are limited or a system is nearing peak capacity, conservation measures targeting outdoor water usage offer more than just water savings. Enhanced efficiencies can easily translate into cost savings by delaying expensive infrastructure projects and upgrades that would otherwise be needed to accommodate growing demand. Unlike many supply- and demand-side management strategies, watering ordinances cost utilities very little to implement. Hence, these ordinances represent one of the most cost-effective strategies for reducing outdoor water usage now and ensuring municipal demands are adequately met down the road.

The two sections that follow elaborate on key components of effective watering ordinances as well as other opportunities to promote outdoor water savings.

DESIGNING & IMPLEMENTING WATERING ORDINANCES

Strong watering rules or ordinances governing outdoor water use start by limiting outdoor irrigation to either no more than one or two days per week. Again, no more than twice per week watering restrictions represent the minimum standard Texas municipalities should adopt. In many parts of the state, climate conditions and landscape watering requirements call for minimal watering during much of the year, so no more than once per week watering restrictions are highly recommended.



In addition to limiting the number of days residents can water their lawn, effective ordinances restrict the time of day watering can occur — usually before 10:00 a.m. and after 7:00 p.m. The purpose of these restrictions is to prevent watering during the hottest and windiest part of the day, when much of the water is lost directly to evaporation. Watering ordinances may also restrict watering during precipitation or freeze events. These rules tend to prohibit water waste — such as leaks and excessive runoff or watering of sidewalks or other impervious surfaces — and may limit the length of time a sprinkler station can run per cycle and number of cycles per day. Some cities have decided to differentiate the spring/summer growing season from a fall/winter dormant season by specifying that no more than twice per week watering may occur during Daylight Savings Time (from March through October) and no more than once per week watering may occur the rest of the year. As discussed in the case study for the City of Austin, some cities limit landscape watering to no more than once per week during any season.

In order to enhance compliance with watering restrictions, it is important to develop requirements that are readily enforceable. Florida, for example, enforces watering ordinances irrespective of the source of water (i.e., private well versus municipal water supply), a practice different from what is occurring in some Texas cities where homeowners are tapping private wells to circumvent watering restrictions. An outdoor watering ordinance could include some or all of these concepts.

When designing a watering restriction ordinance, municipalities need to consider the possibility of increasing the "coincidence" of watering — when outdoor watering occurs on just a few days rather than being spread out across the week. This increase in peak demand — measured by either the peak day or peak hour — can create problems for the distribution system, lowering pressure and possibly draining storage tanks (if supply cannot keep pace with demand). Thus, when developing a watering schedule, cities should carefully consider how different groups of customers watering on certain days of the week will impact peak demand. This schedule needs to be easily communicated to, and understood by, customers, and easily enforced by water utility staff or law enforcement.

Below is a sample watering ordinance that includes time-of-year, day-of-week, and time-of-day provisions, as well as language to address water runoff, maximum irrigation application rates, and freezing conditions.

In addition to watering ordinances, municipalities should adopt requirements that irrigation systems must be inspected at the same time as initial backflow preventer inspection and periodically thereafter, and that prohibit the operation of poorly maintained sprinkler systems that waste water.

A MODEL OUTDOOR WATERING ORDINANCE

1. The use of an automatic irrigation system and hose-end sprinklers is restricted to the following outdoor water use schedule:

a. Residential property ending in an odd number may be irrigated on Wednesday and/or Saturday, but no other day of the week without an approved variance from the City;
b. Residential property ending in an even number may be irrigated on Thursday and/or Sunday, but no other day of the week without an approved variance from the City;
c. Non-residential property (commercial and multi-family) may be irrigated on Tuesday and/or Friday, but no other day of the week without an approved variance from the City;
d. There shall be no irrigation, except by means of a handheld hose, drip irrigation, or soaker hoses on Monday.

2. The outdoor water use schedule set forth above shall be effective year-round.

3. A person may not irrigate outdoors at a residential property or a non-residential property between the hours of 10:00 a.m. and 7:00 p.m., even if the irrigation occurs on a designated outdoor water use day for the location.

4. No more than 1 inch of water may be applied per irrigation zone on each day that irrigation occurs, and in no event shall irrigation occur for more than 1 hour per irrigation zone on each day that irrigation occurs.

5. No outdoor watering of landscapes is allowed during precipitation events or when temperatures are below 40°F.

6. It is unlawful for any person to waste water through use that serves no practical purpose. The following types of water waste are prohibited:

a. Failure to repair a controllable leak, including but not limited to a broken sprinkler head, a broken pipe, or a leaking valve;
b. Operation of an irrigation system with a broken head; a head that is out of adjustment and the arc of the spray head is over a street, parking area, or other impervious surface; or a head that is misting because of high water pressure;
c. Allowing water to flow during irrigation that runs, flows, or streams in a way that extends into a street, parking area, or other impervious surface for a distance of 50 feet or greater; or allows water to pond at a depth greater than 0.25 inch in a street, parking area, or on other impervious surfaces.

Not all public water systems in Texas have the authority to enact watering ordinances, however. Only municipalities and utility districts currently have clear regulatory authority to adopt watering ordinances, whereas investor-owned utilities and water supply corporations may be limited in their ability to enact mandatory, year-round watering restrictions. In some instances, though, wholesale customers may be required under contractual agreement to impose similar restrictions as their wholesale provider.

Of the total estimated savings calculated in the previous section, approximately 26 percent are attributable to municipalities with landscape watering restrictions and some level of enforcement and education already in place. However, improved implementation efforts may be required to achieve the projected savings. The

Of the total estimated savings calculated in the previous section, approximately 26 percent are attributable to municipalities with landscape watering restrictions and some level of enforcement and education already in place. However, improved implementation efforts may be required to achieve the projected savings.

remaining savings are projected to come from public water systems that do not currently have restrictions. Approximately 10 percent of the remaining water savings, however, are tied to utilities that do not currently have clear authority to impose and enforce watering ordinances.

FIGURE 4: SHARE OF ESTIMATED WATER SAVINGS BY UTILITY TYPE

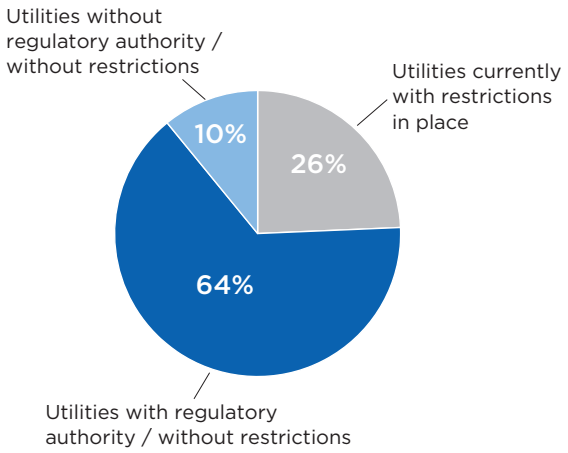
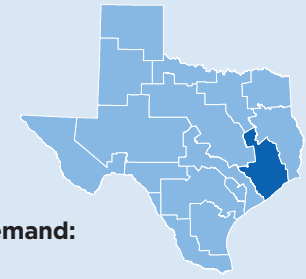


Figure 4: Share of estimated savings: utilities with restrictions already in place; utilities without restrictions in place, but with the authority to impose them; and utilities without restrictions in place, but without current clear authority to impose them.

Case Studies

The Woodlands

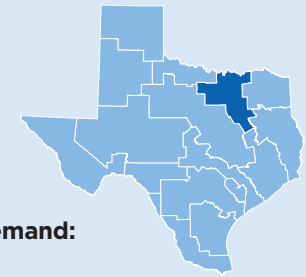


- **Population:** 100,073
- **Regional Water Planning Group:** Region H
- **Household Outdoor Demand:** 68 gallons per day
- **Water Customers:** 96% single-family residential, 1% multi-family residential, 3% commercial/industrial/institutional

The Woodlands designed a policy to help forestall a pending water crisis in the township, as well as other parts of Montgomery County. Instituted in 2013 and updated the year after, the Woodlands Joint Powers Agency's Policy Number ENF-60 restricts outdoor watering for private residences, businesses, churches, and all other public properties to twice a week. Addresses ending in an odd number are permitted to water from 8:00pm on Fridays to 6:00am on Saturdays, and from 8:00pm on Tuesdays to 6:00am on Wednesdays. Addresses ending with an even number are allowed to water from 8:00pm on Saturdays to 6:00am on Sundays, and from 8:00pm on Wednesdays to 6:00am on Thursdays.

The ordinance, which is enforced year-round, may allow for variances to be granted in extenuating circumstances. To enforce the ordinance, inspectors with cameras patrol neighborhoods and issue notices to those who are in violation of the schedule. Time and date-stamped photos are taken to confirm the violation. If the resident or occupant is on the property at the time of the observation, the notice will be given to them. If not, a notice will be hung on the front door, in addition to information about best practices for lawn care. An initial violation will result in the provision of a warning notice. A second violation will result in a $50 surcharge, while a third violation will result in a $100 surcharge. A fourth and any subsequent violations will result in a $200 surcharge. All surcharges will be added to a resident/occupant's water bill within 20 days of a violation notice, unless the resident/occupant appeals the surcharge within 15 days of the violation notice.

Frisco



- **Population:** 156,957
- **Regional Water Planning Group:** Region C
- **Household Outdoor Demand:** 66 gallons per day
- **Water Customers:** 76% single-family residential, 15% multi-family residential, 9% commercial/industrial/institutional

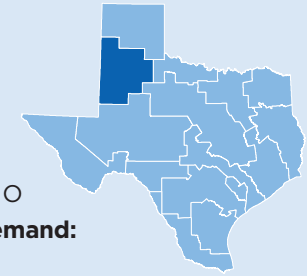
Effective as of May 2015, the City of **Frisco**'s Water Efficiency Plan with Best Management Practices has instituted year-round and seasonal restrictions to help better manage local water resources. Throughout the year, water runoff flowing away from property, watering of impervious surfaces such as streets, parking lots, alleys, and driveways; watering during precipitation or at temperatures below 40° F, and the use of leaking or damaged irrigation systems are prohibited.

Frisco's annual spring and summer watering schedule is in effect through the duration of Daylight Saving Time. Watering is permitting once a week on a resident's trash pickup day, before 10:00am and after 6:00pm. These watering times have been adopted to reduce water waste during the heat of the day to evaporation and high winds. Hand watering and watering with bubblers or drip irrigation systems for up to 2 hours on any day. Watering is allowed on a second day, with the same time of day restrictions, only if the City determines its weather station data indicate the need for additional watering. First-time violations receive a door-hanger with a $50 administrative fee included on the next available water bill. This violation can be waived with the completion of a free sprinkler system checkup. A $100.00 fee will be applied for the second violation, and a $200 fee for the third violation. Further violations will include the issuance of a citation, which could potentially mean a disconnection of the violator's sprinkler system.

During the Fall and Winter, Frisco permits once per week watering on the residential trash pickup day. Time-of-day watering restrictions are relaxed during Central Standard Time. During this period of time, watering is prohibited during precipitation or temperatures colder than 40° F in order to prevent freezing conditions on sidewalks and streets. Over-seeding and watering cool season grasses are also prohibited. The financial penalties for violations during fall and winter are the same as those during spring and summer.

Year-round, violations can be submitted using the City of Frisco's online water waste report form, and are also observed by Public Works employees, who conduct random patrols through neighborhoods. These instances are documented by electronic photographs and filed for review.

Lubbock



- **Population:** 248,640
- **Regional Water Planning Group:** Llano Estacado Region O
- **Household Outdoor Demand:** 84 gallons per day
- **Water Customers:** 67% single-family residential, 26% multi-family residential, 7% commercial/industrial/institutional

Effective in January 2017, the City of **Lubbock** made the year-round water restrictions in place for the last 10 years permanent. The restrictions utilize a twice-per-week watering schedule. Under these permanent watering restrictions, properties with an address ending in 0, 3, 4 or 9 may water on Monday and Thursday, properties with an address ending in 1, 5 or 6 may water on Tuesday and Friday, and properties with an address ending in 2, 7 or 8 may water on Wednesday and Saturday. No landscape irrigation is allowed on Sundays, during precipitation events, and when the temperature is below 35°F. Hand watering for landscape irrigation purposes is allowed on a daily basis regardless of the time of year and regardless of the time during the day. There are also seasonal permanent restrictions to be observed in the summer and winter. Summer restrictions from April until October don't allow irrigation from 10 a.m. until 6 p.m. and allow only up to 1.5 inches per week. The winter restrictions state that watering must be kept to under 1 inch per week. Like College Station and New Braunfels, Lubbock also uses multi-stage restriction process in the event demand exceeds certain amounts of the city's capacity. Stage 1 drought restrictions are similar to the permanent water conservation measures, except watering is only permitted from 9:00pm to 9:00am. Stage 2 drought restrictions continue the previous stage, but limit watering to once a week between 9:00pm and 9:00am. Stage 3 drought restrictions go further by limiting watering to once per month and prohibit filling up pools. Stage 4 emergency restrictions prohibit all landscape irrigation and flushing fire hydrants, while calling for reduced water system pressure.

Watering Ordinance Adoption

There are currently no state statutes that expressly require Texas cities to implement outdoor watering restrictions. However, the Texas Water Code does require that water suppliers seeking to authorize a transfer of surface from one river basin to another must implement the highest practicable levels of water conservation and efficiency achievable, which, under any reasonable definition, would include outdoor watering restrictions. Absent such an interbasin transfer, Texas communities that have already implemented no more than twice per week watering restrictions, or more stringent requirements, have done so on their own initiative because they saw the value of these restrictions as more than just a temporary response to drought. There can be no question that outdoor water use represents a huge opportunity for water savings, and as the findings of this report indicate, a significant share of these savings could come from outdoor watering restrictions, alone.

Successful adoption of watering ordinances requires widespread support, and the first step in this process is to demonstrate the value of restrictions and the opportunities for water savings. Garnering the support of key city decision-makers and the general public for the adoption of no more than twice per week watering restrictions begins with education and awareness.

To lay the foundation for these efforts, communities can take a closer look at outdoor water use in their service territory and determine how much water each municipal use category consumes for outdoor purposes. Conducting customer surveys to assess the prevalence of automated irrigation systems, landscaping preferences, and irrigation scheduling can also provide valuable insight into opportunities for reducing outdoor water use. Information gathered from the end use analysis and customer surveys can be reported back to city board members and the general public as a call to action for curbing outdoor water use. This insight can also be incorporated into educational campaigns to help broaden public awareness around efficient outdoor watering practices.

The next step is to create opportunities for engaging the public and conveying the importance of watering restrictions to city-wide conservation objectives. Cities can build on these efforts by developing a strategic approach to the design and implementation of watering ordinances. Depending on local context and needs, cities will have to carefully determine whether no more than twice per week or no more than once per week watering restrictions are best for their community. Even after watering ordinances have been adopted and implemented, cities can leverage the success of these efforts to refine their approach to outdoor water use — for instance, a city may decide later on that its twice per week watering ordinance should be replaced with once per week restrictions. Measuring the overall effectiveness of watering restrictions — in terms of both water savings and public compliance — is, therefore, a crucial component of the implementation process. In addition, offering education resources on the ability of well-adapted landscapes to flourish with limited supplemental watering is equally important.

Watering Ordinance Implementation

Admittedly, there are several challenges to establishing effective ordinances. Ensuring adequate education/outreach, establishing appropriate watering schedules, and creating effective enforcement mechanisms represent the most significant challenges to implementation.

Ensuring Adequate Education and Outreach

An important aspect of implementation involves educating residents on the need for, and value of, outdoor water use restrictions and proper irrigation practices. Without community-wide support, it will be difficult to ensure ongoing compliance with the ordinance. Watering restrictions alone do not guarantee residents apply the correct amount of water at the correct time, so educating them on proper landscape watering requirements is critical to the successful implementation of these ordinances. Through education, outreach, and Community-Based Social Marketing (CBSM) programs, cities can encourage residents to adopt water-saving irrigation and landscaping practices with the goal of driving behavioral change. Effective programs focus on removing the barriers that prevent the adoption of certain behaviors and enhancing the benefits of those behaviors (Ontario Water Works Association, 2008). By approaching these challenges from customer's point-of-view, these educational efforts can better address their needs and help them better understand the benefits of changing their outdoor water use patterns.

Municipalities can utilize a variety of outlets to disseminate their message and broaden the impact of their outreach efforts. This can include partnering with local plant nurseries and garden centers to share information about water-efficient irrigation practices and proper landscape watering requirements. Homeowners typically do not view their municipalities as experts in landscaping and irrigation, but they do consider plant nurseries and garden centers trusted advisors' they can look to for this information (Ontario Water Works Association, 2008). Cities can also send routine watering recommendations and tips to their customers. The City of Frisco, for instance, offers weekly watering advice based on data from the city's weather station, which is emailed to residents every Monday as part of the city's WaterWise Newsletter campaign. Many of these education, outreach, and CBSM programs target customers community-wide, but in some instances, these programs can be more effective if they specifically target residents with high outdoor irrigation demands.

A recent study on the relationship between single-family household behavioral change and public awareness revealed that widespread news media coverage of water- and drought-related issues played a key factor in reducing household water use.

A recent study on the relationship between single-family household behavioral change and public awareness revealed that widespread news media coverage of water- and drought-related issues played a key factor in reducing household water use (Quesnel and Ajami, 2017). During times of drought, the publicity generated by heighted news media coverage helped encourage residents to change their short-term watering behaviors. Over the long-term, public education programs and

outreach campaigns are essential to sustaining permanent behavioral changes. Consistent messaging is equally important for ensuring compliance with outdoor watering restrictions.

To help ensure ample and effective education and outreach efforts, cities can incorporate the following solutions in tandem with adopting outdoor watering restrictions.

EDUCATION & OUTREACH	
Issue	**Solutions**
Ensuring adequate education and outreach	• Implement Community-Based Social Marketing Programs • Quantify savings from outdoor watering restrictions and report information back to the public • Provide ongoing, consistent messaging campaigns • Promote educational opportunities, both internally and externally (e.g., at local nurseries and garden centers) • Team with educational institutions to offer information-based tools to residents • Engage local media to broaden reach of the message

Establishing an Appropriate Watering Schedule

Another consideration in implementing a watering ordinance involves selecting a watering schedule. The concept of once or twice per week watering restrictions is supported by a widely-held standard that watering deeply only once or twice a week is more effective in maintaining lawn health compared to frequent shallow watering because deep watering promotes deep root growth (Ontario Water Works Association, 2008). Approaches to developing watering schedules can vary, but the most common is to designate watering days based on odd- and even-numbered addresses. These types of watering restrictions assign watering days to residential and commercial properties based on whether their address is even or odd. Other types of watering schedules designate watering days according to garbage pickup day or to different municipality areas/ subdivisions. A disadvantage of these approaches, however, is that they can inadvertently encourage people to over-water on their designated day, even if conditions do not call for supplemental watering (Dukes et al, 2017). Educating residents on proper landscape watering needs is key to overcoming this drawback and capturing greater water savings.

Another aspect of watering schedules cities must consider is the differentiation between watering by hand, by hose-sprinkler, and by automatic irrigation system. When developing a schedule, it is important to clarify which methods of watering the restriction applies to, whether it is solely automatic irrigation or if it also includes hand-held hoses and hose-end sprinklers. For instance, the City of Austin limits outdoor watering by an automatic irrigation system to one day per week, whereas the use of a hose-end sprinkler is allowed up to two days per week and the use of a hand-held hose is allowed any day of the week. Over-watering can occur under any of these circumstances, but the leading assumption is that households with automatic irrigation systems use far more water outdoors than those without irrigation systems, so stricter limitations should be placed on this method of outdoor watering.

Establishing an effective watering schedule requires careful consideration of outdoor water usage patterns across all municipal water users. Because outdoor water usage patterns and preferences vary by community, insight into customer behaviors can help cities determine the best strategy for assigning watering days and how to go about limiting each method of watering. It is also important to evaluate what impact, if any, the proposed watering schedule would have on system capacity, including both peak hourly demand and peak daily demand.

The table below outlines specific solutions for addressing these implementation challenges.

WATERING SCHEDULE	
Issue	**Solutions**
Establishing an appropriate watering schedule	• Assess outdoor water usage patterns across each municipal user category • Evaluate the effectiveness of different types of watering schedules (e.g., odd/even addresses) based on system thresholds to determine any impact on water system operations and peak demand • Engage with the general public and key stakeholders to solicit feedback on the proposed watering schedule • After implementation, monitor water usage to ensure peak demand issues do not arise

Ensuring Effective Enforceability and Enforcement

Without an effective enforcement mechanism in place, it can be difficult to ensure residents are properly adhering to watering restrictions. Studies have shown that lack of enforceability often hinders the effectiveness of water conservation measures (Whitcomb, 2006). Enforceability can be enhanced by designating specific days residents can water their lawn, either according to their address or to garbage pickup day. With this strategy, it is easier to identify properties that are not complying with the restriction.

Communities often lack sufficient budget and staff resources to thoroughly enforce watering restrictions. In most instances, cities rely upon their constituents to report watering violations. The City of Fort Worth, for example, allows its residents to report water waste both online via its website and on their smartphone via the MyFtWorth app. This reporting mechanism helps cities create stronger customer connections by giving them an opportunity to both engage with residents and to educate them on what the city's watering ordinance does and does not allow.

Upon receiving a report of water waste, cities typically issue a warning for first-time violations — however, in cities like Austin and Frisco, they can incur a fee of $25 to $50. Fines increase for each subsequent offense, and after the third violation, cities often reserve the right to issue a citation. Another enforcement strategy established by the City of Fort Worth is to lock out in-ground irrigation systems. With this approach, the city physically impedes outdoor watering by placing a locking device on either the backflow device of a single-family residential irrigation system or the irrigation meter on a commercial or multi-family property.

To help beef up enforcement efforts, cities can also send more staff out into the field to patrol for potential watering violations. It is more common for cities to employ this strategy during times of drought, when there is a greater urgency to scale back outdoor watering. In the past, the City of Dallas has enlisted its code enforcement officers to do this. This strategy primarily serves as an extension of community outreach efforts because the primary intent is to warn residents who may not have been aware that their outdoor watering practices violated city code. Whether it is a resident not knowing that watering restrictions exist or a resident not knowing what the proper watering requirements are for their landscape, lack of information is a key contributor to excessive outdoor water use. Regardless of drought conditions, education and increased awareness represent essential strategies for enhancing limited enforcement capabilities at all times.

COMPLIANCE & ENFORCEMENT	
Issue	**Solutions**
Ensuring effective enforceability and enforcement	• Establish an appropriate fee schedule for watering ordinance violations • Provide residents with an easily accessible method for reporting water violations (online form, hotline, web app) • Amplify education and public outreach efforts to help ensure residents are aware of outdoor watering restrictions

STRATEGIES FOR LOCKING IN & INCREASING WATER SAVINGS ALONGSIDE OUTDOOR WATERING RESTRICTIONS

As a standalone strategy outdoor watering restrictions can yield substantial water savings. However, to lock these savings in and leverage them even more, cities can expand the reach of their efforts by targeting a comprehensive set of landscaping and irrigation practices. The type of landscaping homeowners choose to plant, soil depth, and the design and operation of irrigation systems all impact water savings potential.

Promoting water-efficient landscaping and irrigation practices — through water-saving technologies, drought-resistant landscaping, irrigation system auditing, and ample education and outreach — is key to securing even deeper reductions in outdoor water use. Utilities should complement watering restrictions with programs to encourage homeowners to take an active approach to reducing their outdoor water use.

Strategies discussed below are:

- Native Landscaping
- Understanding Landscape Watering Needs
- Water Smart Landscaping
- Limited Irrigation Landscapes
- Smart Irrigation Controllers
- Drip Irrigation

Native Landscaping

The typical Texas landscape often requires a disproportionately large amount of water to maintain its lush green color because it contains non-native plants that are not well adapted to Texas' diverse climate.

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Ideally, residential landscapes would contain plants well adapted to the local region, for example, plants should be selected based on their tolerance to local temperature ranges and natural water availability. For many reasons — aesthetic, cultural, lack of selection or availability, personal preference — our planted landscapes are often ill-suited to Texas' regional climates. The advent of in-ground irrigation systems has made it much easier to use water in this unsustainable pattern, resulting in increased landscape water use. During times of average or below- average rainfall, drought, or just the heat of the Texas summer, we often supplement rainfall by irrigation systems to keep our yards uniformly green. Non-native plants, especially poorly adapted turf grasses, tend to require more water to keep them looking aesthetically pleasing during the growing season than native plants. A growing body of evidence suggests that even these poorly adapted landscapes could get by with *a lot less water* than is typically applied, especially if plants are well-established in adequate soil.

If there is at least six inches of soil, once a week watering is sufficient to maintain a lawn's appearance in Texas (Finch, 2014). Twice per week watering will replenish moisture if soil is shallower than six inches. During severe droughts, watering a lawn with St. Augustine grass on six inches of soil once every two weeks will provide enough water for it to survive (Finch, 2014). More drought-tolerant turf varieties such as Bermuda, buffalo, and zoysia can go even longer without water because they can enter a dormant-like state. Native flowering plants, shrubs, and trees are adapted to long stretches without water.

The City of Georgetown

In 2014, the City of Georgetown updated its city code pertaining to residential landscaping. As part of this update, new residential developments are required to have a soil depth of at least six inches. Additionally, developers must choose new plant materials (excluding lawn/turf grasses) from a list of preferred plants provided by the city.

Understanding Landscape Watering Needs

Even in Texas, with our hot and dry summers, landscapes only need about an inch of water per week, whether from rain or from irrigation. It is important to keep in mind, however, that the amount of water a specific landscape needs depends on a variety of factors: plant selection, soil depth, day-to-day weather variability, and the effectiveness of different types of irrigation technologies. Because so many factors go into determining watering requirements, overwatering frequently occurs. In Florida, a study revealed that homeowners over-watered by as much as 2-3 times the amount needed by plants when compared to climate-based estimates of recommended water replenishment (Hayley et al., 2007). This study also reported that although homeowners used significantly less water in the winter months, when plant water requirements are at a minimum, they are still prone to over-irrigate. Multiple studies show that at least some segment of the population overwaters and some of those over-irrigators overwater by a very large margin (e.g., De Oreo, 2011).

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A study conducted by Texas A&M University in College Station found that replacing 70 percent of the water lost to evapotranspiration, through a combination of rainfall and supplemental watering, was sufficient to maintain landscape quality during the summer months (White et al., 2004). Similar conclusions have been reached in other studies (e.g. Aquacraft, 2006). It is possible to estimate irrigation needs based on knowledge of how much water different plants lose to the atmosphere

(i.e., transpiration) and how much water is lost from the soil surface via evaporation under different climatic conditions.

Texas A&M's Water-My-Yard Program

Most homeowners do not have the time or expertise to incorporate evapotranspiration data into their daily watering schedules, so to help them, Texas A&M created the Water-My-Yard Program. Through this free program, homeowners can access an online tool that helps them determine the exact amount of water needed to properly water their lawn. Once a homeowner enters their address in the portal, it only takes a few short steps to begin receiving automated emails or text-messages with information about how much water their landscape requires based on local weather conditions. The online portal takes otherwise inaccessible data and presents it to homeowners in an easy to understand manner that can instantly translate into water savings.

The City of Frisco, Texas, uses a weather station and rain gauges to provide residents with weekly watering recommendations based on climate conditions. In 2010, the city advised residents that lawns did not need any supplemental irrigation 25 weeks out of the year (TRWD, 2014). For the remainder of the year, the city only recommended watering more than once per week during three weeks. Even during the record drought of year 2011, the city recommended watering twice per week during 11 weeks and once per week watering during eight weeks. Mother Nature provided sufficient rainfall for landscaping, without any supplemental watering, the remaining 33 weeks.

Landscape plant growth in Texas is minimal between November and April (White et al., 2004) and plants need very little, if any, supplemental water due to the combination of cool temperatures, periodic rainfall (most years), and plants being dormant or otherwise growing very slowly. During a drought, turf might benefit from a little supplemental watering, but a monthly application of one-half inch would be sufficient ("Winter lawn watering," 2009).

Water Smart Landscaping

The greatest savings in outdoor water conservation will likely come from landscape conversions to "water smart landscaping" (i.e., landscaping and gardening that substantially reduce or eliminate the need for supplemental water). Such landscaping emphasizes native plants that are well adapted to the prevailing climate.

With its arid and hot climate and ever-declining water supply, Nevada has been very aggressive in banning turf in new developments and subsidizing the conversion of existing high water-demanding plantings to desert-adapted landscapes. A study conducted by Aquacraft (2000) documented a reduction of nearly 40 percent in outdoor water use associated with landscape conversions to types that were suited to the Nevada climate. Follow-up research by the Southern Nevada Water Authority has shown that for every 10 customers that convert turf to a Water Smart Landscape, one will have no water savings, one will have increased water usage, and eight will save water. Overall, they have documented annual savings of 55 gallons per square foot converted (Bickmore and Francis, 2014). In Southern California, a turf conversion program of the Metropolitan District yielded an 18 percent reduction in water use by participating single-family homes (Ramos, 2014).

Limiting-Irrigated Landscapes

Georgetown, Texas, adopted a comprehensive array of irrigation measures in 2014 to reduce outdoor usage. According to updated city code, new construction must meet the following requirements:

- **Irrigated turf area of the lawn is limited to 2.5 times the foundation footprint area of the house or 10,000 square feet, whichever is less. The limit does not apply to non-irrigated space such as natural areas or landscaped areas such as flower beds that are irrigated with drip irrigation or bubblers. The limitation does not affect the overall size of a residential yard.**
- **When a lot is developed, the irrigated turf area is required to have at least six inches of soil. Areas of a residential lot left in its natural state are exempt from the soil depth requirement.**

- **Turf grass should be a variety that is dormant in the hot summer months and has less need for water. Turf grasses, such as St. Augustine, that require more water can only be used in shady areas of a lawn.**

Other elements of the ordinance include requirements for rain sensors and soil moisture sensors on irrigation systems and the placement of irrigation spray heads at least four inches from paved surfaces to reduce overspray. This type of proactive approach is helpful in making new development more water efficient. Many cities in Texas are growing and adding new housing at a rapid rate. Putting an ordinance in place that provides for efficient landscape watering from the beginning is an important step in the right direction.

Landscape regulations for efficient irrigation that apply to new development can be found in other parts of the country. For example, Tampa Bay, Florida, limits turf with a permanent irrigation system to 50 percent of landscaped area (Hazen and Sawyer, 2005). Desert cities in Nevada, New Mexico, Arizona, and California have adopted similar measures restricting the extent of irrigated landscaping and/or plant materials. In Texas, the City of Boerne has taken the step of limiting turf grasses planted at all new residential and commercial development within the city limits to zoysia, buffalo, or Bermuda grasses or other grasses approved by the city.

Smart Irrigation Controllers

Our understanding of how to optimally irrigate landscapes continues to advance. New technologies such as "smart" irrigation controllers and wireless soil-moisture sensors offer potential efficiency improvements. Determining the least amount of water that can be applied to maintain acceptable landscape appearance and health is the goal of a lot of current evapotranspiration (ET) research by agronomists, horticulturists, and landscape experts. A number of studies have emerged that demonstrate the water savings from smart irrigation controllers as this technology becomes more popular. These studies highlight the overall conservation savings that can be achieved as well as the reductions in peak outdoor demands stemming from the application of smart controllers.

A 2009 study in Utah found that the majority of overwatering occurred at the end of the growing season (August through October) when automatic timers on sprinkler systems had not been adjusted to lower ET requirements (Utah DNR, 2010). Even during the dormant season (November through March) watering remains a common practice and generally equates to over-watering. ET-based irrigation systems can be advantageous in matching the quantity of water applied to a landscape to a scientifically-derived value.

- **A 2016-2017 pilot program in Ohio showed that smart irrigation controllers can yield an average of 12 percent in savings.** Participants of the pilot were divided into three cohorts (lower water users, medium water users, and higher water users) based on their average household use. The greatest savings potential was observed in the higher water user group, which saw as much as 21 percent in savings. This is because high water users typically overwater their lawns, but the smart irrigation controllers help to ensure their landscaping receives more appropriate amounts of water. The results of this study demonstrate the importance of targeting high water users for participation in smart irrigation controller pilot or rebate programs. (AIQUEOUS, 2017)
- **Smart irrigation controller technology has also been shown to be an effective strategy for reducing demands during peak irrigation season.** As part of another pilot project, a New Jersey water supplier used centralized remote control to shutoff the controllers of 15 participating households on days where outdoor demands were forecasted to peak. Results from this study revealed that smart irrigation controllers could reduce peak irrigation demands by as much as 10 million gallons per day with 5,000 to 17,300 participating households. Peak demand savings can, in turn, translate to significant reductions in capital expenditures that would otherwise be necessary for expanding system capacity. As this study noted, the greatest barrier to realizing the depth of these savings is recruiting customers to participate in a large-scale deployment of smart irrigation controllers. Targeted education and recruitment campaigns can, however, enhance participation levels.

Drip Irrigation

Drip irrigation exceeds 90 percent efficiency compared to conventional sprinkler systems that typically range from 50 to 70 percent efficiency (Wilson and Bauer, 2014). Drip irrigation achieves higher efficiency because water is delivered under low pressure directly to plants and much more slowly than with sprinkler irrigation. Water dripped to plants is not subject to loss from runoff, wind, and evaporation. It is ideal for sloping terrain where water is more likely to runoff before it can penetrate the soil if applied via a spray system. Drip irrigation has the additional benefit of helping to maintain a desirable balance of air and water in the soil through its low-volume application of water, which facilitates even soil moisture and healthy plant growth (Wilson and Bauer, 2014). But drip systems do not work well for lawn irrigation because of the difficulty of spreading the water evenly. As with any irrigation system, proper installation and maintenance are key to achieving high quality results, and it is possible to waste water through over-irrigation with any system.

CONCLUSION

Overwatering of landscapes is a ubiquitous issue across the entire state, and the best way to curb excessive outdoor water use is through more efficient landscape and irrigation practices. The bottom line: very significant savings could be achieved if Texas cities adopt ordinances restricting outdoor watering to no more than twice per week. Business as usual is not good enough to meet Texas' long-term municipal water needs.

As our analysis of all 16 water planning regions demonstrates, as much as 460,000 acre-feet of water per year could be saved statewide through well-implemented no more than twice per week watering restrictions by 2020. The savings continue to increase as our population and water demand grows, reaching a level of almost 760,000 acre-feet by 2070. We are confident that through robust education and enforcement efforts, these savings can be realized, if not exceeded. Outdoor watering restrictions have always been the first line of defense for communities facing the short-term impacts of drought on their local water supplies; it should be the new norm for Texas communities whether or not we are in drought.

Although none of us can be certain when the next drought will hit, we can all be certain that it will and that water conservation will play an integral role in securing our state's future municipal water needs. As the state fluctuates along a climate spectrum of prolonged, severe droughts to intensive, devastating rainfall events, landscape watering restrictions must become a permanent line of defense. Long-term measures to reduce discretionary, outdoor water usage include permanent, year-round watering restrictions; robust public education efforts; use of native and drought tolerant landscapes; limitations on size of irrigated areas; minimum top soil requirements in new development; and more. All of these measures are already being implemented by cities in Texas. The entire state can and should follow their lead.

Proactive, on-going conservation measures represent the most cost-effective strategy for helping to ensure we have adequate supplies of water to meet our growing demands in the decades ahead. Regardless of whether the state is experiencing drought or not, conservation will play an integral role in securing Texas' water future. Because savings from watering ordinances can be sustained in periods of non-drought too, it just makes sense to make these measures permanent.

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