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Water Conservation on Campuses of Higher Education in Texas

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Water Conservation on Campuses of Higher Education in Texas

by

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Thesis

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Energy and Earth Resources

The University of Texas at Austin

August 2014

Acknowledgements

I would like to acknowledge and thank Dr. Suzanne A. Pierce for her guidance and support. I would also like to thank Alice Gerhart and Jim Walker for their help developing and distributing the TRACS survey. I am grateful to the TRACS steering committee for their efforts and without whom this project could not have come to fruition.

Abstract

Water Conservation on Campuses of Higher Education in Texas

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Facing drought and water shortages, many regions of the United States and the world have been forced to improve water resources management. In water-stressed areas of the US, water conservation has become the most economically viable water supply option available. As such, water conservation efforts are an increasingly popular method of demand management and have proven effective at various scales throughout the country. Many states in the arid southwest, including Texas, have incorporated water conservation strategies into their state water plans to reduce demand during drought conditions.

At the 2013 Summit for the Texas Regional Alliance for Campus Sustainability (TRACS), water conservation was identified as a critical issue for higher education institutes (HEI) across the state. HEIs are analogous to small cities in terms of their resource use, and can also serve as test labs for sustainability concepts and resource management strategies. In response to concerns about water scarcity, TRACS launched an evaluation of water conservation strategies across Texas' HEI campuses. The project collected data focused on the use of water conservation methods and their perceived effectiveness in irrigation and landscaping, building use, and utilities. Additionally, water conservation educational efforts, and the goals and policies of HEIs were considered. The objectives of the project were to collaborate with Texas HEIs, compile a database of best practices, and identify regional preferences in a state with varying climates and water resources.

The results of the survey determined that native and adaptive plants were the most-widely used water conservation method for irrigation and landscaping as well the most effective strategy. In buildings, low-flow plumbing was reported to be the most widely-used and also most effective water conservation method. A variety of water conservation measures were used in utilities; metering, maintenance, and recycling water were viewed as most effective. While many HEIs reported offering opportunities for students to learn or participate in research about water conservation, only half reported offering workshops or courses for managerial staff and faculty. Education for staff and faculty is a particularly important area for improvement, as many staff members are closely involved in managing water use across campuses. Many of the HEIs reported having water conservation policies in place or pending and some participating HEIs reported having target reduction plans and involvement with agencies related to water conservation. It is important for the administration of educational institutions to put policies and plans in place to guide the everyday operations of a campus. HEIs in the state are making great strides in water conservation, but establishing a network to share best practices and improvements could significantly enhance campus water conservation initiatives.

Table of Contents

INTRODUCTION

Water scarcity is affecting many regions of the United States and around the world. Drought and water shortages coupled with population and economic growth have forced policymakers and utilities to improve water resources management. Until recently, the response to increased demand was to increase supply via additional storage construction and distribution infrastructure.[1] Increasing demand due to rapid population and economic growth is straining water supplies to the point where increasing supplies in a conventional way is either an inadequate or uneconomical response to rising water needs. In areas with increasingly scarce development opportunities and prohibitively large costs, water conservation strategies including efficiency, waste reduction, and water recycling are critical for managing water demand.[2] Water conservation strategies are becoming increasingly popular and have proven effective at various scales – from large regions to cities and universities and, even at the individual homeowner level -- in areas facing drought and water shortages. Texas has experienced extreme drought and water shortages for the past decade and has begun to rely on water conservation strategies as a tool to survive periods of serious drought.[3]

Water conservation strategies can help to ensure future and current water supplies by reducing water demand. Conservation reduces costs associated with the development, treatment, and delivery as well as creating a new water supply.[4] Water demand management can be achieved by reusing water or by increasing efficiency and reducing waste. Methods for water conservation include tech-based solutions such as irrigation products that reduce waste, low-flow plumbing fixtures, and water-efficient cooling towers for utilities. Conservation methods can also include behavioral changes that can be taught through targeted training, e.g., taking shorter showers.

At the 2013 summit for the Texas Regional Alliance for Campus Sustainability (TRACS), water conservation was identified as a critical issue for higher education institutes (HEI) across the state. HEIs represent a unique laboratory for technological and behavioral innovation, as they function much like small cities in terms of resource use and environmental impacts. In their efforts to develop better conservation methods and train future leaders, they play an important role in promoting and demonstrating sustainability concepts directly on their campuses.[5;6] In response to concerns about drought conditions, TRACS members launched an evaluation of water conservation programs and practices across HEI campuses in the state of Texas.

The project collected data for irrigation and landscaping, building use, utilities, education, and governance and policy initiatives. The project focused on the use of water conservation methods and the perceived effectiveness of those methods. Additionally, water conservation education efforts at each HEI and their goals and policies were collected and analyzed. The objectives of the project were to collaborate with Texas HEIs to compile a database of best practices and to identify regional conservation preferences. In a state as large as Texas with considerable regional variation, differing climates, water availability, political landscapes, and conservation strategies impact the options available to a particular HEI in addressing the need to conserve water. Further, the size and type of HEI (public, private, or community) can greatly impact an institution’s strategy. HEIs in the state are making great strides in water conservation, but establishing a network to share best practices and improvements could greatly enhance campus water conservation initiatives.

The results of the survey determined that native and adaptive plants were the most-widely used water conservation method for irrigation and landscaping as well the most effective strategy. Low-flow plumbing, low-flow faucets in particular, were reported to be the most widely-used and also the most effective method for water conservation in buildings. Utilities use a variety of water conservation measures, with metering, maintenance, and reusing water viewed as most effective. Expanding the use of effective water conservation techniques to all HEIs in the state could greatly increase water savings.

While many HEIs reported offering opportunities for students to learn or participate in research about water conservation, only half reported offering workshops or courses for managerial staff and faculty. Therefore, increasing educational opportunities for faculty and staff is one important area for improvement, as many staff members are closely involved in managing campus water use. As well as promoting water conservation through course and workshops, many of the HEIs reported having water conservation policies in place or pending. Some participating HEIs reported having target reduction plans and involvement with agencies related to water conservation. It is important for the administration of educational institutes to put policies and plans in place to guide the everyday operations of a campus. HEIs in the state are making great strides in water conservation, but establishing a network to share best practices and improvements could greatly enhance campus water conservation initiatives.

Chapter 1: Water in Texas

Texas has a long history of cyclic droughts that have affected resource management decisions from the earliest settlers to modern day legislators.[7] The state's water supplies are inseparably tied to growing industries and municipalities in the state and securing future supplies is critical for continued economic growth in Texas. Currently, the state does not have enough existing water supplies to meet demand in serious drought conditions.[3]

The Texas Water Development Board (TWDB), a state agency charged with the planning and administration of water programs, has developed several strategies to increase water supply and reduce water demand in times of drought in their 2012 Water Plan.[3] The state water plan is issues every five years and includes the contribution of 16 water planning regions as shown in Figure 1.0. The plan evolves with the growing population and economies in the state as well as climatic, environmental, and economic considerations. Recommended water management strategies include drought management, increasing reservoirs and wells, desalination projects, and water reuse and conservation. Conservation and water reuse strategies are projected to contribute about 34 percent of the increased supply volume for the state and are becoming increasingly valuable as demand management techniques.[3]

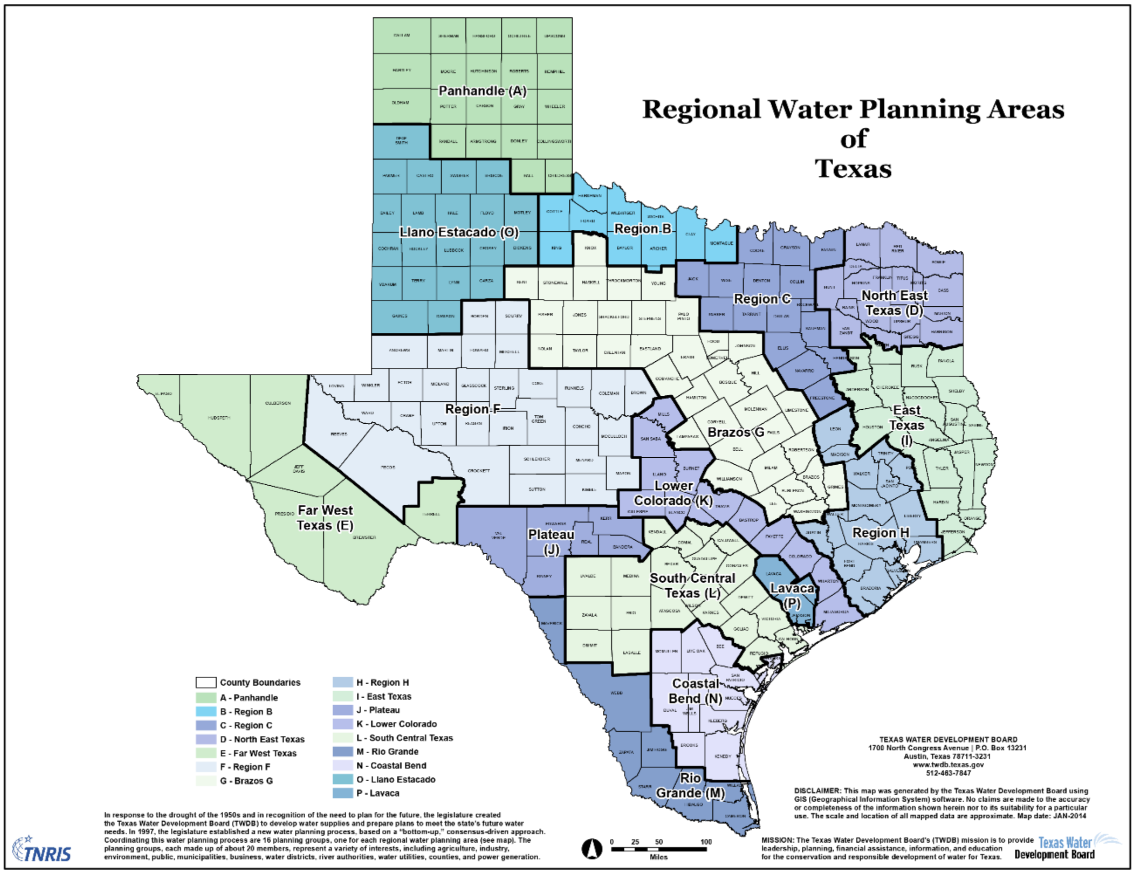

Figure 1.1: Map of TWDB planning regions.[3]

Water Sources

Texas has three sources of water: surface water, groundwater, and reused or recycled water. Existing water supplies are defined as supplies that are currently physically and legally available with existing infrastructure and permits.[3] The term "water availability" refers to water resources in the state disregarding legal and infrastructure limitations.

As of 2010, the state's existing surface water supply was estimated to be 8.4 million acre-feet per year while its available surface water supply was over 13.5 million acre-feet per year.[3] Texas's total existing water supplies were estimated to be 17 million acre-feet per year and are projected to decrease by 10 percent in the next five decades as non-renewable sources are depleted (Figure 1.1)

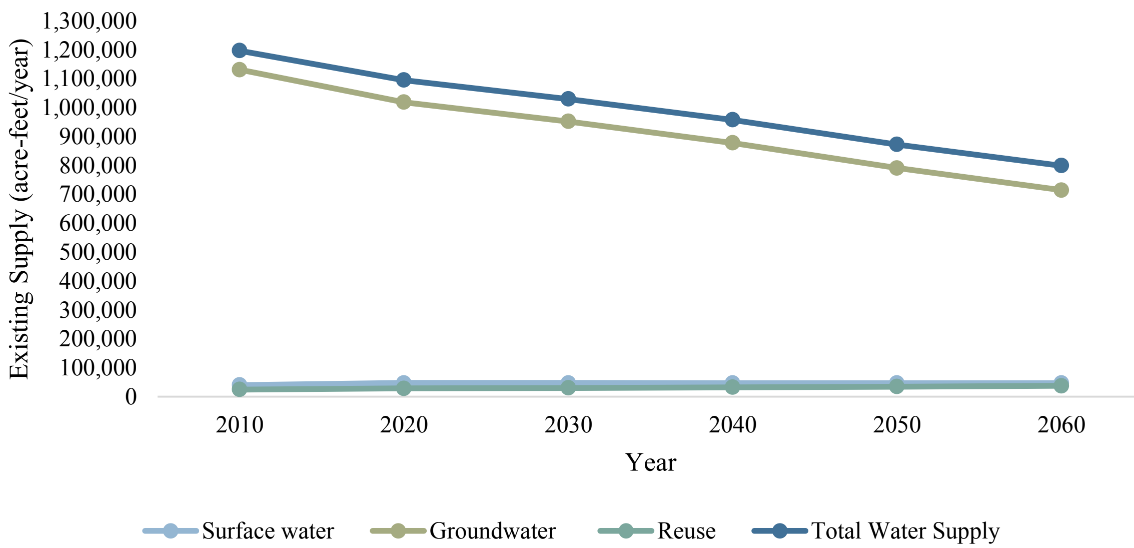

Figure 1.1: Projected existing water supplies for the state of Texas (acre-feet/year).[3]

Surface Water

Surface water in the state of Texas includes rivers, streams, lakes, reservoirs, springs, wetlands, bays and estuaries, and the Gulf of Mexico. Total existing surface water supplies were 8.4 million acre-feet in 2010 and account for nearly 40 percent of the water used in Texas.[3] The state contains 15 major basins, 191,000 miles of streams and rivers, and seven major estuaries (Figure 1.2). Of the 16 water planning districts in Texas, nine rely primarily on surface water for existing and future supplies of water. In the year 2010, water availability was estimated at 13.5 million acre-feet per year and is projected to decrease by 200,000 acre-feet in the next 50 years shown in Figure 1.3. Surface water availability correlates with precipitation patterns and is vulnerable to the persistent drought conditions that the state experiences.[3]

Figure 1.2: Texas's major river basins.[3]

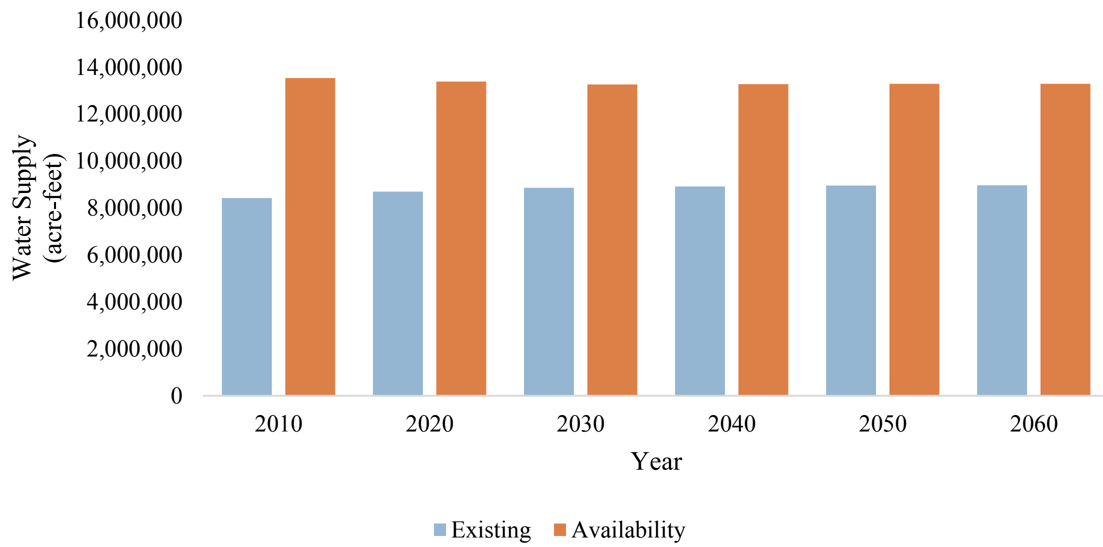

Figure 1.3: Projected existing surface water supplies and surface water availability from 2010-2060.[3]

Groundwater

Groundwater supplies are critical for providing adequate water for the needs of Texas, especially in times of drought. Texas has nine major and 21 minor aquifers that can provide varying quantities and qualities of water (Figure 1.4). Existing groundwater supplies in 2010 were an estimated 8.1 million acre-feet per year.[3] They are projected to decline in the next 50 years to about 5.7 million acre-feet per year due to reduced production in the Ogallala Aquifer and the Gulf Coast Aquifer. In 2010, total groundwater availability was about 13.3 million acre-feet per year and is also projected to decline in the subsequent 50 years.

Groundwater production greatly increased after the 1950's drought of record, as available surface water supplies could not be relied upon to satisfy the demand in drought conditions.[3] According to the TWDB's latest Water Use Survey, groundwater currently provides 60 percent of the water used in the state. Approximately 15 percent of the state's groundwater is used by municipalities and 80 percent is used by farmers to irrigate crops. Agriculture in the High Plains region is identified as the main activity contributing to falling aquifer levels in the Ogallala. The Ogallala is the sole groundwater source in the High Plains and pumping rates have become unsustainable and new supplies will be necessary.[8] Until the year 2000, when new supplies were added to the system, the Edwards Aquifer was the sole source of drinking water for the city of San Antonio.[9] Other cities rely heavily on groundwater as well. Groundwater provides about 35 percent of all municipal water demands in the state.[3]

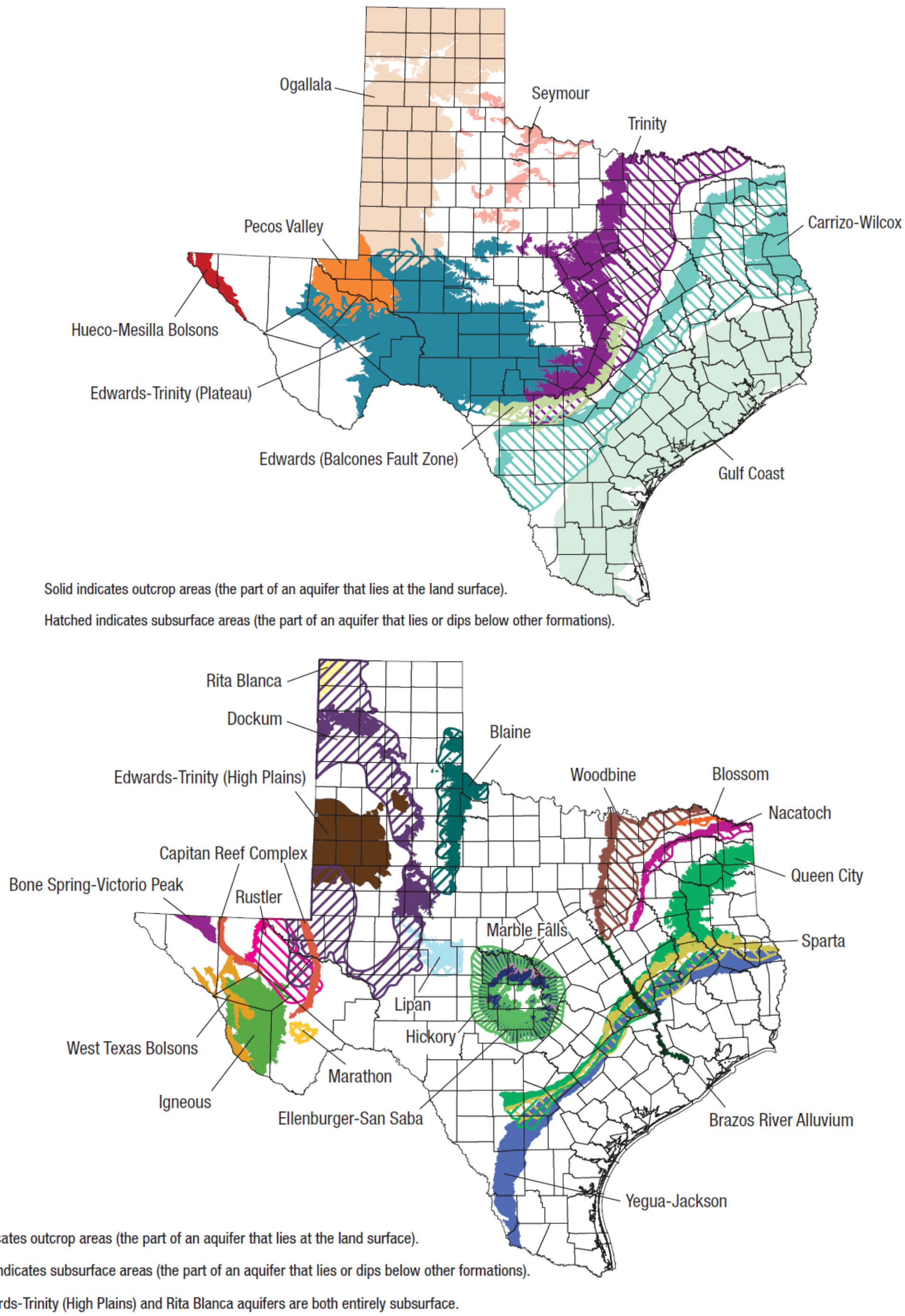

Figure 1.4: Texas's major (top) and minor (bottom) aquifers.[3]

Reuse

Reused water is defined as groundwater or surface water that has already been beneficially used.[3] The term is often interchangeable with "reclaimed" or "recycled" water. Direct and indirect use of recycled water has been growing in Texas for the past twenty years.[3] Reclaimed water that is directly used travels from a water treatment plant to the distribution system while indirectly used reclaimed water is transported from a treatment plant to another water supply and stored for later use. According to the State Water Plan, a reported 62 thousand acre-feet of water was reused directly in the year 2010.[3] Existing supplies of recycled water were approximately 482,000 acre-feet per year in 2010 and are projected to increase to about 614,000 acre-feet per year in the next 50 years with increased permitting. Water reuse will continue to be a critical water management strategy in times of serious drought.

WATER DEMAND

Water demand in Texas is expected to increase from approximately 18 million acre-feet per year in 2010 to an estimated 22 million acre-feet per year in 2060.[3] This 22 percent increase in demand comes largely from rapid population growth and mounting water-reliant industries. Population growth and expanding industries that require sizeable water supplies are not distributed evenly throughout the state. Growth is concentrated in certain regions, creating an additional strain on water management and planning in those regions during times of drought.

Population

Texas is the second most populated state and represents one of the fastest growing states in the nation. Within the TWDB's 50-year planning horizon, the population of

Texas is expected to increase 82 percent, to over 46 million residents (Figure 1.6).[3] New residents require water to use in their homes, lawns, and in foods and materials they purchase. Population growth is not distributed evenly across the state and growth rates vary considerably. In the next five decades, 225 Texas cities are expected to at least double in population while 158 cities are expected to decrease or remain constant. The TWDB has divided the state into 16 water planning regions. Most of the growing regions are concentrated in the eastern portion of the state or follow the Interstate Highway-35 corridor as shown in Figure 1.7.

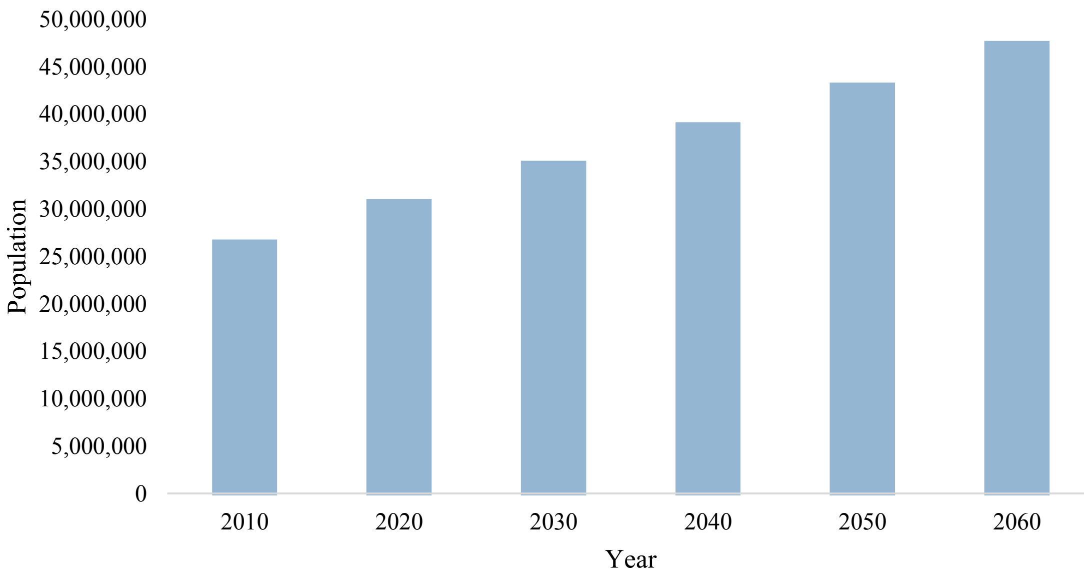

Figure 1.6: Estimated Texas population growth from 2010-2060.[3]

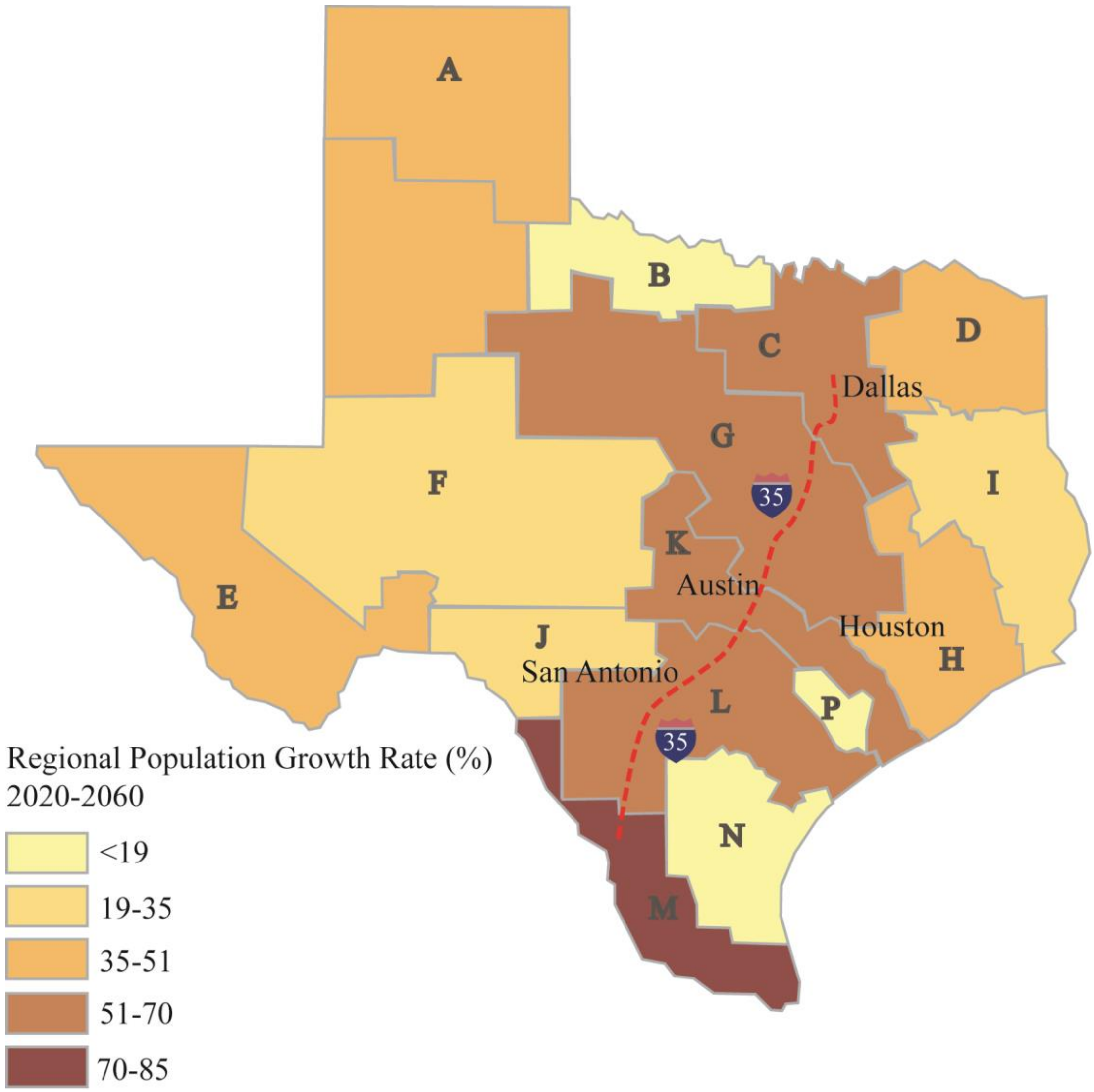

Figure 1.7: Map of Texas showing projected population growth rate percentages of TWDB planning regions as well as the locations of major cities and the Interstate Highway-35.[3]

As shown in Figure 1.7 and 1.8, regions C, G, H, L, and M contain rapidly expanding municipal areas and are projected to experience the most growth. These regions surround the Dallas-Fort Worth area (Region C), College Station (Region G), Houston (Region H), San Antonio (Region L), and the Lower Rio Grande Valley (Regional M). The growth of municipalities in Texas contributed approximately nine percent of the total identified water need in 2010, and this percentage will continue to increase to a projected 41 percent in 50 years.[3] Due to concentrated population growth and water supply issues that vary by region, some planning regions will be more affected by serious drought conditions than others. By 2060, all regions except region P are expected to be affected by future municipal water shortages as shown in Figure 1.9.

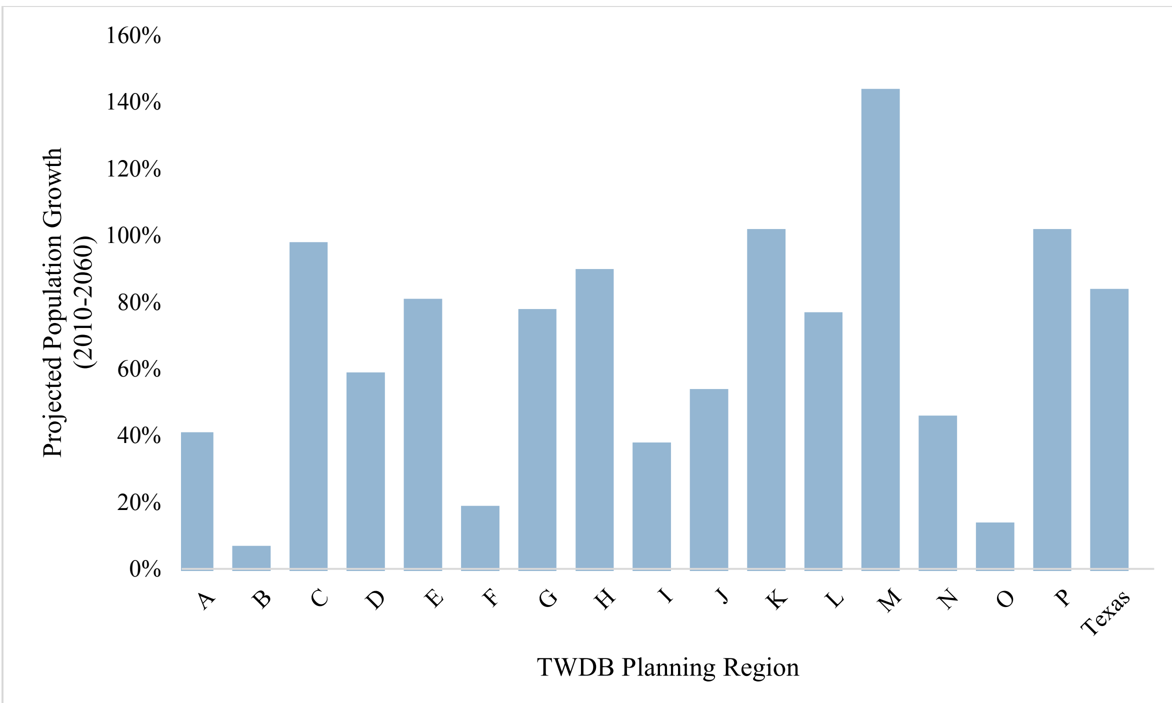

Figure 1.8: Projected population growth for planning regions for 2010-2060.[3]

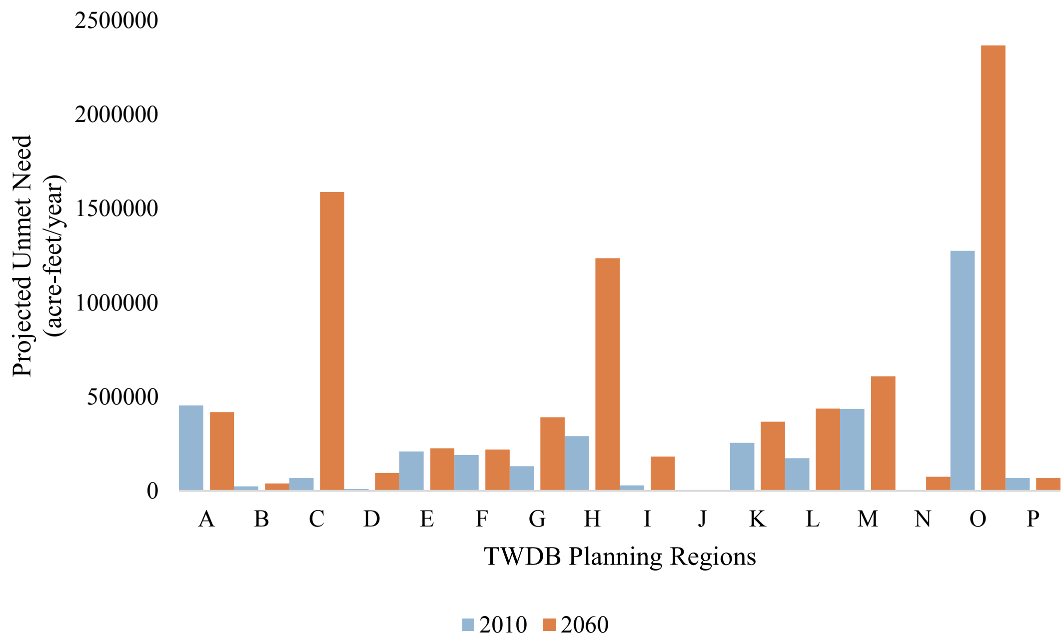

Figure 1.9: TWDB projected unmet water need for planning regions in the years 2010 and 2060.[3]

Water Uses

The largest non-municipal water uses in Texas include irrigation, manufacturing, livestock, steam-electric, and mining (coal, oil and gas, aggregate producers).[3] Irrigation agriculture uses more water than any of the other water user categories. Over half of the water in Texas is used for irrigation in Regions A, O, and M as well as the rice producing areas on the coast. Irrigation water demand is expected to decline over the next 50 years by 17 percent largely due to efficiency improvements, land use change, and the cost of groundwater pumping. The water demand will be shifted to other users in the state. Manufacturing industries require water for large facilities that process chemicals, food, paper and other materials, as well as oil and gas refining. Manufacturing water demands are projected to grow 67 percent in the next 50 years from the current 1.7 million acre-feet. Livestock water demands for cattle, hogs, poultry, horses, sheep, and goats are projected to increase only by 15 percent in the next 50 years.

Energy and water are linked in many ways such as water demand for power generation and as well as for fuel mining and production purposes. The amount of water required to generate electricity depends on the source fuel, the type of cooling system in place, and whether the water will be diverted, withdrawn or consumed in the process.[10] Water use for electricity generation is expected to increase 121 percent in the next five decades.[3]

The oil and gas industries in Texas are substantial and increasing in activity due to recent expansions in hydraulic fracturing use, but mining remains the least demanding of all the water user categories. Water demand for mining is even expected to decline by one percent in the next 50 years.[3] Studies on the effect of hydraulic fracturing on water use have initially shown that the overall percentage of water used is small in the state. Hydraulic fracturing operations have moved to the drier western and southern portions of Texas and have been forced by climate conditions and water scarcity to better manage and conserve water. In the year 2010, water used for hydraulic fracturing made up only one half of a percent of the state's total water use. The effects are significantly more pronounced in localized areas where production takes place.[11]

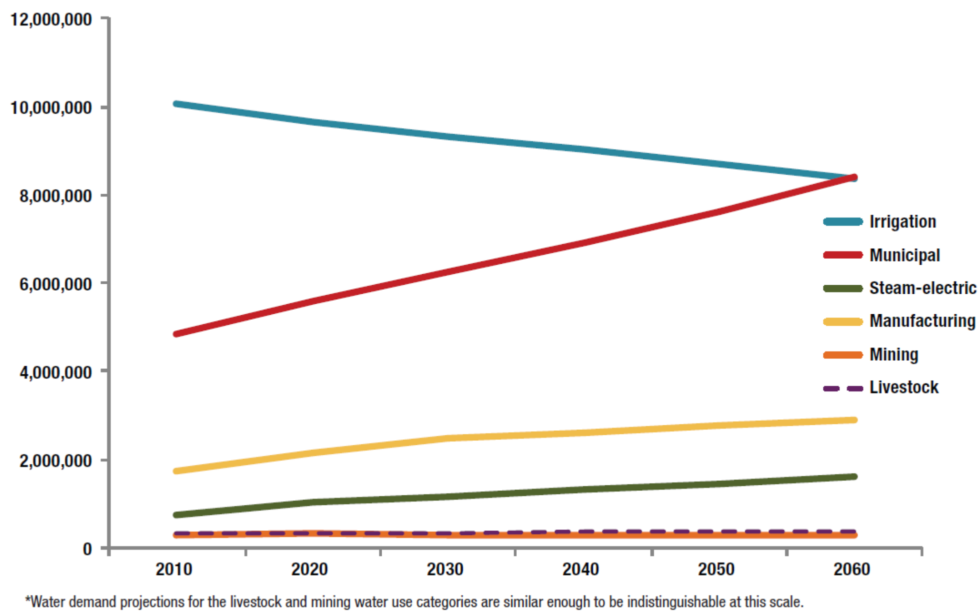

Figure 1.8: Projected water demands by use (acre-feet/year).[3]

Climate and Drought

Due to its size, climate varies in Texas from arid to sub-tropical with 10 distinct climate zones shown in Figure 1.9. Climate is an important factor to consider in water management because drought and precipitation control both surface water reservoirs and groundwater recharge. The eastern portion of the state is generally wetter than the remaining area of the state where evaporation exceeds precipitation (Figure 1.10). Average annual precipitation ranges from over 50 inches in the southeastern part of the state to nine inches in the dryer west.[12] Average annual temperatures vary with latitude.[3]

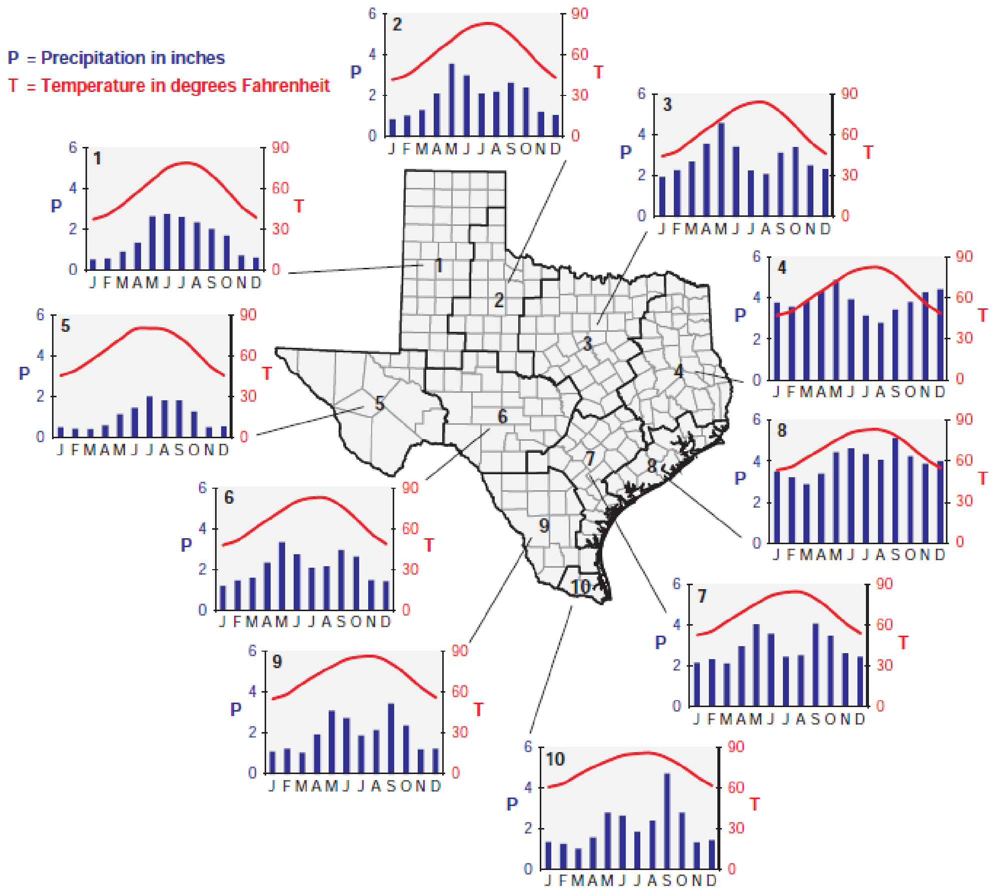

Figure 1.9: Map of climate regions with corresponding precipitation and temperature graphs.[3]

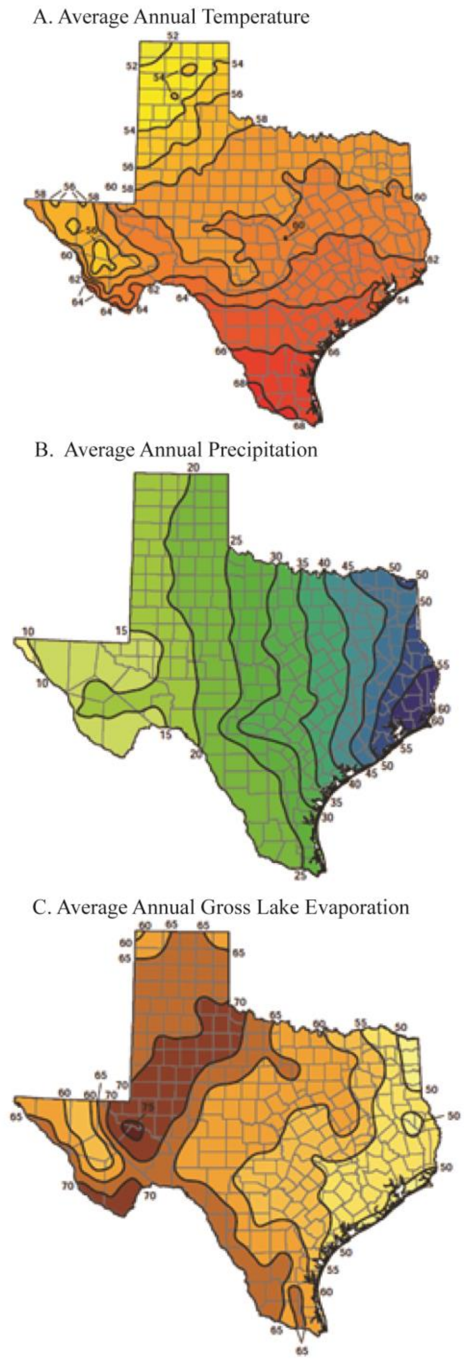

Figure 1.10: Maps of Texas showing *A)* average annual temperature for the years 1981-2010; *B*) average annual precipitation for the years 1981-2010 in inches; and *C)* average annual gross lake evaporation for the years 1971 to 2000 in inches.[3]

Texas has experienced drought, or periods of less than average precipitation over a prolonged period, since before the first settlers arrived in the state during the 1700s. Tree ring data shows evidence of cyclic drought in the state for the last thousand years.[7] Droughts can be as economically and environmentally devastating as hurricanes, floods and tornadoes and can have effects that last for decades.[3]

The historic drought of the 1950s provides a reference point for scientists and policy makers. During the driest year, 1956, the state received only half of its normal annual precipitation. The comparable and most recent drought of 2011 has alerted and alarmed the state's utility providers, legislators, and the general public (Figure 1.11). From October of 2010 to September of 2011, Texas and the surrounding states experienced nearly 100 days of triple digit temperatures, large precipitation deficits, extreme drought severity indexes, along with substantial declines in streamflow and reservoir levels (Figure 1.12).[14] John Nielson-Gammon, the State Climatologist, declared the year 2011 to be the worst one year drought in recorded Texas history.[12] In September of 2011, and estimated 99 percent of the state was experiencing severe, extreme, or exceptional drought conditions (Figure 1.13).[3] While drought conditions peaked in 2011, Texas is currently and will continue to experience exceptional to extreme drought conditions in many regions, affecting both existing and available water supplies in the state.

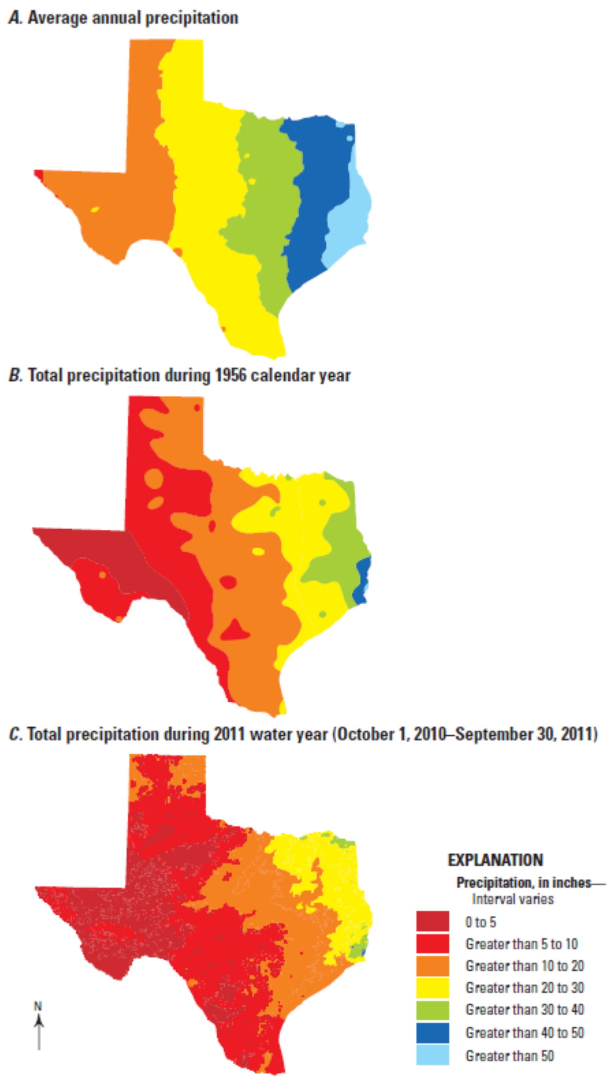

Figure 1.11: Maps of Texas showing *A)* the average annual precipitation in inches; *B)* the total precipitation during the 1956 calendar year in inches (during the drought of record); *C)* the total precipitation during the 2011 water year in inches.[12]

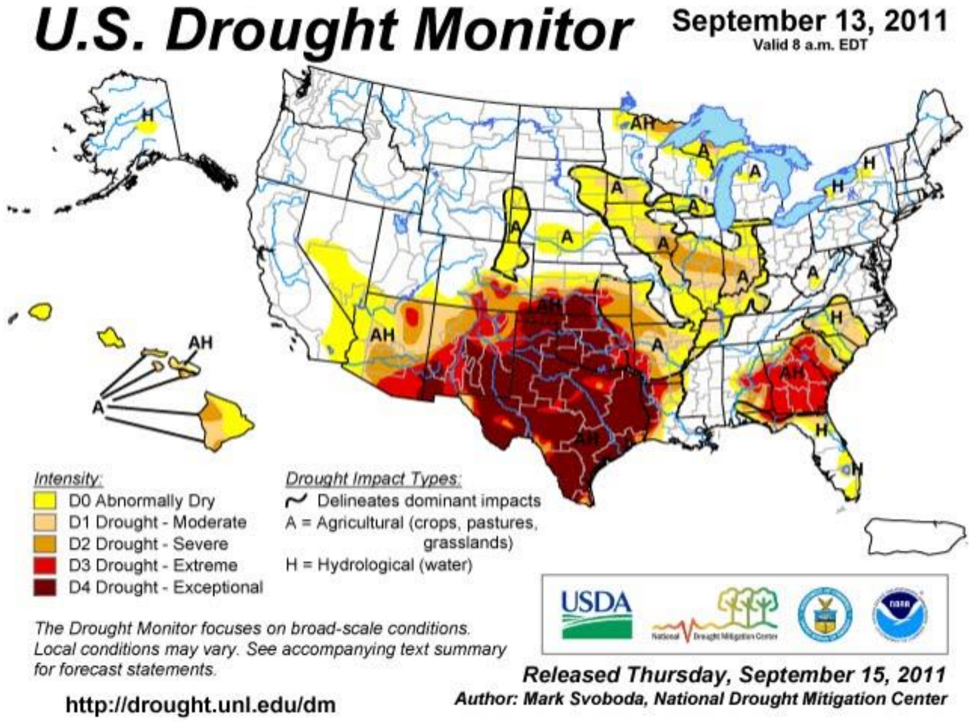

Figure 1.12: Drought Monitor map showing Texas's and the rest of the nation's drought severity for September 13^{th}, 2011.[13]

PLANNING, AND MANAGEMENT STRATEGIES

Planning and resource management are necessary to supply enough water for the state's growing demand in future drought conditions; water supply deficits would have economic as well as environmental effects. If 1950s' level drought conditions impacted the entire state again, economic models showed that Texas would lose nearly $12 billion in income in 2010 and $116 billion by 2060.[3] In an attempt to avoid such losses, water management strategies recommended by the 2012 State Water Plan would provide an additional 9.0 million acre-feet of water per year. These strategies include drought management, additional reservoirs and wells, desalination plants, water reuse and conservation (Table 1.0). Water reuse and conservation would provide nearly 34 percent of the additional supply volume and will become more significant as further development of conventional sources becomes less economic.[3] The implementation of conservation strategies is critical for the state of Texas to avoid economic repercussions due to water shortages.

Type of Water Management Strategy	2010	2020	2030	2040	2050	2060
Municipal Conservation	137,847	264,885	353,620	436,632	538,997	647,361
Irrigation Conservation	624,151	1,125,494	1,351,175	1,415,814	1,463,846	1,505,465
Other Conservation *	4,660	9,242	15,977	18,469	21,371	23,432
New Major Reservoir	19,672	432,291	918,391	948,355	1,230,573	1,499,671
Other Surface Water	742,447	1,510,997	1,815,624	2,031,532	2,700,690	3,050,049
Groundwater	254,057	443,614	599,151	668,690	738,484	800,795
Reuse	100,592	428,263	487,795	637,089	766,402	915,589
Groundwater Desalination	56,553	81,156	103,435	133,278	163,083	181,568
Conjunctive Use	26,505	88,001	87,496	113,035	136,351	135,846
Aquifer Storage and Recovery	22,181	61,743	61,743	72,243	72,243	80,869
Weather Modification	0	15,206	15,206	15,206	15,206	15,206
Drought Management	41,701	461	461	461	461	1,912
Brush Control	18,862	18,862	18,862	18,862	18,862	18,862
Seawater Desalination	125	125	143	6,049	40,021	125,514
Surface Water Desalination	0	2,700	2,700	2,700	2,700	2,700
Total Supply Volumes	**2,049,353**	**4,483,040**	**5,831,779**	**6,518,415**	**7,909,290**	**9,004,839**

*Other conservation is associated with manufacturing, mining, and steam-electric power industries.

Table 1.0: Recommended water management strategies from 2010-2060 and their respective supply volumes.

Chapter 2: Water Conservation in Texas

WATER CONSERVATION

The Texas Water Development Board (TWDB) defines water conservation as a plan or program consisting of several strategies or techniques that when implemented together reduce the overall demand for water and increases the efficiency of the water supply system.[3] Demand management is an important strategy for regions where water demand cannot be satisfied with additional conventional supplies such as building more reservoirs or drilling more wells. As the economy and population grow, the demand increases while water supplies stay relatively constant or decline. Water supplies can decline due to pollution or contamination, and changes in climate and management practices.[2] In Texas, many of the readily accessible and available fresh water supplies are already being utilized, and development opportunities have become increasingly scarce with disproportionate costs associated with projected future supply options. Water conservation is growing in importance as a tool for resource management statewide, as well as locally in water planning regions and municipalities.

Texas has begun to rely on water conservation strategies more heavily for environmental, economic, and resource limitation reasons. The 2012 State Water plan recommends an additional 129,400 acre-feet of water conservation when compared with the previous 2007 State Water plan. The TWDB is struggling to identify water supplies in severe and persistent drought conditions and have recommended conservation as a principle solution. The state water plan projects variations in conservation strategies across regions with municipal conservation accounting for nearly 650,000 acre-feet while irrigation and other efforts are expected to add 1.5 million acre-feet annually through 2060, as shown in Figure 2.0.[3]

Region	2010	2020	2030	2040	2050	2060
A	0	299,077	488,721	544,840	553,661	556,914
B	13,231	13,798	13,833	13,875	13,891	14,702
C	46,780	107,975	154,950	197,288	240,912	290,709
D	0	0	0	0	0	0
E	0	33,275	37,275	41,275	46,275	52,275
F	3,197	43,113	80,551	81,141	81,769	82,423
G	10,857	24,873	31,473	33,757	38,011	41,758
H	116,880	137,151	147,529	156,336	172,831	183,933
I	20,111	30,480	33,811	36,085	41,381	41,701
J	579	622	641	643	669	681
K	18,498	169,207	179,630	192,541	221,622	241,544
L	33,843	41,032	47,818	53,944	64,761	82,297
M	15,743	54,469	102,047	154,932	217,882	286,629
N	1,664	2,449	3,398	4,466	5,766	7,150
O	485,275	442,100	399,095	359,792	324,783	293,542
P	0	0	0	0	0	0
Total	**766,658**	**1,399,621**	**1,720,772**	**1,870,915**	**2,024,214**	**2,176,258**

Table 2.0: Supply volumes from recommended conservation strategies by region over the planning horizon (acre-feet per year).[3]

CONSERVATION STRATEGIES

There are two approaches to water conservation: technology-based solutions and behavioral-based strategies. Technology-based water conservation programs focus on detecting and reducing waste through efficiency and metering. Many of these strategies can be viewed as passive solutions because the user does not behave any differently. According to a TWDB efficiency study, applied tech-based strategies in irrigation, building-use, and utilities can save significant amounts of water and money (Table 2.1).

TWDB Efficiency Study Results				
	Estimated Cost			
Conservation Tool	Direct	Indirect	Total	Water Savings (gpcd)
Toilet Retrofit	$ 60.00	$ 15.00	$ 75.00	10.50
Showerhead and Aerator	$ 3.00	$ 1.00	$ 4.00	5.50
Clothes Washer Rebate	$ 100.00	$ 20.00	$ 120.00	30.00
Irrigation Audit	$ 130.00	$ 20.00	$ 150.00	125.00

Table 2.1: Results of multi-family residence efficiency study.

Tech-based irrigation conservation tools focus on reducing waste from over-watering or leaks. Over half of the water used in Texas is used for large- and small-scale irrigation. Therefore, irrigation or landscaping that incorporates smart-, weather-informed or drip irrigation, use of non-potable or reclaimed water, xeriscape landscaping, and leak detection strategies can help significantly reduce this overall demand. Smart and weather-informed irrigation use evapotranspiration meters to avoid over-watering.[16] Drip irrigation systems provide water directly to the plant root zone using surface or subsurface applicators. Irrigation is a great use for non-potable or reclaimed water as well.

For building-use, these tech-based strategies include low-flow faucets, toilets, showerheads, as well as dual flush toilets, waterless urinals, front load laundry machines, and efficient dishwashers.[4; 15] Toilet design has seen the most changes reducing water usage from seven gallons per flush to the 1.6 gallon per flush US standard low-flow toilet.[16] Simply installing and using these products helps to reduce water demand. According to the EPA's *Watersense*, proper maintenance of infrastructure and plumbing appliances can significantly reduce wasted resources and money (Table 2.2).[17]

Malfunction	Leaking Flow Rate (gallons per minute)	Water Loss	Estimated Cost of Water Loss
Leaking Toilet	0.5 gpm	21,600 gallons per month	$2,100 per year
Drip Irrigation Malfunction	1.0 gpm	43,200 gallons per month	$4,300 per year
UnattendedWater Hose at Night	10.0 gpm	5,400 gallons per day	$16,000 per year
Broken Distribution Line for:			Up to $64,000 per year
One Day	15.0 gpm	21,600 gallons	
One Week	15.0 gpm	151,200 gallons	
One Month	15.0 gpm	648,000 gallons	
Tempering Water Line on a Steam Sterilizer Stuck in the On Position	2.0 gpm	86,400 gallons per month	$8,600 per year
Stuck Float Valve in a Cooling Tower	5.0 gpm	216,000 gallons per month	$21,000 per year

Table 2.2: Potential losses from water leaks.[17]

Electric utility providers necessitate large amounts of water for cooling purposes. Thermoelectric, or steam electric, generation accounts for 90 percent of electricity in the US and for nearly 40 percent of freshwater withdrawals and three percent of consumption.[18] Low-water cooling technologies such as cooling towers, hybrid wet-dry and dry cooling systems can greatly reduce water requirements for a plant.[10] Recirculating wet cooling towers have water withdrawal rates up to 100 times less than the rates of once-through water cooling systems. Despite the additional capital and operating expenditure, it is economical for some facilities in Texas to upgrade to more drought resistant cooling technologies to avoid rolling black- and brown-out during severe drought conditions.[18] Power plants can also reduce their water demand by switching to a less water-intensive fuel, such as natural gas, and improving their energy conversion efficiency. Nearly 50 percent of power plant generators in Texas currently run on natural gas. Power plants utilizing combined cycles require close to 30 percent of the cooling water needed by traditional steam turbine plants.[14]

Behavioral-based water conservation programs strive to change water use habits by increasing public awareness and education. Studies have shown that water use declines when consumers are knowledgeable about where their water comes from and how much they use.[2] A study of metropolitan consumers in California that were aware of where their water came from and the costs of transporting and treating it, used their resource more economically, often reducing their water use by 15-20 percent. Education campaigns endeavor to inform the public about ways to conserve water such as planting native or adaptive plants which require less water as well as behavioral changes like taking shorter showers and watering lawns at night. A well designed long-term water conservation program can reduce water consumption 10-20 percent over 10-20 years.[19] In Texas, the cities of Austin and San Antonio have implemented successful water conservation initiatives discussed in the next section.

CASE STUDIES- SAN ANTONIO AND AUSTIN

On the municipal scale, water conservation initiatives and projects in San Antonio and Austin have been proven very effective. Both cities are booming with rapidly increasing populations and industries that result in increased water demands and strained water supplies. San Antonio’s water supply is limited for environmental reasons while Austin’s supply problems are related to inadequate infrastructure. Both cities’ water supplies are severely impacted by drought conditions and have been forced to rely on water conservation in order for the municipality to provide sufficient water supplies to meet demand.

San Antonio Water Conservation

The city of San Antonio has very restricted available water supplies and relies heavily on water conservation to reduce demand for both environmental and economic reasons. Historically, the Edwards Aquifer has been the sole source of water for the city of San Antonio. Pumping from the aquifer was largely unregulated and quintupled from the 1930s to the 1980s causing aquifer levels to drop and spring flows to decline.[9] During the peak of the 1950s drought of record, the springs dried up completely. The threatened springs are the home to many unique species so in 1993, the Edwards Aquifer Authority (EAA) was established in response to violations of the Endangered Species Act. The EAA limits aquifer withdrawals and mandates a minimum spring flow to protect the diversity of species unique to the Edwards Aquifer. The EAA issues water allocation permits to limit the volume of water pumped from the Edwards. Permits can be sold or leased, creating an active water market in the city. Unused water can be sold to other water users producing an incentive for investment in water conservation initiatives.

In 1984, San Antonio residents were using approximately 225 gallons of water per capita per day, but by 2007, that usage was cut nearly in half. Despite increasing population, pumping began to decline in the 1990s due to pumping restrictions, water conservation, and the use of other water sources (Figure 2.0). Urban and agricultural conservation programs created by the city and its water utility provider, the San Antonio Water System (SAWS), help to keep water prices among the lowest 10 percent of US cities. SAWS has implemented a successful water conservation awareness campaign that includes information about ways to reduce their use and how consumers compare to the average user in the city on consumers' bills.[20] The agency also has offered a series of educational programs that teach young students about water conservation. The city has relied on wastewater recycling since the 1930s and in the year 2000, SAWS completed the construction of the nation's largest recycled water distribution system. The system supplies non-potable water totaling 20 percent of the water pumped from the Edwards. With continued growth, San Antonio may need to further diversify their water supply with costly desalination plants and importation from other aquifers. On a per-unit basis, these new water sources will be much more expensive than their conservation programs (Figure 2.1).

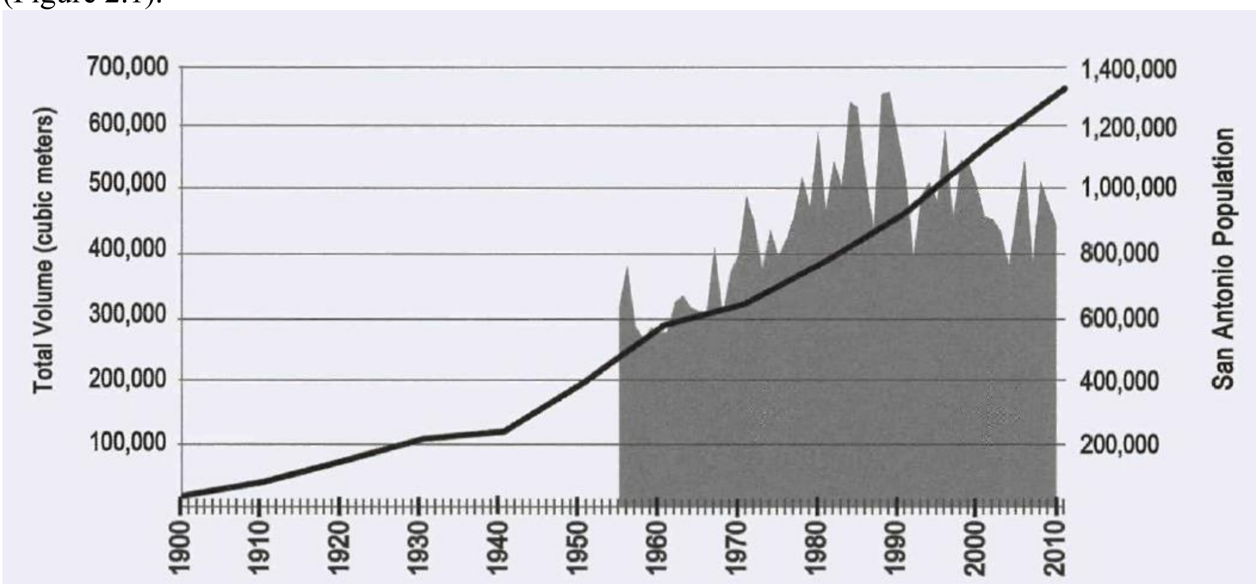

Figure 2.0: San Antonio's population growth (line) and pumping volumes from the Edwards Aquifer (faded area).[9]

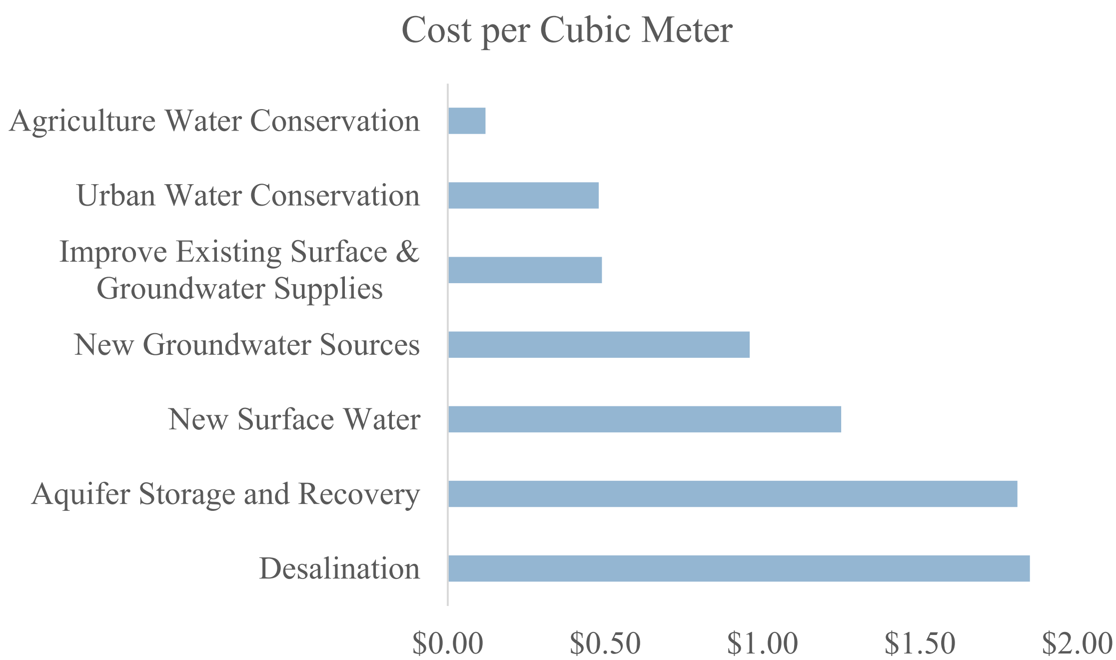

Figure 2.1: Cost of future water supply options for San Antonio in 2003 US dollars.[9]

A report prepared for the San Antonio Water System (SAWS) by BBC Research & Consulting concluded that conservation projects in the city pay for themselves relatively quickly.[21] Comparative analysis of conservation projects with low and high water demand scenario indicated savings estimates of sixty thousand dollars (low) and a billion dollars (high) when calculated in 2003 equivalent dollars (Table 2.1). The cost savings from conservation come from lower operating costs and from avoiding the capital costs associated with expensive water supply projects. The consulting firm found that SAWS would see a cost savings of about four to seven dollars for every dollar invested in conservation (in US 2003 dollars). Reduced demands from conservation strategies can also affect the timing and sizing of additional water supply projects if they are still required.[21]

	With Conservation	No Conservation (Low Scenario)	No Conservation (High Scenario)
Total customer demands	12.3 million acre-feet	15.2 million acre-feet	16.8 million acre-feet
Average annual demands	246,000 acre-feet	304,000 acre-feet	336,936 acre-feet
PV capital and operating cost	$1.94 billion	$2.55 billion	$2.98 billion

Table 2.1: Comparison of SAWS water demands and resource costs, with conservation and without conservation at low demand and high demand from 2003 through 2052.[21]

Austin Water Conservation

Austin receives all of its water from the Colorado River with firm water rights that are expected to meet demand through the year 2040. In response to infrastructure inadequacies in the 1980s, the Austin Water Utility developed the Emergency Water Conservation Ordinance to help reduce demand.[22] The initiatives that started from this crisis response have evolved into programs designed to reduce average per capita use, as well as peak-day demand in the short term. In the long term, the programs endeavor to delay the construction of additional water treatment plant capacity and to extend the time the city has before it exceeds its water rights. With an aggressive water conservation program, the city will have sufficient water rights through 2050.

Regarding the conservation of irrigation water, Austin offers free irrigation audits to detect and reduce waste in automatic irrigation systems, free hose timers for homeowners, and promotes xeriscape landscaping. The city installed 37,903 low-flow shower-heads and 52,471 toilet dams from 1984-1990 to reduce demand for building-use. Austin issued ordinances mandating retrofits for commercial and residential customers as well as a low-flow toilet rebate. The toilet replacement program distributed over 50,000 toilets and as of 2005; the program had saved more than 700,000 gallons per day (GDP) of water. The city also requires metering for commercial properties and multi-family homes. Austin has increased public awareness about water scarcity and conservation by joining the Lower Colorado River Authority on the Water IQ campaign. The city is developing an online tool to help consumers analyze and audit their own water use.[20]

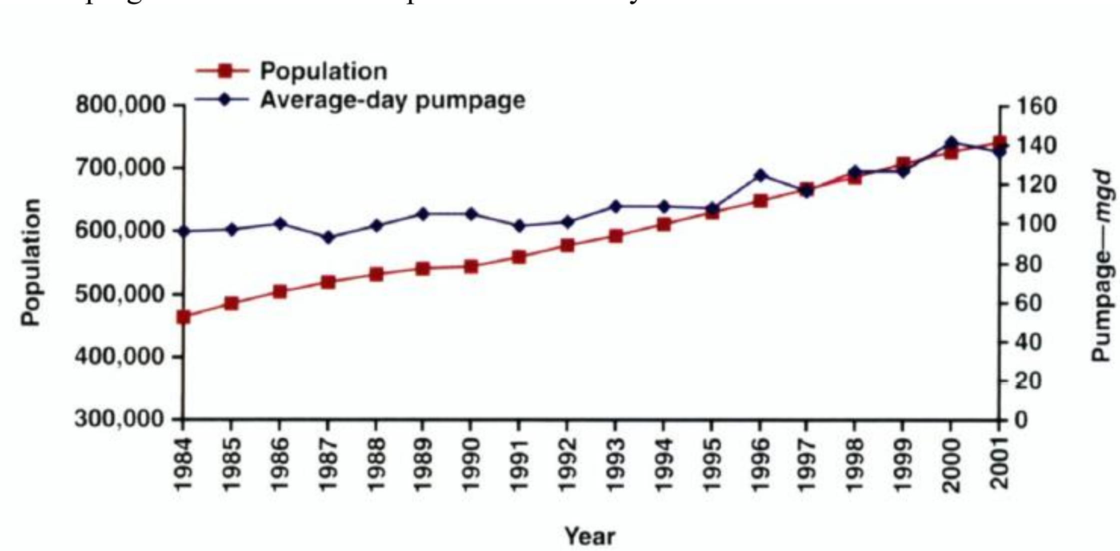

Figure 2.2: Austin area population and total water use changes from 1984-2001.[22]

Year	Inefficiency	Program	Peak Day Savings Per Measure	Savings Through 2005 *gpd*	Avoided Cost of Infrastructure *$3.48/gpd*
1984	Excessive irrigation	Watering restrictions	Not quantified		
1984	Excessive irrigation	Xeriscape education	1 gpd/person	4,676	$16,272
1986–90	Inefficient shower heads	Door-to-door retrofit	Not quantified		
1986–90	Inefficient toilets (existing)	Door-to-door retrofit with dams	Not quantified		
1991	Inefficient toilets (new)	City ordinance for 1.6 gpf (6 Lpf)	13.8 gpd/single family, 15.2 gpd/multifamily, 26.0 gpd/commercial	993,099	$3,455,984
1991–92	Inefficient fixtures (new)	State and federal legislation	No additional savings beyond 1991 city ordinance		
1992	Excessive irrigation	Irrigation audits	100 gpd/single family	483,500	$1,682,580
1993–present	Inefficient toilets (existing)	Incentives for retrofitting	13.8 gpd/single family, 15.2 gpd/multifamily, 26.0 gpd/commercial	1,424,163	$4,956,087
1993–present	Inefficient shower heads	Distribute free shower heads	7 gpd/fixture	197,428	$687,049
1994	Excessive irrigation	Incentives for water-wise plants	100 gpd/property	75,900	$264,132
1994	Excessive commercial irrigation	Revised commercial landscape ordinance	100 gpd/property	65,500	$227,940
1996	Water-inefficient commercial processes	Incentive to switch to efficient processes	Dependent on savings achieved	2,192,503	$7,629,910
1997	Irrigation water waste	Provide free hose timers	5 gpd	26,040	$90,619
1998	Inefficient clothes washers	Efficient clothes washer rebates	15 gpd/appliance	244,250	$849,990
1999	Irrigation water waste	Ordinance prohibiting water waste	Not quantified		
2000	Two-, three-, and four-dwelling properties not separately metered	Rule requiring separate meter for new construction	Not quantified		
2000	Commercial buildings not managing water use	Rule requiring separate irrigation meter for new construction	Not quantified		
2001	Apartments not individually metered	State submetering legislation	Not quantified		
2001	Rainfall not collected	Sell subsidized rain barrels; offer rebates for larger systems	5.5 gpd/barrel; larger systems dependent on storage capacity	49,177	$171,136
2003	Ultralow-flush toilets not retaining flush volumes	Offer rebates for toilets that maintain flush volume	Reinforces previous savings		
2004	Restaurant water waste	Distribute free spray rinse valves; conduct indoor and outdoor audits	200 gpd/spray valve	19,200	$66,816
2004	Limited customer awareness	Electronic newsletter founded	N/A; boosts participation in other programs		

N/A—not applicable

Table 2.2: Austin water conservation initiatives.[22]

Chapter 3: Water Conservation in Higher Education

Sustainability programs, and particularly water conservation programs, at institutions of higher education (HEI), are important for several reasons. University campuses are comparable to small- and medium-sized cities due to the relative extents of their populations, acreage, resource consumption and environmental impacts. As small cities, their resource use is not enormous, but can be considerable especially in regions that face periodic or prolong drought conditions. Approximately 6 percent of the total water used in commercial and institutional facilities takes place in schools, universities, museums and libraries.[17] Water use on university campuses can be reduced through conservation programs that focus on efficiency technology and behavioral changes.

HEIs can act as living laboratories where technological and behavioral innovation flourish. Research facilities in HEIs play an important role in developing and experimenting with tech-based conservation strategies and can introduce and train generations of students to behave in a more sustainable manner.[5;6] Campus water conservation programs have the potential to be effective forces of change to combat the growing threat of water scarcity.

Water Use and Conservation

Higher education campuses use water resources for irrigation, use in buildings, and utilities. The largest water demands on educational campuses are from restrooms, landscaping, heating and cooling, and cafeteria kitchens as shown in Figure 3.0. According to the EPA's *Watersense* program, estimates suggest that implementing water-efficient strategies can decrease both energy and water use by 10 percent and 15 percent respectively on HEI campuses. Along with reducing resource use, these measures can also decrease operating costs by 11 percent.[17]

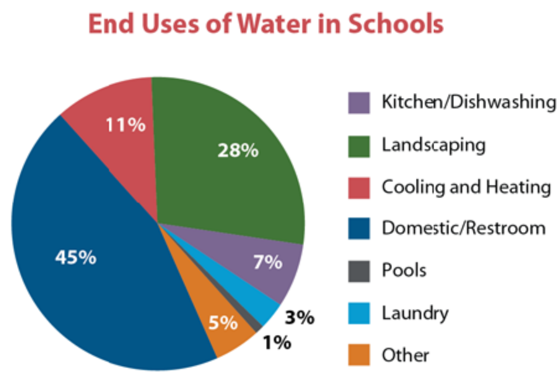

Figure 3.0: Percentages of major water uses at educational institutes.[17]

Water scarcity is a global problem that universities and colleges in drought-prone regions are attempting to address and ameliorate. Water conservation initiatives and studies executed on university campuses in Brazil, Ghana, and Mexico highlight successes and challenges to water conservation implementation in areas affected by water scarcity.[5;6;23] These studies are some of the few published literature about water conservation initiatives on HEI campuses and helped to shape this project on water conservation on campuses in Texas.

The AGUAPURA program at the Federal University of Bahia (UFBA), in the northeast of Brazil, ran from 1999-2008 and reduced per capita water use by half.[5] The program focused on collecting consumptive practice data through metering and featured online reporting to increase public awareness of water use. Online reporting allowed users to be more aware of the consequences of their behavior by giving them access to daily and monthly water consumption data in each building. The program faced difficulties because it was largely organized and operated by researchers and students and was not fully incorporated into the administrative routines of the university. The UFBA does not have any managerial routines which focus on environmental goals and the researchers felt that the program remained only an academic experiment without the practical support of the administration and staff. The shortcomings addressed in this study prompted the survey questions that inquired about governance and policy as well as courses and workshops provided to campus faculty and staff.

A university in Kumasi, Ghana, surveyed students from six residence halls about their water use to determine target reduction areas. The study found that the average per capita water use was approximately 115 liters per day and with the greatest water use coming from bathing.[23] The study calculated that retrofitting showerheads with water-efficient fixtures would reduce the annual water demand by over 30 percent. The study also found that the payback time period would be only six and a half years making the proposed project economically feasible. The efficiency of retrofitted showerheads found in this study inspired the survey questions about the use and degree of implementation of low flow plumbing on Texas' campuses.

The University of Sonora in northwestern Mexico implemented a Sustainability Management System (SMS) in order to optimize their water use. The researchers concluded that water resource decisions on HEI campuses should be based on an efficiency-benefit ratio, rather than a cost-benefit ratio.[6] The efficiency-benefit ratio takes into account the environmental and other impacts, such as water scarcity in the Sonora region, without deeming costs to be the most important factor. The researchers determined that reducing the water waste must not be based merely on cost savings. The results of this study prompted survey questions about influential factors contributing to water conservation initiatives on Texas' HEI campuses and project funding.

TRACS WATER CONSERVATION SURVEY

In the fall of 2013, the Texas Regional Alliance for Campuses Sustainability (TRACS), a voluntary state-wide organization, launched an evaluation of water conservation strategies being implemented on Texas's HEI campuses. The goal of the evaluation was to form a collaborative database of best practices and increase the dialogue surrounding water conservation efforts on campuses throughout the state. The project collected data from participating HEIs about water conservation strategies in five areas: irrigation and landscaping, building use, utilities, education, and governance and policy through an online survey.

The comprehensive survey was designed so that multiple individuals from a participating HEI could report and submit data on sections pertaining to their expertise or employment. In order to generate a clear picture of water use and management, it was necessary to involve staff from different departments and subsequently aggregate and consolidate responses for each HEI. The survey requested multiple choice responses pertaining to which and to what degree water conservation methods were used on a campus. The degrees of implementation included appropriate use, use in some areas of campus, and no use on campus. Participants were also asked how effective the methods were perceived to be, and finally if the HEI had any plans to modify or augment conservation methods in use. The survey provided areas for write-in responses if the multiple choice matrices did not include an appropriate response. Additionally, the participating HEI were surveyed on water conservation education efforts taking place on campus as well as the administration's water resource goals and policies.

There are 176 HEIs in the state of Texas and 22 institutes voluntarily participated in the survey. Participants were contacted via email or phone by TRACS steering committee members and the low response rate may be attributed to insufficient outreach and lack of involvement of targeted HEI personnel. The participating HEIs represent public, private, and community institutions of higher education and range in enrollment size and location as shown in Table 3.0. Some schools participated more fully and submitted responses to multiple sections. Many participating HEIs could only partially complete the survey. In this instance, the lack of data expresses quite a bit of information about the significance of water conservation in some areas.

Participants in the TRACS survey include 13 public, 2 private, and 7 community colleges. Their enrollment can be classified into 5 size ranges. Size 1 included small (under 1500-5000 students) medical research institutes. Size 2 included schools ranging in enrollment size from over 5,000 to under 10,000. Size 3 included that most amount of institutes with enrollment ranging from over 10,000 to 20,000. Size 4 included only public schools and ranged in enrollment from over 28,000 to under 40,000. The largest HEI size classification included schools with enrollment over 50,000.

Institute	Enrollment	Size	TWDB Planning Region
Baylor College of Medicine	1,486	1	Region H
University of North Texas Health Science Center	1,760	1	Region C
University of Texas Medical Branch	2,255	1	Region H
University of Texas Southwestern Medical Center	4,590	1	Region C
Midwestern State University	5,870	2	Region B
Cedar Valley College	6,222	2	Region C
University of Texas Tyler	7,500	2	East Texas
Mountain View College	10,000	3	Region C
Southern Methodist University	10,893	3	Region C
North Lake College	10,932	3	Region C
DCCCD/Brookhaven College	12,900	3	Region C
Richland College	19201	3	Region C
University of Texas San Antonio	28623	4	South Central Texas
Texas Tech University	33111	4	Llano Estacado
University of Texas at Arlington	33806	4	Region C
Texas State University	34225	4	South Central Texas
University of Houston	39540	4	Region H
University of Texas at Austin	52213	5	Lower Colorado
Texas A&M College Station	53187	5	Region G
Austin Community College District	60100	5	Lower Colorado
Lone Star College	90000	5	Region H

Table 3.0: Table of participating HEIs with their corresponding enrollment from the most recent year available, their size category, and the TWDB planning region where they are located.

The participating HEIs are clustered in major cities such as Dallas, Austin, San Antonio, and Houston, but some are more rural. The campuses are located in TWDB regions B, C, G, H, East Texas, South Central, Llano Estacado, and the Lower Colorado. Many of these areas are affected by drought and water scarcity as shown in Figure 3.1.

Current water conservation efforts at these HEI campuses are already providing a reliable water supply in regions where demand is currently or is projected to exceed supply in the future. Implementing water conservation methods and instilling sustainable behavior in students on campuses of HEIs could impact water resource use in these regions.

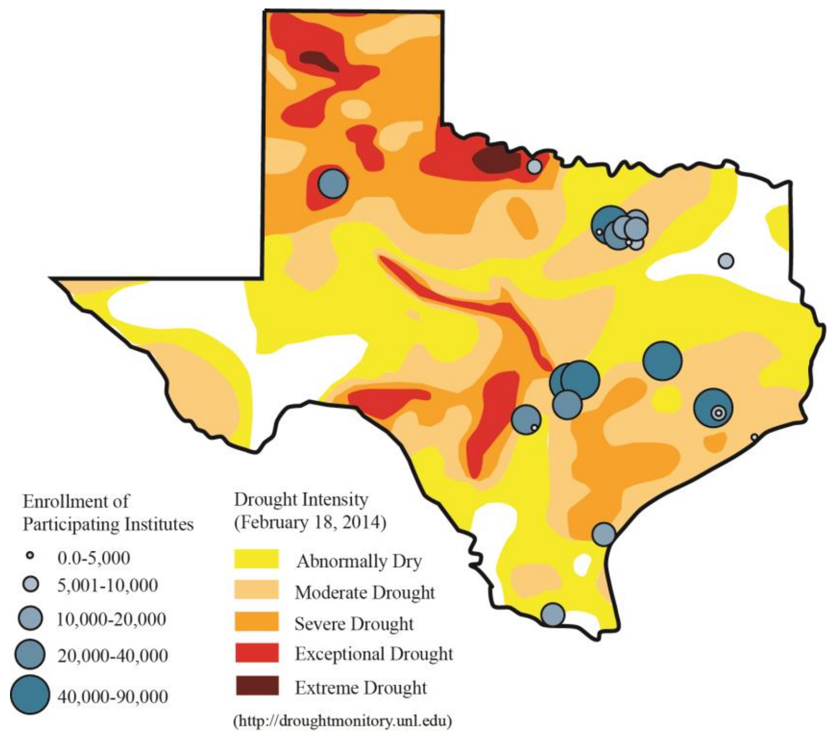

Figure 3.1: Map of Texas with recent drought conditions[13] featuring the locations of participating HEIs.

WATER CONSERVATION SURVEY RESULTS

Many of the HEIs that participated in the survey are in water-stressed planning regions that have been affected by the recent drought. All of the HEIs reported using water conservation in some capacity on their campus. When asked to rate the importance of factors that encouraged their HEI to invest in water conservation methods, the majority reported that water shortages and the drought were the most important factors influencing their choice (Figure 3.2). Also, none of the participating HEIs rated these two factors as the least important. Regulation requirements and cost savings were also rated as most important for many HEIs. Incentives, educational demonstration, administration demand, and building code requirements were not rated as very highly as influencing factors.

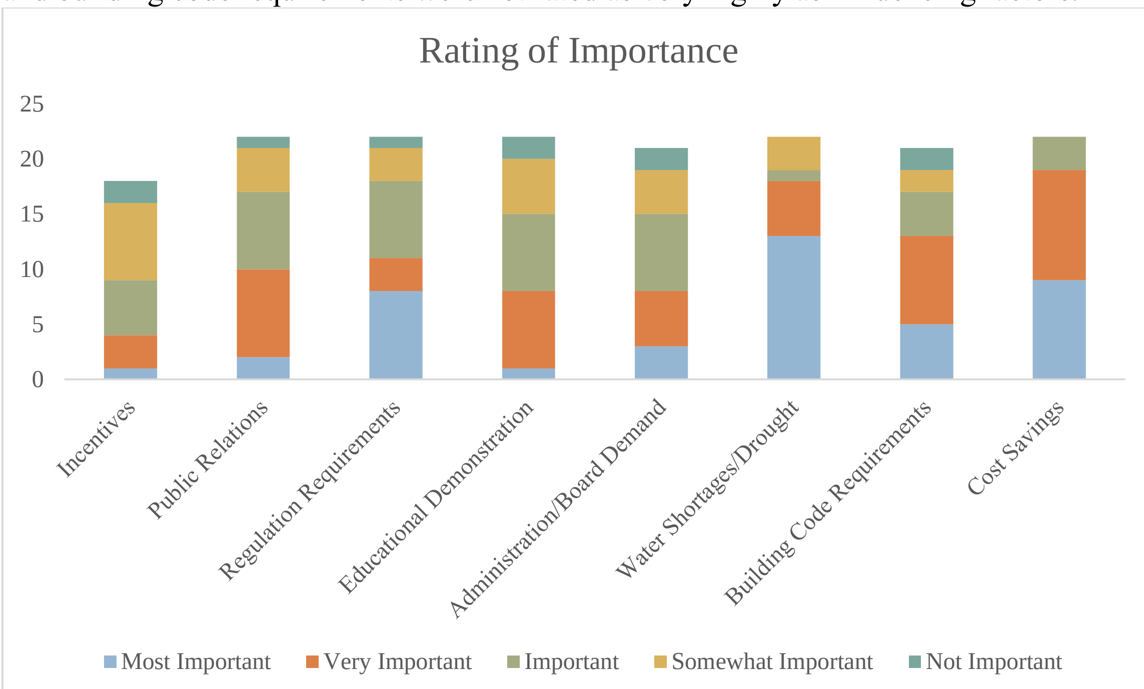

Figure 3.2: A graph of the rated importance of reasons for conserving water on HEI campuses.

Irrigation

Irrigation is one of the largest water demands on higher education campuses. As such, many participating HEIs were able to report on water conservation methods used on their campuses for landscaping and irrigation. The average number of irrigated acres on an HEI campus was below 200 acres. The average annual consumption for irrigation purposes was nearly 50,000,000 gallons/year. For participating HEIs that reported irrigation information, the average application rate was 241,020 gallons/acre/year, but due to the wide range of campus sizes and number of irrigated acres, the standard deviation is great (Table 3.1). Larger campuses tended to use more water in general and more water per acre of land. There were not enough responses for statistical significance, but some overall trends can be observed in water conservation methods among the different size classifications and water planning regions.

Size Class	Average gallons/acre
1	34,752
2	23,248
3	144,474
4	50,546
5	445,258

Table 3.1: Table of average gallons of water used per acre in five HEI enrollment size classification.

The most widely-used water conservation technique for irrigation among participating HEIs was the use of native or adaptive plants and drip irrigation (Figure 3.3). All of the HEIs responded that they used native or adaptive plants to some degree on their campus with 80 percent using it everywhere that is appropriate, and 20 percent using it only in some areas of the campus as shown in Figure 3.4. All of the HEIs reported using drip irrigation to a degree, but fewer HEIs reported using drip irrigation everywhere that is appropriate, and 40 percent reported only using it in some areas. Overall, the least popular water conservation method for irrigation was the use of reclaimed water. Only half of the participating HEIs reported using reclaimed water at all on campus and only 20 percent using it everywhere that is appropriate.

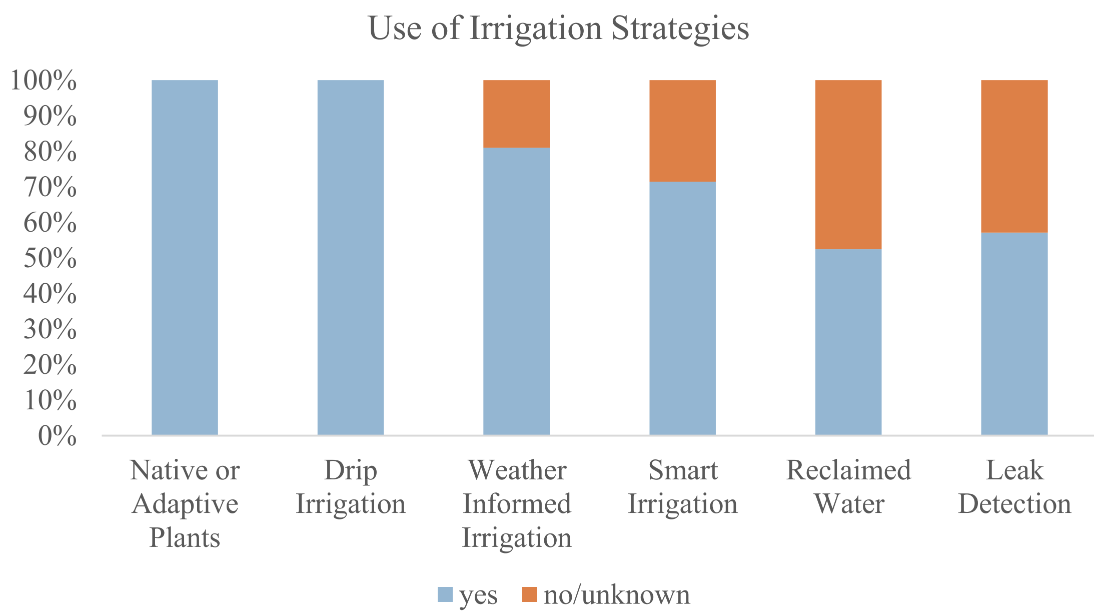

Figure 3.3: Percentage of participating HEIs that reported using water conservation methods for irrigation use to any extent on campus.

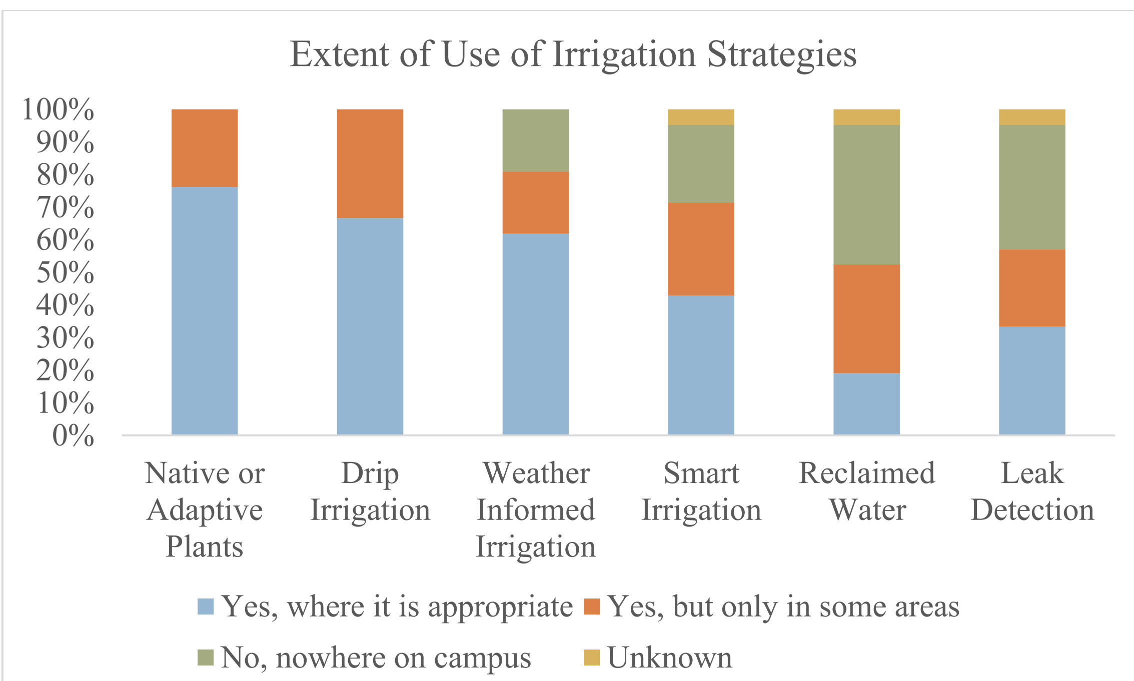

Figure 3.4: Percentage of participating HEIs that reported utilizing a water conservation method for irrigation use to various degrees.

Some irrigation water conservation methods were more popular in certain HEI size ranges (Figure 3.5). Of HEIs within the size 1 classification, 66 percent used both native plants and drip irrigation. The least popular method was reclaimed water. Two-thirds of the schools also used weather-informed irrigation and smart irrigation to some degree on campus. All schools reported use of leak detection, but only one-third used it to the highest degree of implementation (everywhere it was appropriate). HEIs in the size 2 range used implemented fewer conservation methods when compared with smaller schools in the size 1 range. Native and adaptive plants remained the most popular. None of the size 2 HEIs reported using leak detection or smart irrigation as conservation methods. HEIs in the size 3 class reported using more water conservation methods in more areas than size 2 campuses. All of the irrigation conservation strategies were used to some degree on the campuses except for one-third reporting to not use leak detection. Class 4 HEIs reported using reclaimed water less than class 3 campuses. Smart irrigation, reclaimed water and leak detection were the least used methods on class 4 campuses. Similar results are present in the class 5 campuses. Use of leak detection was the most variable water conservation method among the five size classes.

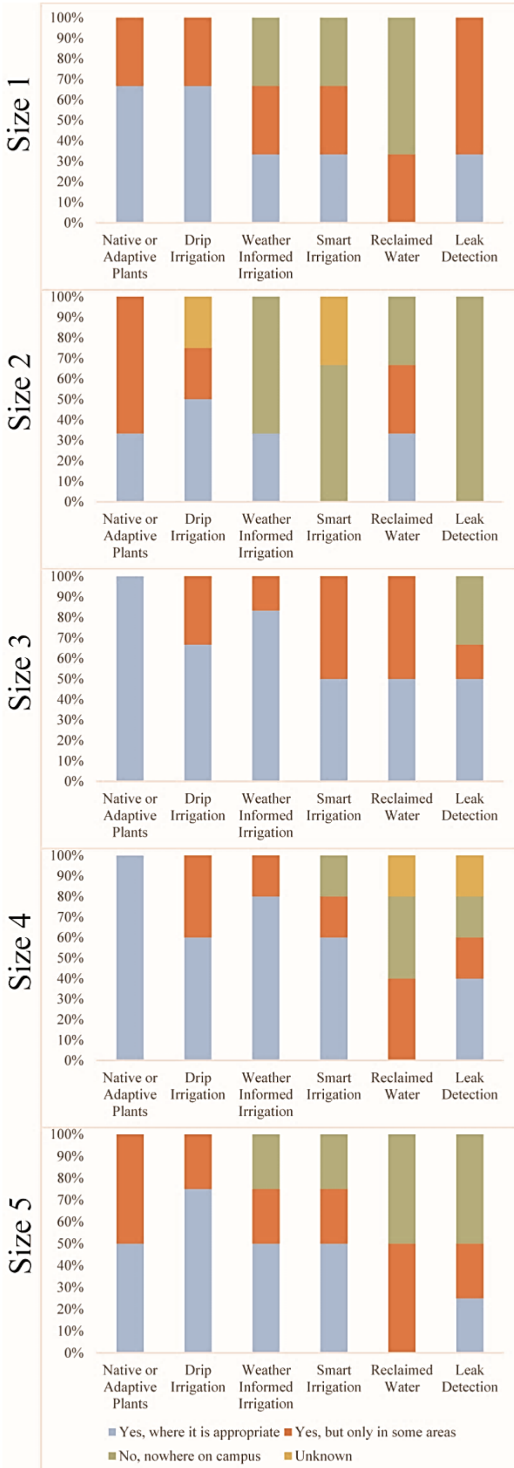

Figure 3.5: Extent of use of irrigation water conservation methods in five size classification.

While some regions are only represented by one institute (regions B, G, Llano Estacado, and East Texas), minor regional trends in irrigation water conservation can still be observed in the Texas HEIs. Native and adaptive plants were reportedly used to some degree on all campuses throughout the state as shown in Figure 3.6. HEIs in the dryer western portion of the state reported more wide-spread use of native and adaptive plants than campuses in the east where some institutes reported use only in some areas. More western HEIs reported use of weather-informed irrigation than campuses in the wetter regions in the east.

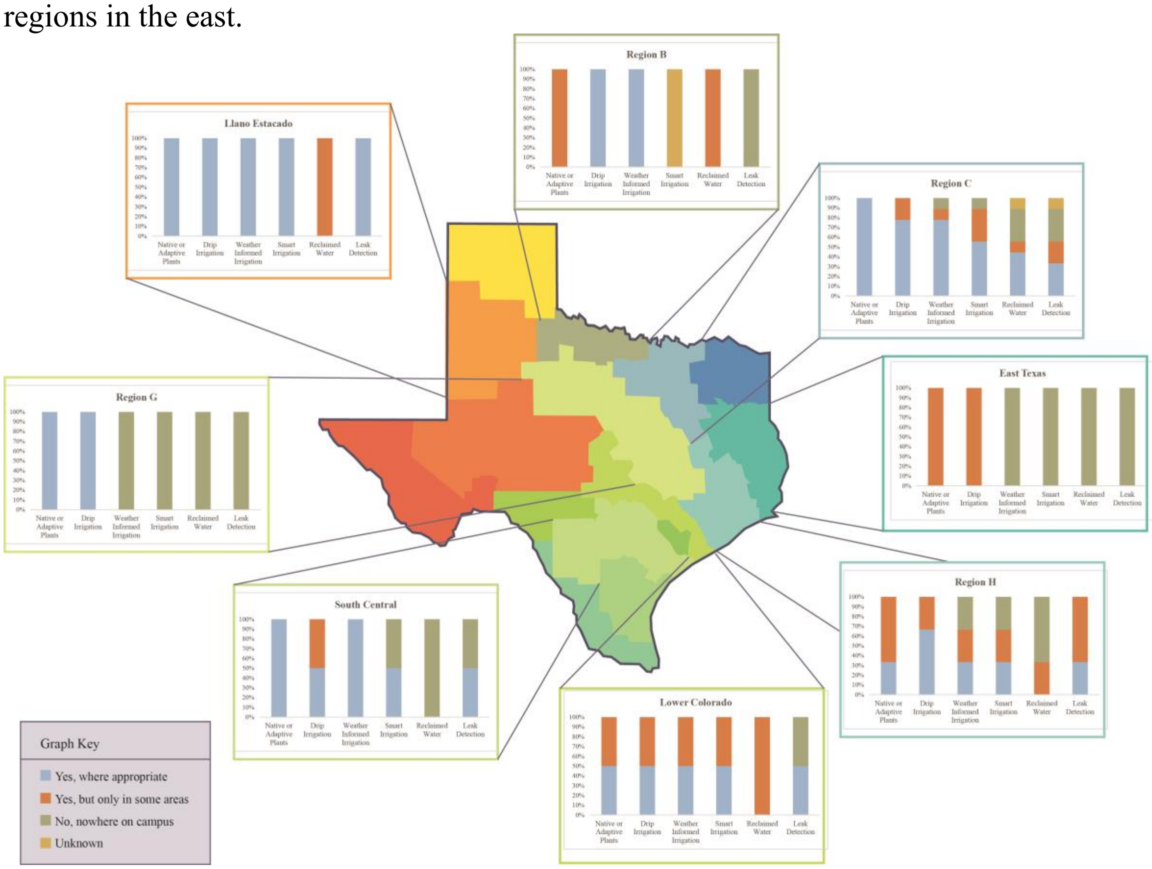

Figure 3.6: Map of TWDB regions and graphs depicting the extent of adoption of water conservation methods within regions B, C, G, H, East Texas, Lower Colorado, Llano Estacado, and South Central.

HEIs that reported use to any degree of an irrigation water conservation method also reported on the perceived effectiveness of those methods, rating them most effective, effective, somewhat effective, least effective and unknown. Overall, the use of native and adaptive plants, leak detection, and smart irrigation had the largest percentage of users rating them at the most effective (Figure 3.7). However, drip irrigation and native and adaptive plants were the only conservation methods that received a "least effective" response from HEIs that used them. The effectiveness of a method may be affected by the degree of use as shown in Figures 3.8 and 3.9. Fewer methods were rated most effective if use was limited on campus. Although used by fewer HEIs, leak detection had a limited range of responses from effective to most effective even when it was only used in some areas.

Figure 3.7: The perceived effectiveness of irrigation water conservation methods if used to any extent on a campus.

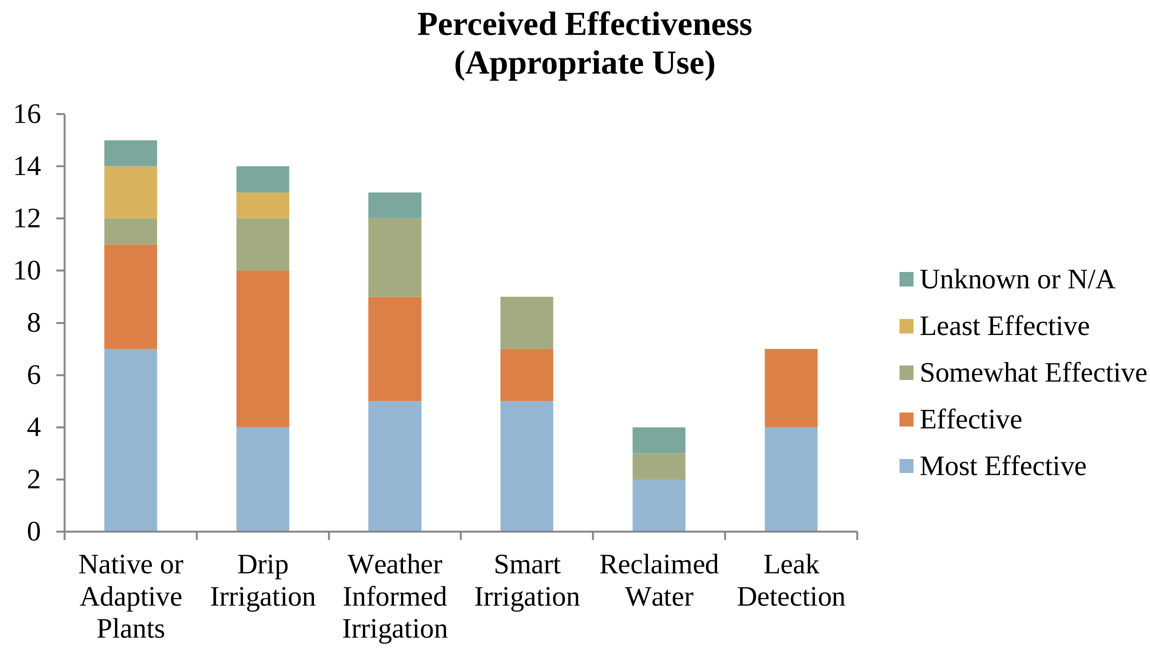

Figure 3.8: Reported effectiveness of irrigation water conservation methods if the method was used in all appropriate areas of campus.

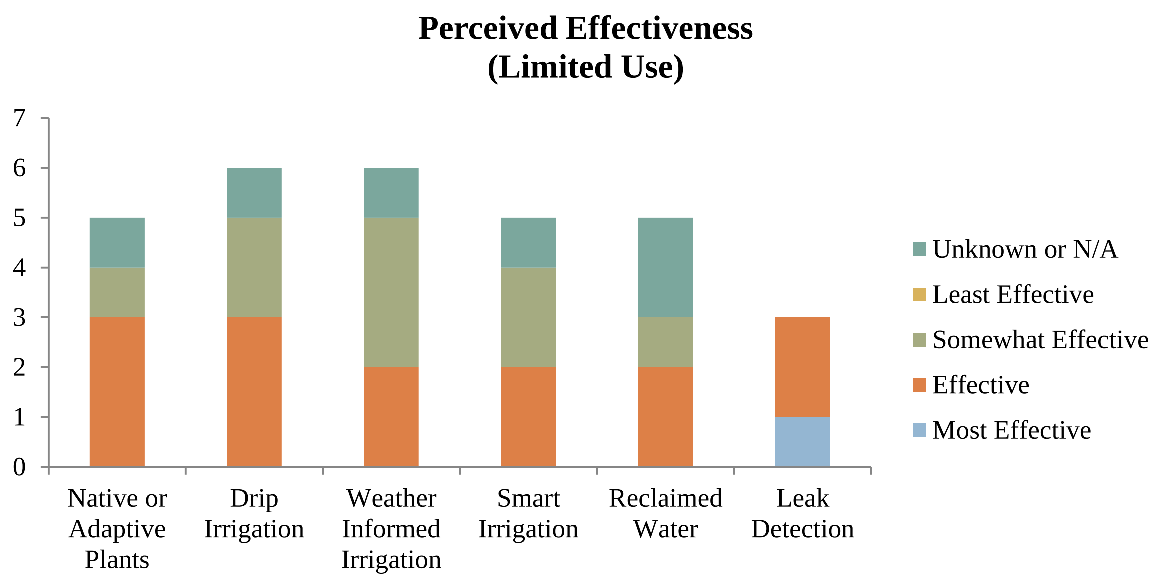

Figure 3.9: Reported effectiveness of irrigation water conservation methods if the method was used in only some areas of campus.

Building Use

One of the largest water demands on campuses of HEIs comes from building-use, particularly in restrooms. Of the 14 HEIs that reported water use in buildings, the average gross building area on campus was nearly 7.5 million ft^2. The average annual reported water consumption for building-use was over 217 million gallons. Many of the community colleges reported lower annual consumptions likely due to the higher population of students that commute to campus and fewer residents on campus. Restrooms, including those in resident dormitories, generate the highest water demands in buildings.

The most widely-used water conservation methods for building-use were low-flow plumbing fixtures (Figure 3.10). Nearly 95 percent of the participating HEIs reported use of low-flow toilets, faucets, and showers to some extent on campus. Low-flow faucets received the most reported use with 75 percent of the HEIs reporting use in all appropriate places on campus as shown in Figure 3.11. Waterless urinals were the least used water conservation method on HEI campuses in Texas.

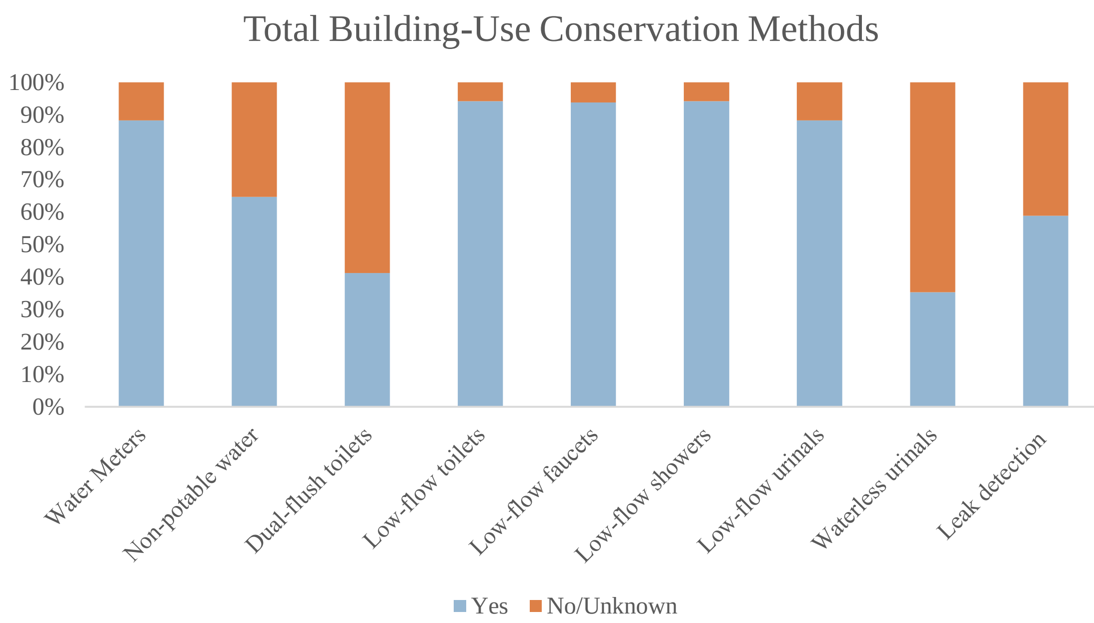

Figure 3.10: Percentage of participating HEIs that reported using a water conservation method for building-use to any extent on campus.

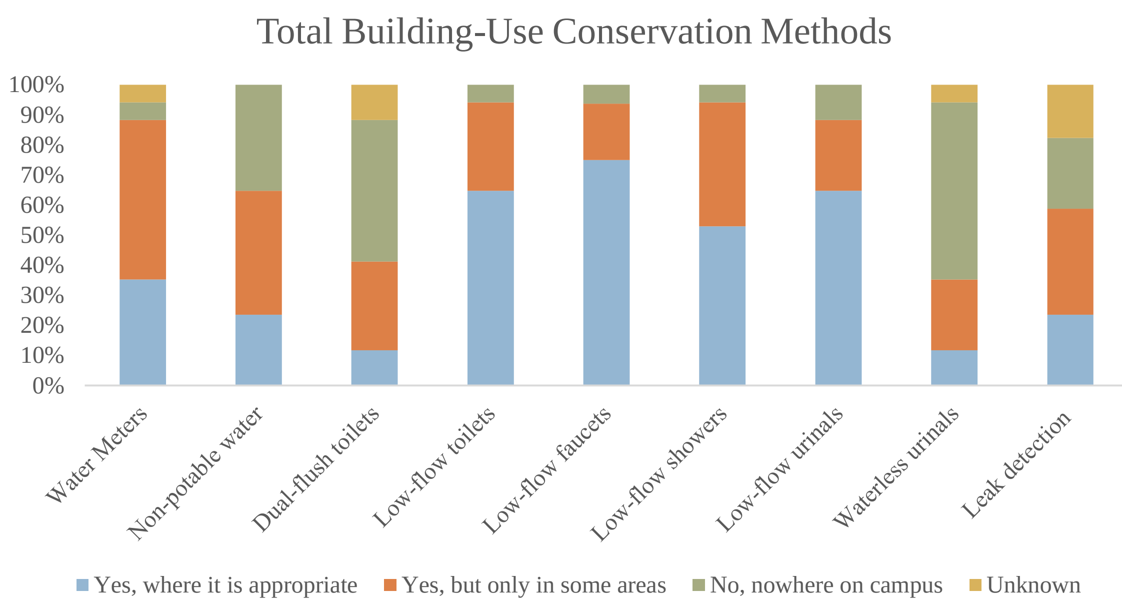

Figure 3.11: Percentage of participating HEIs that reported utilizing a water conservation method for building-use to various degrees.

Although the data is limited, some trends related to HEI size can be observed in the reported use of water conservation methods on campuses (3.12). Dual flush toilets were not a very popular conservation strategy; only 40 percent of participating HEIs reported use to any extent on campus. HEIs in size ranges 1 and 2 did not report use of dual flush toilets and the technology only become utilized in sizes 3 through 5. The extent of non-potable water use varied throughout the size classifications. Size 4 HEIs reported the most use of non-potable water, with all HEIs using it to some extent and over half using it everywhere that is appropriate.

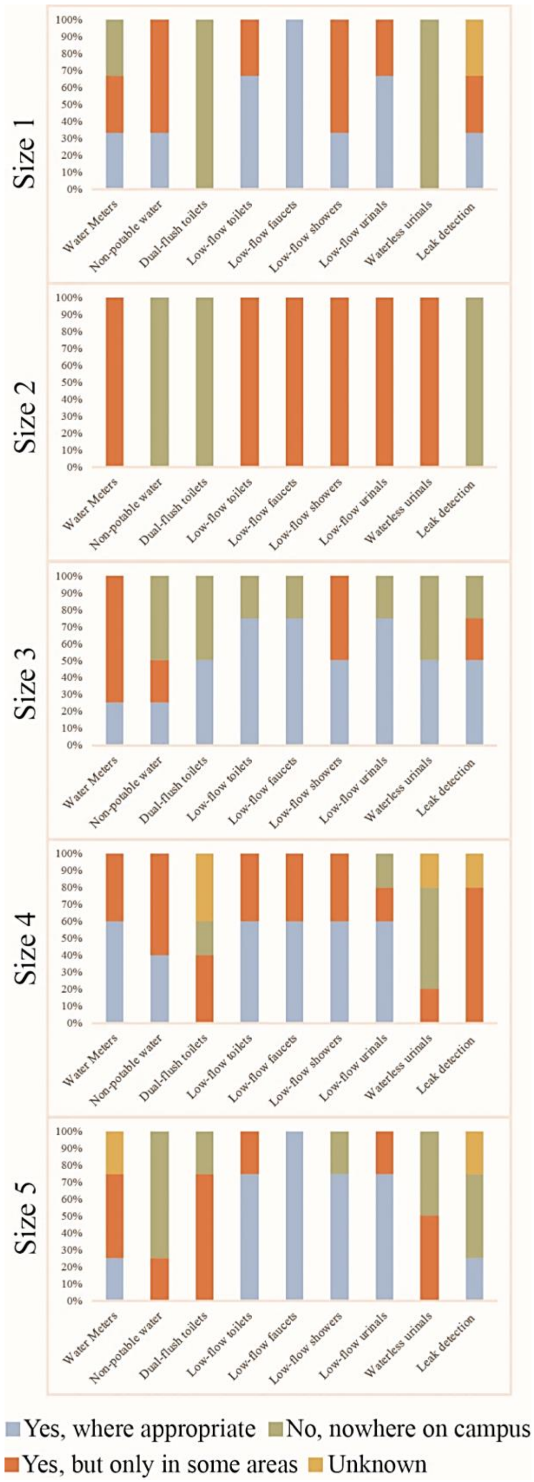

Figure 3.12: Extent of use of building-use water conservation methods in five size classifications.

Regionally, use of water conservation methods in buildings varied greatly, but with few visible trends. Region B, the Llano Estacado, and Region G are under-represented with only one HEI reporting on water conservation methods in buildings per region. The uneven distribution of participating HEIs makes it difficult to conclude any regional preferences for conservation strategies (Figure 3.13).

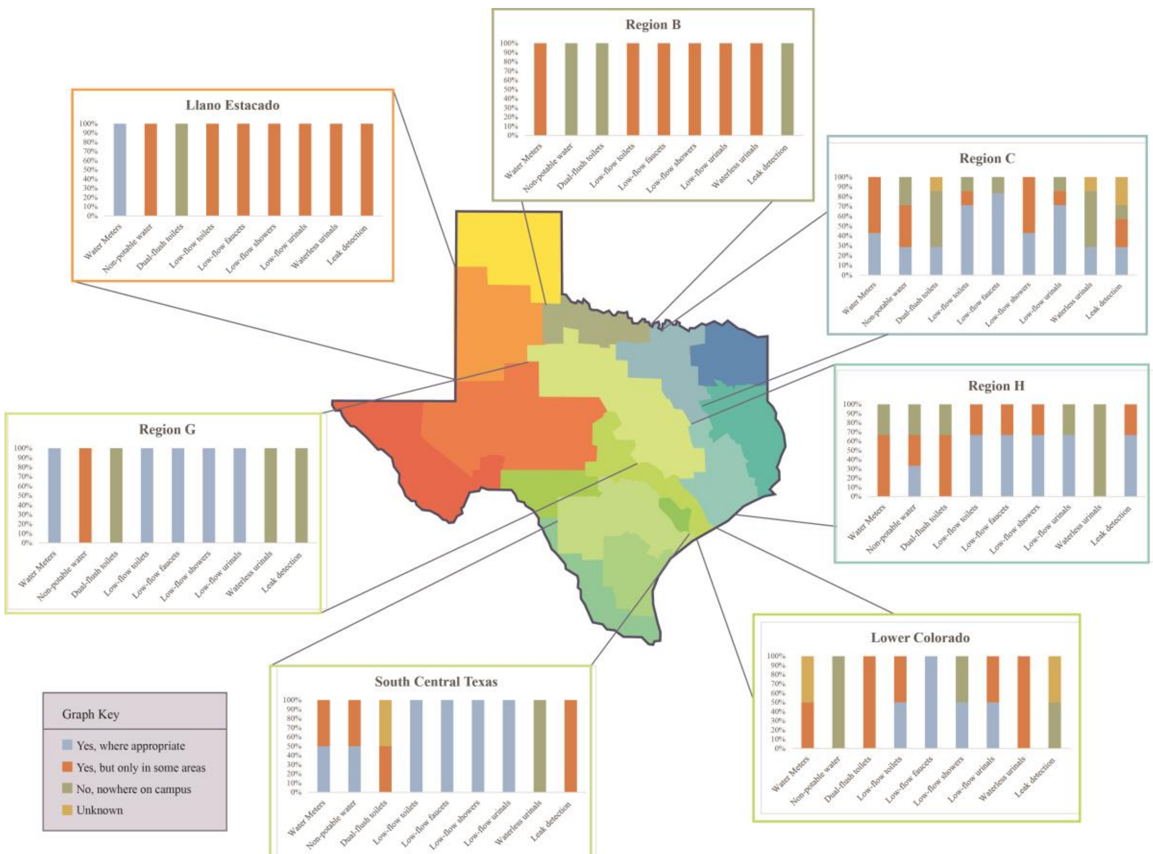

Figure 3.13: Map of TWDB regions and graphs depicting the extent of adoption of water conservation methods within regions B, C, G, H, Lower Colorado, Llano Estacado, and South Central.

HEIs that reported use to any degree of water conservation methods for building-use also reported on the perceived effectiveness of those methods, rating them most effective, effective, somewhat effective, least effective and unknown. Most of the methods received very mixed results. Low-flow plumbing fixtures were perceived as the most effective by the most users. None of the participating HEIs perceived low-flow faucets as the least effective method. Dual flush toilets and waterless urinals were perceived as the least effective by the most users. Use of water meters and non-potable water were reported to be effective with nearly 75 percent of participating HEIs reporting them to be somewhat effective to most effective. The effectiveness of leak detection had the least known results from survey participants.

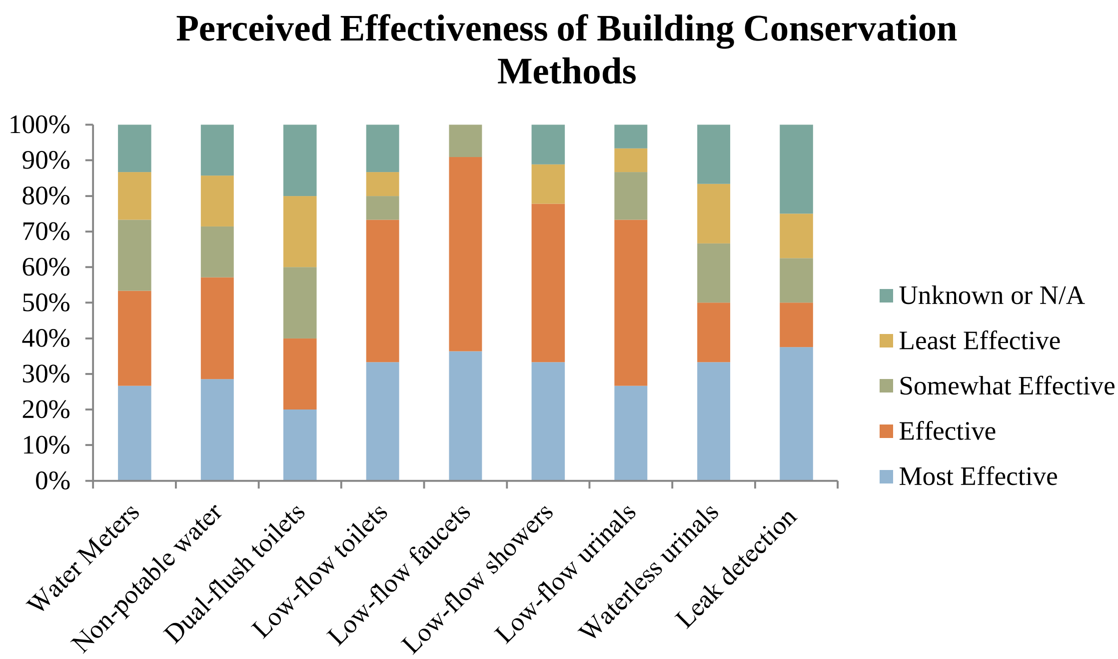

Figure 3.14: The percentages of perceived effectiveness of building-use water conservation methods if used to any extent on a campus.

Participants that reported using water conservation methods anywhere that is appropriate on campus generally perceived higher effectiveness of the method. None of the participating HEIs used dual-flush toilets to a large extent, but all of the other methods that were used appropriately were reported to be largely the most effective or effective. With limited use, the perceived effectiveness varied greatly for any given conservation method. Water meters and dual-flush toilets were perceived as the least effective by the most participants with limited use.

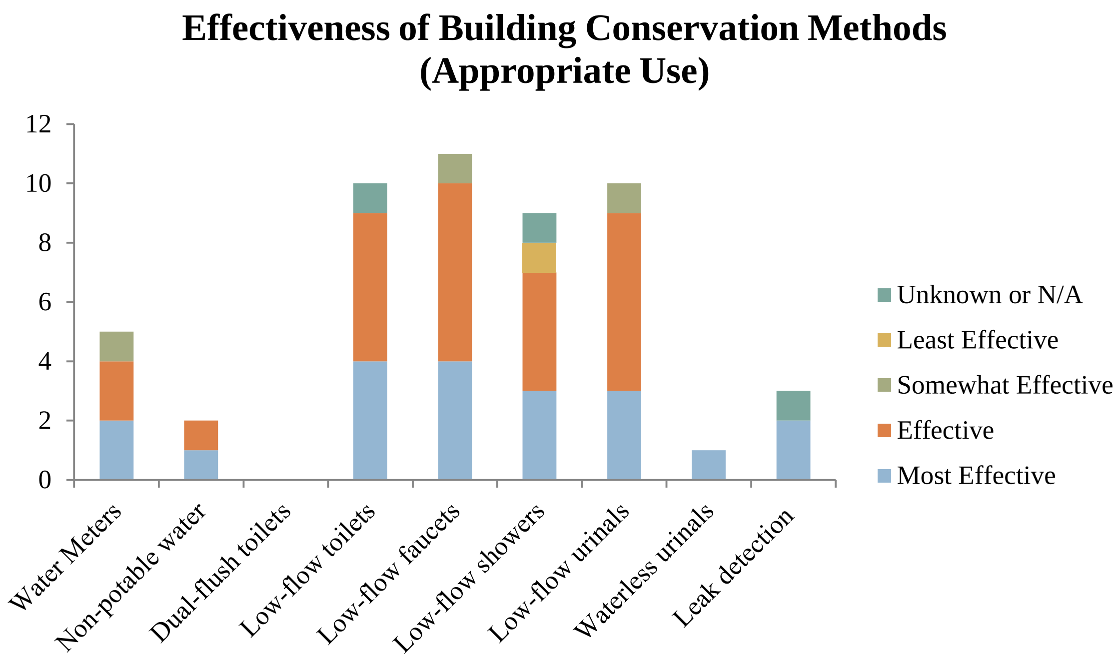

Figure 3.15: Reported effectiveness of building-use water conservation methods if the method was used in all appropriate areas of campus.

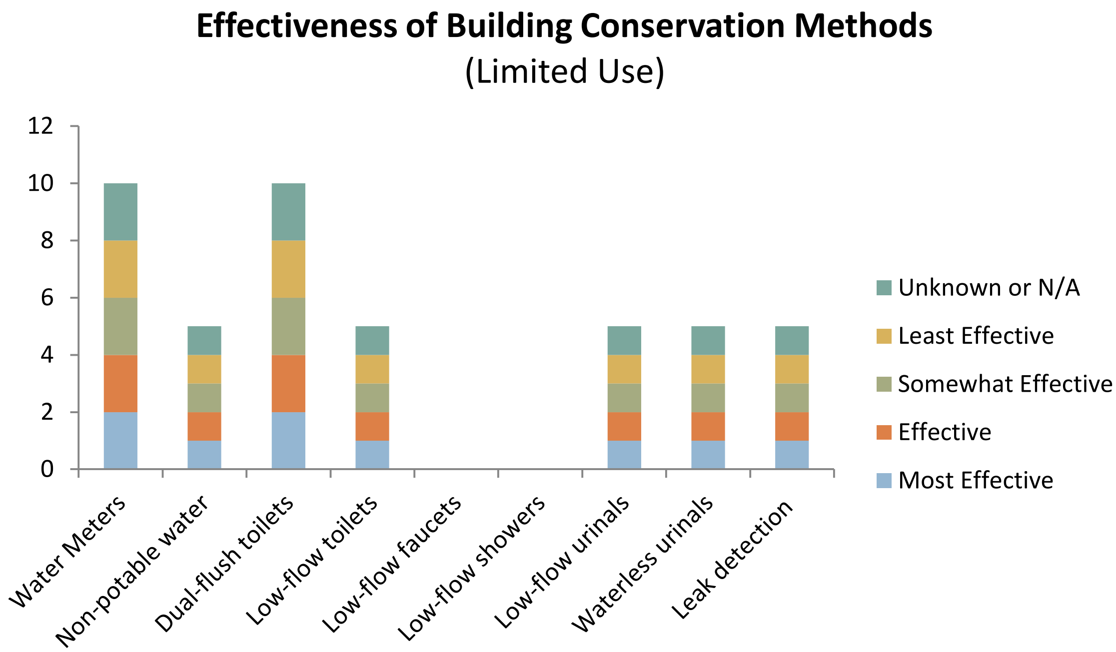

Figure 3.16: Reported effectiveness of building-use water conservation methods if the method was reportedly used in only some areas of campus.

Utilities

HEI campuses in Texas use large quantities of water for utilities such as cooling and electricity. The average annual water consumption for participating institutes' utilities was just under 4.7 million gallons. Most HEIs receive electricity from a municipal utility and do not provide their own electricity on campus. The exceptions are the two largest public universities in the state which have their own power plants. The majority of HEI provide their own cooling on campus. Large quantities of water are consumed by cooling towers due to evaporation. Many HEIs reported no water conservation strategies for cooling towers. Campuses that use water conservation methods for cooling towers mentioned leak detection and metering for evaporation, maintenance and upgrades to fin fan coolers, and chemical water treatment, multi-cycle cooling, and use of reclaimed water and condensate. One HEI reported substituting aircooled equipment when possible. Metering, maintenance, and reusing water were viewed as the most effective water conservation methods for utilities.

Education

HEIs can play an important role in educating students, faculty, and staff about sustainable technology and behavior, especially pertaining to water use. Half of the participating HEIs reported that their institute offered workshops or co-curricular courses on water conservation for faculty and staff. Nearly 70 percent of participating HEIs reported offering for-credit courses covering water conservation to students. Close to 64 percent of HEIs reported that they were student groups focusing on water conservation at their institute. A large majority (75 percent) of HEIs reported water-related research was occurring at their institute. Just over 60 percent of participating HEIs reported that there are opportunities for students to work with staff members on water conservation projects on their campus. Education about water conservation has been shown to greatly reduce water use[2]. Of the participating schools that reported a reduction in annual water consumption, 63 percent also reported offering courses or workshops as shown in Table 3.2.

	Reduction in Water Consumption	No Reduction in Water Consumption
Workshops or co-curricular courses offered	5	0
No workshops or co-curricular courses offered	3	3

Table 3.2: Number of schools that reported offering or not offering workshops or co-curricular courses and the number of schools that reported or did not report a reduction in annual water consumption.

Governance and Policy

For water conservation initiatives to be effective, it is important for HEI administrative Figures to create policies that encourage and assist those projects. The majority of participating HEIs reported that their institute had a policy related to water conservation or sustainability practices. Seven of the participating HEIs have approved policies, and three had pending policies related to water conservation. Fewer HEIs had conservation strategic plans or target reductions. Two-thirds of participating HEIs reported having conservation funds to support water conservation initiatives on their campus. Over half of the HEIs are involved with the EPA's *Watersense* or some other agencies with a focus on water conservation. Of the participating HEIs that reported reducing their annual water consumption, all but one reported having an approved or pending water conservation policy for their campus (Table 3.3). The majority of HEIs that reported reductions in consumption also reported having target reductions as shown in Table 3.3.

	Reduction in Water Consumption	No Reduction in Water Consumption
Water Conservation Policy	5	1
No Water Conservation Policy	0	2
Target Reductions	5	0
No Target Reductions	2	3

Table 3.3: Number of participating HEIs that reported a reduction or no reduction in annual water consumption as well as having or not having a water conservation policy and having or not having target reductions.

Conclusions

Water scarcity is a problem affecting the state of Texas. Increased demand due to rapid population and economic growth coupled with stagnant or diminishing supplies have created water shortages in some regions. Recent and persistent drought has further strained resources and complicated water planning. New sources for water supply are often economically or physically unfeasible in regions of Texas. In these areas, the TWDB has recommended that water conservation serve as a new water supply. In cities like Austin and San Antonio, water conservation initiatives were put in place due to infrastructure and supply limitations and have proven to be effective for conserving resources as well as cost savings. Conserving water often postpones the need for additional water rights or expensive new supplies.

Water conservation can be technology-based –such as weather informed irrigation and low-flow plumbing fixtures – or behavior-based. University and college campuses are great places to observe the use and effect of both types of water conservation. Many higher education institutes are also research institutes where cutting edge sustainable technology can be developed, tested, and demonstrated. Exposing students, faculty and staff to technology-based conservation methods and educating them about the importance of water conservation can change the behavior of large groups of people. HEIs are comparable to small cities in terms of their resource use and environmental impact. Educating and training students, faculty and staff about water conservation can help reduce overall resource use on campuses and can ripple beyond the campus when they leave.

The Texas Regional Alliance for Campus Sustainability (TRACS) collected data on water conservation initiatives taking place on campuses of higher education in Texas.

A comprehensive online survey inquired about the degree of use of water conservation methods and their perceived effectiveness in the areas of irrigation, building-use, and utilities. The project also collected data about educational initiatives and overall governance and policies relating to water conservation. Participation in the survey was low. Therefore, conclusions and trends observed are speculative and require more data and further analysis.

The results of the survey determined that drought and water shortages were the most influential reasons for implementing water conservations initiatives on HEI campuses. The survey responses also demonstrated that some water conservation methods are more widely used than others and some are perceived to be more effective. Survey results concluded that native and adaptive plants were the most-widely used water conservation method for irrigation and landscaping as well the most effective. Weather-informed irrigation techniques were more popular in the dryer western portion of the state, although they would be more effective in the eastern portion due to higher precipitation rates. Low-flow plumbing, low-flow faucets in particular, were reported to be the most widely-used and also the most effective for water conservation in buildings. A variety of water conservation measures were implemented for utilities. Metering, maintenance, and reusing water were viewed as the most effective water conservation methods for utilities. Methods that were perceived to be more effective were not always utilized on all of the participating campuses, therefore, there is room to improve in these areas but increasing implementation.

HEI campuses offer an opportunity to change the behavior of students, faculty and staff to achieve sustainability standards. While many HEIs reported offering opportunities for students to learn or participate in research about water conservation, only half reported offering workshops or courses for managerial staff and faculty. Staff and faculty education is an area that should be improved upon because many staff members are closely involved in managing water use on campus. Previous studies have concluded that incorporating water conservation initiatives into all tiers of a campus synchronizes efforts and results in more effective water conservation. Many of the HEIs reported having water conservation policies in place or pending. Some participating HEIs reported having target reduction plans and involvement with agencies related to water conservation. It is important for the administration of educational institutes to put policies and plans in place to guide the everyday operations of a campus.

There is a need for more collaborative sustainability initiatives among HEIs in the state. Sharing best practices, failures, and successes in a network of HEIs would increase the effectiveness of any individual HEIs' sustainability initiatives. Future work on evaluating water conservation efforts on HEI campuses would need to include a different method of data collection. The data collected from voluntary survey participants was insubstantial and unreliable, therefore, conclusions from this evaluation are speculative but hint at water conservation strategy trends within the state. Further work may reveal more obvious trends in water conservation methods used in smaller schools versus larger one, private versus public, as well as regional trends. More accurate and statistically relevant data could show the actual effectiveness of implemented water conservation methods as opposed to the perceived effectiveness and could help to calculate the amount of water conserved using these strategies. These trends could help guide sustainability policy decisions in Texas HEIs.

Appendix

Survey Questions

1. General Information
   1.1. Institute (required)
   1.2. Full Name (required)
   1.3. Department (required)
   1.4. Title (required)
   1.5. Contact Email (required)
   1.6. How many students are enrolled at your institution?
   1.7. How many staff (FTE) are employed by your institution?
   1.8. How many faculty (FTE) are employed by your institution?
   1.9. How many people are housed at your institution?
   1.10. Is your institution public or private?
   1.11. Does your institution use any water conservation methods?
   1.12. How long has your institution utilized conservation methods? (years)
   1.13. How long has your institution been collecting water conservation data? (years)
   1.14. How much total water does you institution consume annually? (calendar year is preferable)
   1.15. If you have or will have water conservation initiatives on campus, please rate the most important factors in your decision to implement these technologies: Incentives, Public Relations, Regulation Requirements, Educational Demonstration, Administration/Board Demand, Water Shortages/Drought, Building Code Requirements, and Cost Savings
   1.16. Do you know if your overall water consumption has decreased on campus in the past 5 years? If yes, p...-Consumption has decreased in the past 5 years (yes, no)? If yes, please enter a reduction percentage, reduction rate, or other metric.
   1.17. What is the water source(s) for your institution?
   1.18. Irrigation and Landscaping
   1.19. How many irrigated acres are on your campus?
   1.20. How much water did your institution consume for irrigation/landscaping purposes (the most recent year available) –Gallons, Year data collected.
   1.21. On average annually, how many gallons per acre are used for irrigation?
   1.22. Does your institution use water conservation techniques for campus irrigation and landscaping?
   1.23. Does your institution use any of the following water conservation techniques on campus?(If you use a method not listed here, please enter it when

prompted later in this section)

	Yes, where appropriate	Yes, but only in some areas	No, nowhere on campus	Unknown
Native or Adaptive Plants				
Drip Irrigation				
Weather Informed Irrigation				
Smart Irrigation				
Reclaimed Water				
Leak Detection				

1.24. If you've implemented any of the water conservation methods below, please rate them on a scale of least effective to most effective in terms of which had the largest measured impact on reducing water consumption.

	Least Effective	Somewhat Effective	Effective	Most Effective	Unknown or N/A
Native or Adaptive Plants					
Drip Irrigation					
Weather Informed Irrigation					
Smart Irrigation					
Reclaimed Water					
Leak Detection					

1.25. Please indicated the priority level of implementing the following water conservation methods

	Already in Use	Will be used in the next year	Will be used in the next five years	Will be used in the future	Not a priority
Native or Adaptive Plants					
Drip Irrigation					
Weather Informed Irrigation					
Smart Irrigation					
Reclaimed Water					
Leak Detection					

1.26. Does your institution utilize any xeriscape landscaping techniques and principles? Planning and Design, Soil Analysis, Plant Selection, Practical Turf Areas, Efficient Irrigation, Use of Mulches, and/or Maintenance

1.27. Does your institution manage storm-water?

1.28. Does your institution employ irrigation management staff?

1.29. What other water conservation measures does your institution use for irrigation/landscaping?

1.30. Which measures have been most effective in saving water for irrigation and landscaping?

2. Building Use: General and Educational

2.1. How many gross square feet are on your campus?

2.2. How much water did your institution consume for general and educational building (most recent year available) – Gallons, Year data collected

2.3. Does your institution use water conservation methods for building use?

2.4. Does your institution use any of the following water conservation methods in campus buildings?(If you use a method not listed here, please enter it when prompted later in this section)

	Yes, where appropriate	Yes, but only in some areas	No, nowhere on campus	Unknown
Building water meters				
Use of non-potable water				
Dual-flush toilets				
Low-flow toilets				
Low-flow faucets				
Low-flow showers				
Low-flow urinals				
Waterless urinals				
Leak detection and reduction				

2.5. If you've implemented any of the water conservation methods below, please rate them on a scale of least effective to most effective in terms of which had the largest measured impact on reducing water consumption.

	Least Effective	Somewhat Effective	Effective	Most Effective	Unknown or N/A
Building water meters					
Use of non-potable water					
Dual-flush toilets					
Low-flow toilets					
Low-flow faucets					
Low-flow showers					
Low-flow urinals					
Waterless urinals					
Leak detection and reduction					

2.6. Please indicate the priority level of implementing the following water conservation methods

	Already in use	Will be used in the next year	Will be used in the next 5 years	Will be used sometime in the future	Not a priority	Unknown or N/A
Building water meters						
Use of non-potable water						
Dual-flush toilets						
Low-flow toilets						
Low-flow faucets						
Low-flow showers						
Low-flow urinals						
Waterless urinals						
Leak detection and reduction						

2.7. What other water conservation measures does your institution use for building use?

2.8. What measure has been most effective in saving water for building use on your campus?

3. Building Use: Auxiliary (Athletics, recreational sports, residential housing and food)

3.1. How much water did your institution consume for auxiliary building use (in the most recent year available? –Gallons, Year data collected

3.2. How many irrigated acres does your institution have for auxiliary areas?

3.3. Does your institution use water conservation methods for auxiliary building use?

3.4. Does your institution use any of the following water conservation methods in auxiliary campus buildings

	Yes, where appropriate	Yes, but only in some areas	No, nowhere on campus	Unknown
Building water meters				
Use of non-potable water				
Dual-flush toilets				
Low-flow toilets				
Low-flow faucets				
Low-flow showers				
Low-flow urinals				
Waterless urinals				
Leak detection and reduction				
Front-load laundry machines				
Water-efficient dishwashers				

3.5. If you've implemented any of the water conservation methods below, / please rate them on a scale of least effective to most effective in terms of which had the largest measured impact on reducing water consumption

	Least Effective	Somewhat Effective	Effective	Most Effective	Unknown or N/A
Building water meters	○	○	○	○	○
Use of non-potable water	○	○	○	○	○
Dual-flush toilets	○	○	○	○	○
Low-flow toilets	○	○	○	○	○
Low-flow faucets	○	○	○	○	○
Low-flow showers	○	○	○	○	○
Low-flow urinals	○	○	○	○	○
Waterless urinals	○	○	○	○	○
Leak detection and reduction	○	○	○	○	○
Front-load laundry machines	○	○	○	○	○
Water-efficient dishwashers	○	○	○	○	○

3.6. Please indicate the priority level of implementing the following water conservation methods

	Already in use	Will be used in the next year	Will be used in the next 5 years	Will be used sometime in the future	Not a priority	Unknown or N/A
Building water meters	○	○	○	○	○	○
Use of non-potable water	○	○	○	○	○	○
Dual-flush toilets	○	○	○	○	○	○
Low-flow toilets	○	○	○	○	○	○
Low-flow faucets	○	○	○	○	○	○
Low-flow showers	○	○	○	○	○	○
Low-flow urinals	○	○	○	○	○	○
Waterless urinals	○	○	○	○	○	○
Leak detection and reduction	○	○	○	○	○	○
Front-load laundry machines	○	○	○	○	○	○
Water-efficient dishwashers	○	○	○	○	○	○

3.7. What other water conservation measures does your institution use for auxiliary building use?

3.8. What measure has been most effective in saving water for auxiliary building use on your campus?

4. Utilities

4.1. How much water does your institution consume for utilities annually?-Gallons, Year data collected

4.2. Please indicate your institution's source for the following utilities

	Private	On Campus	Municipal Utility	Other
Electricity	○	○	○	○
Steam	○	○	○	○
Cooling	○	○	○	○
Domestic	○	○	○	○

4.3. What conservation measures does your institution use for cooling towers?

4.4. What water conservation measures does your institution use utilities?

4.5. What measure has been most effective in saving water for utilities on your campus?

5. Education

5.1. Does your institution offer workshops or co-curricular courses on water conservation for faculty, staff, and/or residents?

5.2. Does your institution offer workshops or co-curricular courses on water conservation for faculty, staff, and/or residents?

5.3. Are for-credit courses covering water conservation offered to students at your institution?

5.4. Are there any student groups focusing on water conservation at your institution?

5.5. Is there any water-related research occurring on campus?

5.6. Are there opportunities for students to work with staff members on water conservation projects?

6. Governance and Policy

6.1. Does your institution have a policy related to water conservation? –Yes, approved; Yes, pending; No; Other.

6.2. Does your institution have a water conservation strategic plan or natural resource management plan? –Yes, approved; Yes, pending; No; Other.

6.3. Does your institution have target reduction goals for water use? –Yes, approved; Yes, pending; No; Other.

6.4. Does your institution have a conservation fund or a way to provide funds for water conservation projects

6.5. Is your institution involved with the EPA's Water Sense or collaborating with other agencies on conservation

6.6. How high of a priority is water conservation with…

	Not Important	Somewhat Important	Important	Very Important	Unknown
Students	○	○	○	○	○
Staff	○	○	○	○	○
Faculty	○	○	○	○	○

6.7. Would you (the survey respondent) be interested in participating in a state-wide campaign to conserve water at institutions of higher education?

6.8. Do you think your institution would be interested in participating in a state-wide campaign to conserve water at institutions of higher education?

7.

References

1. Beekman, G. B., 1998, Water Conservation, Recycling and Reuse: International Journal of Water Resources Development, v. 14, p. 353–364.
2. Vaux, H., 2011, Water Conservation, Efficiency, and Reuse: Elements, v. 7, p. 187-191.
3. Texas Water Development Board, Water for Texas 2012 State Water Plan: Texas Water Development Board, January 2012, Online. Available: http://www.twdb.state.tx.us/publications/state_water_plan/2012/2012_SWP.pdf
4. Grima, A.P., Paine, R.L., 2014, Urban Water Conservation: Geojournal, v. 11, p. 257–263.
5. Marinho, M., do Socorro Gonçalves, M., Kiperstok, A., 2014, Water conservation as a tool to support sustainable practices in a Brazilian public university: Journal of Cleaner Production, v. 62, p. 98-106.
6. Velazquez, L., Munguia, N., Ojeda, M., 2013, Optimizing water use in the University of Sonora, Mexico: Journal of Cleaner Production, v. 46, p. 83-88,
7. Cleaveland, M.K., 2006, Extended Chronology of Drought in the San Antonio Area: Tree Ring Laboratory, Geosciences Department, the University of Arkansas.
8. Seo, S., Segarra, E., Mitchell, P. D., & Leatham, D. J., 2007, Irrigation technology adoption and its implication for water conservation in the Texas High Plains: a real options approach: Agricultural Economics, v. 38, p. 47–55.
9. Richter, B., Abell, D., Bacha, E., Brauman, K., Calos, S., Cohn, A., Disla, C., O'Briend, S.F., Hodges, D., Kaiser, S., Loughran, M., Mestre, C., Reardon, M., Siegfriend, E., 2013, Tapped out: how can cities secure their water future?: Water Policy, v. 15, p. 335-363.
10. King, C., Duncan, I., Webber, M., 2008, Water Demand Projections of Power Generation in Texas. The University of Texas Bureau of Economic Geology: Prepared for the Texas Water Development Board, http://www.twdb.state.tx.us/wrpi/data/socio/ est/final_pwr.pdf.
11. Nicot, J.P., Reedy, R.C., Costley, R.A., Huan, Y., 2012, Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report. The University of Texas Bureau of Economic Geology: Prepared for the Texas Water Development Board, http://www. twdb.state.tx.us/RWPG/rpgm_rpts/0904830939_ MiningWaterUse.pdf.
12. Winters, K., 2013, A Historical Perspective on Precipitation, Drought Severity, and Streamflow in Texas during 1951 – 56 and 2011: USGS Scientific Investigations Report 2013-5113: Prepared in cooperation with the Texas Water Development Board.
13. Svoboda, M., 2011, U.S. Drought Monitor September 13, 2011. NDMC, U.S. Department of Agriculture, National Oceanic and Atmospheric Administration.

14. Scanlon, B. R., Duncan, I., & Reedy, R. C., 2013, Drought and the water–energy nexus in Texas: Environmental Research Letters, v. 8, p. 1-14.
15. Koeller, J., & Hammack, K., 2010, Addressing Unnecessary Water Waste in Buildings: ASHRAE Journal.
16. McHale, J.., & Perdue, S., 2014, Recent Advances in Water-conserving Plumbing Products: American Water Works Association, v. 102, p. 122–123.
17. Environmental Protection Agency. (2012). Watersense, http://www.epa.gov/watersense/
18. Stillwell, A., Webber, M., 2013, Novel Methodology for evaluating economic feasibility of low-water cooling technology retrofits at power plants: Water Policy, p. 292-308.
19. Maddaus, W., Gleason, G., Darmody, J., 2014, Integrating conservation into water supply planning: American Water Works Association. v. 88, p. 57-67.
20. McCormick, L., Miller, A., Walker, J., & Camp, M., 2010, Drop by Drop: Seven ways Texas cities can conserve water, p. 1–51.
21. BBC Research & Consulting, 2003, SAWS Water Conservation Cost Savings: final report prepared for Water Resources and Conservation Department, San Antonio Water System.
22. Gregg, T., Strub, D., Gross, D., S., 2014,Water efficiency in Austin, Texas , 1983-2005 : An historical perspective: American Water Works Association, v. 99, p. 76–86.
23. Oduro-Kwarteng, S., Nyarko, K. B., Odai, S. N., and Aboagye-Sarfo, P., 2009, Water Conservation Potential in Educational Institutions in Developing Countries: Case Study of a University Campus in Ghana: Urban Water Journal, v. 6, p. 449-455.