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Cover photo: Anzalduas Dam in Hidalgo County. Photo courtesy of the Texas Water Development Board.

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Residential outdoor water use in one East Texas community

Timothy R. Pannkuk* and Lawrence A. Wolfskill

Abstract: Municipalities continue to implement efforts to encourage water conservation among residents. Landscape irrigation has been central to many of those conservation efforts. Reference evapotranspiration data is a tool that can be used in determining the appropriate amount of water to apply to amenity landscapes. Monthly water-use data for 3 years was examined in 1 neighborhood in Huntsville, Texas. The irrigated area for 1,229 residents was calculated and used to determine the depth of monthly irrigation for each residence. Replacement of 100% of local reference evapotranspiration data, minus rainfall, was used as a determinant of how much water to apply to the landscape each month for 3 years. Potential over-irrigation for each month was then compiled. Data expressed that over-irrigation was occurring among 99.51% of residents, of which 12% of these residents over-irrigated by at least 100,000 gallons in at least 1 month during the 36 month study. In 2011, the entire neighborhood of study over-irrigated by 21.2 million gallons. Outdoor water use accounted for 64% of the total water use by households. Average indoor water usage was 4,302 gallons per month. Based on the data overall, greater conservation efforts in landscape irrigation are crucial for Texas residents if water demands are to be met in the 21st century.
Keywords: evapotranspiration, outdoor water use, indoor water use, residential irrigation

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INTRODUCTION

Potential estimated deficits between water use and water availability continues to be a topic of concern in Texas. On May 28, 2013, the Texas Governor signed House Bill 4, which presented Texas voters with the option of transferring $2 billion from the state's Economic Stabilization Fund, or Rainy Day Fund, to the existing $6 billion in the Texas Water Development Board's bond authority. These funds are dedicated to implementing capital projects in the state's 50-year water plan. On November 5, 2013, 73% of Texas voters approved Proposition 6, which enabled 2 funds that will help finance projects in the state water plan (TWDB 2013).

Municipal-urban water use in Texas has grown to be the second largest water use activity in Texas behind irrigated agriculture (TWDB 2012). Water use in irrigated agriculture has stabilized in recent years due to fewer irrigated acres and greater irrigation efficiency on farms. However, municipal-urban water use continues to increase primarily due to increases in population. The Texas Water Development Board (2012) forecasts that the Texas population will increase by 82% from 2010 to 2060, and water demand will increase by 22%. However, water supplies (surface water, groundwater, and re-use water) are predicted to decrease by about 10% over the same period of time. Information from the state water plan suggests that if Texas does not implement new water projects or plans of management, then farms, businesses, and homes are projected to need 8.3 million acre-feet of additional water supply by 2060 (TWDB 2012). In 2060, irrigation represents an estimated 45% of this total need, and municipal users account for 41% of needs (TWDB 2012). If these water needs are not met, it will result in economic losses and millions of lost jobs by 2060. Water conservation is one of a variety of methods that can be used to curb the projected increase in water demand in Texas. Other methods include demand-side management (e.g. time-of-day or day-of-week restrictions on outdoor water use and banning certain activities such as car-washing) and (sub)urban planning to design low water use into future municipality expansions.

In the municipal-urban water-use sector, where the number of users is continually increasing, conservation has become an integral part of the plan to supply enough water. Beyond human consumption, water has a variety of uses by the municipal user, including: recreation, cleaning, and irrigating the outdoor environment. Residential lawn irrigation has been suggested as a large user of municipal water supply; however that conjecture has not been well tested in the literature (Runfola et al. 2013). Regardless, outdoor irrigation is a highly visible practice and has been the target of many conservation efforts (Austin Water Utility 2014; Dallas Water Utilities 2014a; SAWS 2014). The U.S. Geological Survey (Kenny et al. 2009) found that about 349 billion gallons of freshwater are withdrawn each day in the nation by humans. Irrigation withdrawals accounted for 37% of all freshwater withdrawals and 62% of all freshwater withdrawals excluding withdrawals used for thermoelectric power production (Kenny et al. 2009).

In 2005 — the latest data available from the U.S. Geological Survey — residential water use totaled 29.4 billion gallons per day (Kenny et al. 2009). In 1999, mean residential outdoor water use accounted for 31.4% of total use in single-family homes (DOE 2011). Some estimates of outdoor water use are nearly 50% to 80% of the total residential use (Kjelgren 2000; Vickers 2001). The U.S. Environmental Protection Agency (2009) estimates that over half of this water is used for irrigating plants, including lawns.

To remain healthy and aesthetically pleasing, most plants in the home landscape typically have to be irrigated periodically to supplement insufficient rainfall. An irrigated landscape has a variety of benefits (Frank 2003). Landscape plants increase property value, benefit individuals psychologically, and reduce noise and pollution.

Water conservation methods, tools, and practices include: improved irrigation efficiency, time-of-day watering, odd-even address watering days, rain-off sensors on automatic systems, increased water rates, drought-tolerant plants, and irrigation based on soil moisture or climatological conditions. Many water purveyors and municipalities provide recommendations for conserving water in the landscape (e.g., City of Houston 2014; City of Lubbock 2014; Dallas Water Utilities 2014b; LCRA 2014; SAWS 2014). One effective method is to adjust landscape irrigation based on climatological conditions. This technique most often uses rainfall information to cancel watering whenever significant rainfall is detected. Including reference evapotranspiration from local weather station data can substantially increase the efficiency of irrigation measures (McCready et al. 2009). Reference evapotranspiration is calculated from local daily temperature, humidity, wind speed, and radiant energy (Allen et al. 1998). The reference evapotranspiration calculation can be used over multi-day periods to determine how much irrigation water to apply to a crop or a landscape (Pannkuk et al. 2010). Landscape irrigation based on the principles of reference evapotranspiration is an emerging area of water conservation.

Outdoor water use for irrigation varies geographically and seasonally (Kjelgren et al. 2000; Pannkuk et al. 2010; Cabrera et al. 2013). A recent study analyzed water consumption patterns in standard new homes and in high-efficiency new homes built after 2001 (DeOreo et al. 2011). In that study, only new standard homes had outdoor water use measured, and annual outdoor water use averaged 84,000 gallons. In another recent study, Hermitte and Mace (2012) analyzed metered water-use data from single-family residential connections from 2004 through 2011 from 259 municipalities across

Texas. In that study, outdoor water as a percentage of total water use varied from a low of 13% in Galena Park to a high of 64% in Gail. The weighted average across the entire state was 31% of the total water use. Average outdoor water usage in gallons was also calculated per household for urban areas. Houston had the low at 37 gallons per household per day, and the high was Tyler at 195 gallons per household per day. The Hermitte and Mace (2012) study concludes by recommending that a multi-year study of geographically diverse Texas cities involving individual surveys, billing data, and climatic data be conducted. This type of household-level exploration of single-family residential water consumption would provide more conclusive evidence of how we use our water.

The purpose of this study is to examine residential outdoor water use in one neighborhood in Huntsville, Texas. To accomplish this goal, we used the following: monthly residential water use by household for 3 years, the measured area receiving irrigation for each residential user, monthly local rainfall, and reference evapotranspiration data. These tools provided us with the ability to accurately measure landscape water use each month as well as calculate potential over-irrigation based on actual landscape water needs.

MATERIALS AND METHODS

The city of Huntsville, Texas provided monthly billed water usage data for 2009, 2010, and 2011. The data comprised 1,229 residential units (substantially all) in one neighborhood of the city. Before we received the data, the names and addresses were removed, and a unique identifier was applied to each residence. The city of Huntsville also allowed the researchers to use their ArcGIS© mapping platform and GIS data to measure the lot size, built area, and the irrigated area within each homeowner's lot.

To determine outdoor water usage, researchers measure or estimate indoor usage, and subtract that from total billed water usage. Thus, an accurate measure of indoor usage is critical to proper analysis. Romero and Dukes (2011) identified several methods that could be used to make the estimate. The most common method in the literature is to assume that winter usage includes a negligible amount of landscape watering, therefore the average monthly usage during the winter months must be subtracted from each month's metered consumption. While not exact, this method allows for reasonable estimates without requiring individual homes to be metered separately at each outdoor hose bib and is considered to be adequate for areas where a defined winter season exists.

Another method used in the literature involves estimating per capita consumption patterns and applying the rate to each household (DeOreo et al. 2011). Various rates have been proffered, including 0.57 cubic meters per person per day (Hanemann 1997) and 0.38 cubic meters, from the U.S. Environmental Protection Agency (2009). These 2 figures include both indoor and outdoor usage, and the U.S. Environmental Protection Agency estimates that approximately 30% of the total would be dedicated to outdoor use, while Haley et al. (2007) found in their study that 36% of the total water consumption was outdoors.

For this study, the indoor water usage was calculated for each residence from an average usage from November through February (Romero and Dukes 2011), a time when residents do not normally use outdoor irrigation. During this period, the city measures water usage to calculate sewer rates, so residents are encouraged through bill notices and advertising to limit outdoor water usage to minimize their sewer bill for the upcoming year. This average indoor usage for each residence was subtracted from the remaining months to estimate outdoor water usage. The outdoor water usage, in gallons, was converted to a depth of water, in inches, using the irrigated area information.

Local monthly reference evapotranspiration and monthly rainfall data were then used to determine net water loss in the landscape, which must be replaced using lawn irrigation to maintain a healthy landscape (Figure 1). The depth of monthly outdoor water usage was compared to that month's reference evapotranspiration minus rainfall depth. This calculation created an overwatering/underwatering figure. An example is presented in Table 1 for 1 customer over a 12-month period during 2009. For the customer in this example, overwatering in 2009 was by 12.56 inches, or 8,488 gallons of water. Underwatering figures were converted to zeros. Overwatering figures were calculated monthly and then compiled for each year by residence.

RESULTS

For the neighborhood under study, the 1,229 households had an average irrigation area of 9,300 square feet. Not every property had the full 3 years of monthly data available, and the average number of months of data were 34.5 of the 36 possible months. Eight of the lots (0.7%) had less than 1 year of data available, but we did not choose to discard these data although they could slightly affect the results. The majority of the properties (885, 72.0%) had 36 months of data.

Average monthly total water usage for all the properties was 11,878 gallons per month. Of this total, an average of 4,302 gallons (36.2%) was used indoors per household per month. For calculating the outdoor need, we used 100% replacement of monthly reference evapotranspiration values, minus rainfall, as the base amount of irrigation water that should be applied each month to the landscape. Based on this calculation, 277 residences (22.5%) overwatered by at least 50,000 gallons in

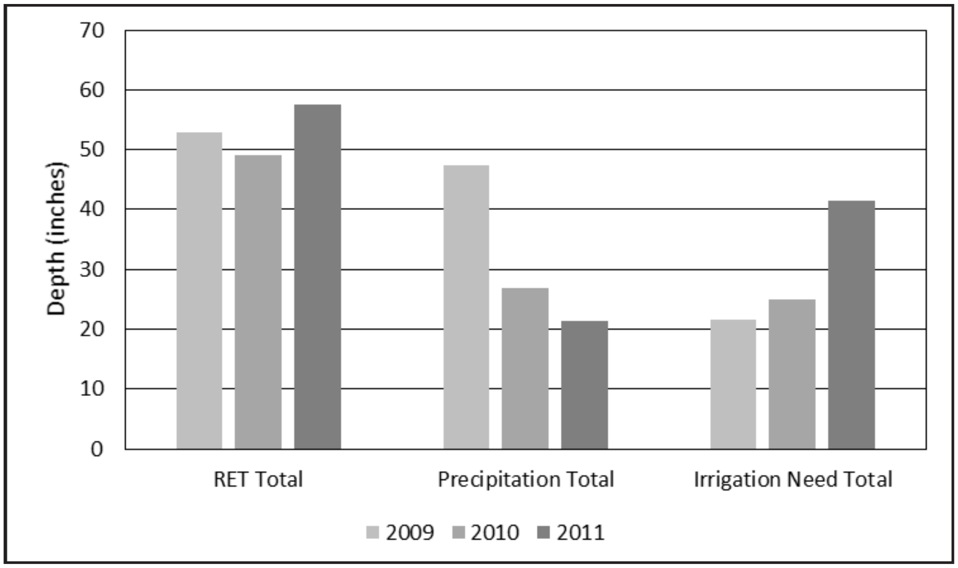

Figure 1. Total reference evapotranspiration (RET), precipitation, and irrigation depth need by year.

at least 1 of the years under study, and 148 residences (12%) overwatered by at least 100,000 gallons in at least 1 of those years (Figure 2).

The entire neighborhood overwatered by about 28.9 million gallons in both 2009 and 2010. In 2011, during a severe drought, the total amount of overwatering was 21.2 million gallons. Note that this is not the amount of water needed for irrigation each year but rather an extra amount of water that is above the rainfall plus reference evapotranspiration requirement. It could be considered "wasted water." Over the 3-year period of study, only 6 of 1,229 households (0.49%) did not have a net level of overwatering.

A common method in the industry for considering landscape watering relates to inches of irrigation, which is comparable from one site to another, irrespective of the actual square footage of each site. For the properties under study, the average overwatering per month was 0.62 inches, with a maximum of 33.55 inches (Figure 2). Of the studied households, 173 (14.1%) had a monthly average overwatering of at least 1 inch for all the months recorded for that property.

Table 1. Example of data organization and calculation from one household in 2009 with a Lot Area, Building Area, Pavement Area, and Irrigation Area of 12200, 3237, 633, and 8329 square feet, respectively.

Billing date	Total consumption (gallons)	Outdoor usage (gallons)	Depth of irrigation (inches)	Reference Evapotranspiration (inches)	Rainfall (inches)	Reference Evapotranspiration - Rainfall (inches)	Excess monthly water (inches)
20090210	12100	5660	1.10	2.66	1.06	1.6	0.00
20090310	11900	5460	1.06	3.50	1.9	1.6	0.00
20090408	21800	15360	2.97	3.97	4.85	0	2.97
20090511	9600	3160	0.61	4.87	7.84	0	0.61
20090611	31000	24560	4.76	5.66	2.68	2.98	1.78
20090714	45200	38760	7.51	7.36	0.25	7.11	0.40
20090811	41000	34560	6.69	7.47	3.51	3.96	2.73
20090914	30000	23560	4.56	6.71	2.70	4.01	0.55
20091013	13200	6760	1.31	3.86	5.56	0	1.31
20091112	5100	0	0.00	3.18	9.68	0	0.00
20091211	7400	960	0.19	2.17	1.87	0.3	0.00
20100112	5400	0	0.00	1.54	5.48	0	0.00

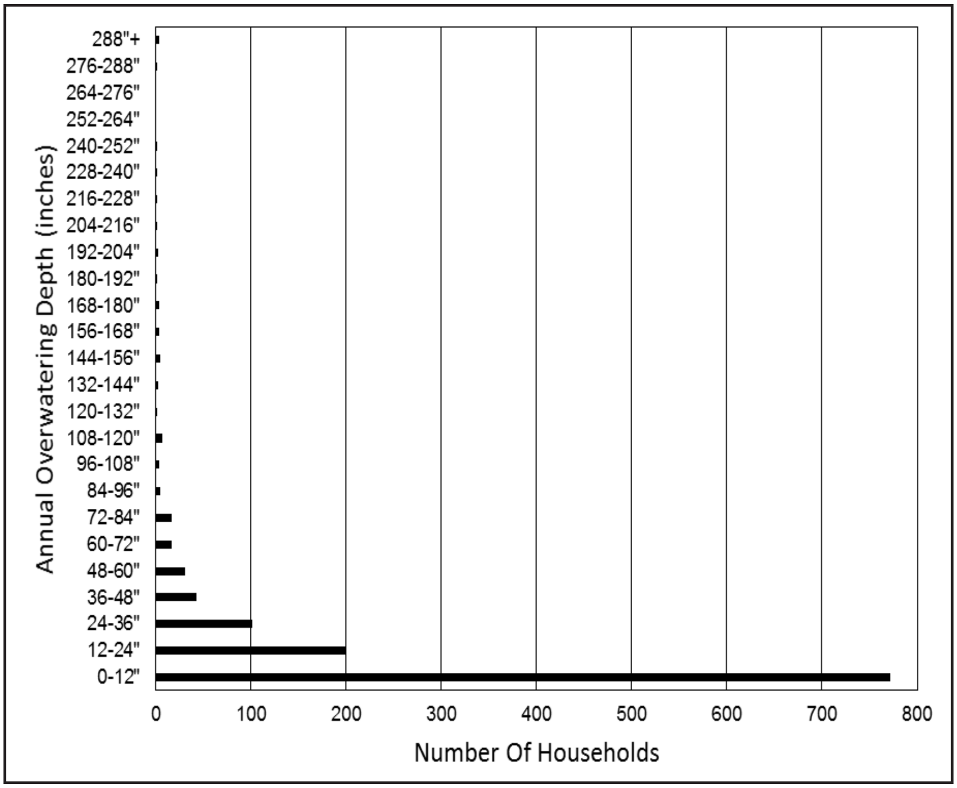

Figure 2. Number of households classified by total depth of overwatering, in inches.

We also performed correlation analysis on the variables being examined to further understand any trends in landscape water use. For this analysis, the PROC CORR procedure of SAS v9 was utilized (SAS 2002). There was no correlation between the size of the irrigated area and the amount of overwatering. This suggests that overwatering is occurring in all sizes of landscapes. There was also a lack of correlation between monthly indoor usage and the amount of overwatering. This is in contrast somewhat to a finding by Tinker and Woods (2000) that found a positive correlation between indoor water usage and outdoor water usage.

CONCLUSIONS AND IMPLICATIONS

This study took a systematic approach in measuring indoor and outdoor residential water usage in one community in Southeast Texas. Monthly water bills and irrigated area of each landscape were used in the calculations. Data provide conclusive evidence of how water was used over a 3-year period. Potential shortcomings of the study include the lack of analysis of water cost and the subsequent effects on water usage and the lack of inclusion of income data per household.

Water is being wasted in Texas residential landscapes during periods of both drought and plentiful rainfall. This wasted water increases demand for pumping, purchase, piping, and treatment of water by the water purveyor. If all the residents of this 1 neighborhood had watered based on reference evapotranspiration, then the yearly demand for the entire city of Huntsville, Texas would have decreased to the point whereby a new water well would not have been needed in 2012 (Reed 2011). The new well cost the city of Huntsville between $1.2 and $1.5 million (Brock 2011). This cost should be a powerful economic motive. In the long run, water users will not pay as much for their overall water bill if expensive water supply projects are delayed by 20 or more years due to conservation efforts.

If Texas is to meet its future water needs, then effective water conservation must be an integral input. Increased education and awareness of reference evapotranspiration principles for landscape watering as well as water purveyors focusing additional conservation information on individual homeowners who waste water, are proving to be viable solutions. One possibility for additional conservation information is providing homeowners a monthly "water budget" based on the size of their landscape. As the scarcity of water increases, evidence indicates that water costs will also rise (White 2012), and this too will further induce conservation.

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