

WATER CONSERVATION POLICY IN TEXAS

AN INTEGRATED APPROACH TO WATER RESOURCE POLICY

The focus of this study is municipal water conservation and how certain explanatory variables, including water control, can describe monthly water use. The goal is to identify cities with the most effective conservation programs and therefore the best water management practices. No previous study has used quantitative measures to rank water conservation programs in Texas. Using Texas as a baseline, this project can be useful in any state where water resources are marginal. Though limited in scope, this study provides a basis on which to judge best practices in water conservation.

In Texas, the principal financing agency for water projects, the Texas Water Development Board (TWDB), requires communities receiving TWDB loans to develop water conservation plans. Water conservation programs include rules for maintaining and replacing water meters, system leak-detection equipment loan programs, water conservation literature distribution, and better water-use accounting systems. Additional voluntary conservation includes the reuse of treated effluent in place of potable water, programs to replace or retrofit less-efficient plumbing fixtures with water conserving plumb-

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ing fixtures, and the development of landscape water-management strategies. Many of the results of these policies are quantifiable.

A three-year comparison between 44 cities with water conservation plans and 113 cities without plans reveals substantial savings because of water conservation policies. Gallons per person per day (GPCD) water consumption as measured each month is the modeled output. The modeled inputs include independent weather variables and policy variables, which explain water use such as evaporation, precipitation, maximum temperature, and the institution of water conservation policies.

This study evaluates effective water conservation plans by explaining water use through weather and policy variables. Analysis begins with modeling the GPCD variable. Three physical independent weather variables determine an efficiency frontier for each month over the 1996 through 1998 period. Using Data Envelopment Analysis (DEA) software, the study calculates which cities in Texas have the lowest water use and precipitation, taking average temperature and evaporation into consideration relative to all other cities. This process identified six cities that consistently have the lowest water use in each base, peak, or transition months: Edinburg, Angleton, Mission, Sanger, Midland, and El Paso. Each city's water conservation annual report is further examined to identify water conservation management best practices from the utility manager's perspective.

BACKGROUND: COMMON USE OF PHYSICAL WEATHER VARIABLES IN WATER USE STUDIES

As one would intuitively expect, Texas-wide research in water use indicates that weather variables, such as evaporation, temperature, and precipitation, affect municipal water use. Two previous studies (described below) compared Texas cities with conservation plans against cities without plans and examined the relationship between GPCD municipal water use in Texas, precipitation, and temperature. Several other studies have analyzed water use at the local level and also confirmed that weather affects water use.

The Texas Water Development Board (TWDB)

compared water use in a group of cities that received water infrastructure loans and required maintaining a water conservation plan, with a group of cities without funding from TWDB. This study normalized GPCD into three climatic factors (evaporation, temperature and precipitation) for selected major cities. These factors are commonly used to confirm their effects on water use. They should also be adjusted to compensate for the cyclical nature of weather and, consequently, water use.

A second study estimated long-term water use using Markov processes. A Markov process model presumes that water use in one time period can be correlated over space and time with use during earlier time periods. Precipitation and temperature variables were statistically significant in this analysis. Besides statewide studies local studies have sought to confirm the relationship

between weather and water use.

Another project related the amount of water pumped by purveyors in Nassau County, New York to the number of households in the county, combined heat and dryness indices, and the effects of a Nassau County Water Conservation Plan. This study attributed a reduction in pumping to education, drought contingency efforts, and leak detection programs.¹ The heat and dryness indices used in the Nassau County study were functions of temperature and evaporation. Water conservation analysts across the country use these same methodologies.

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METHODOLOGY

Scholars at the LBJ School of Public Affairs presented a method for estimating water savings and economic costs resulting from implementation of a drought management program in Corpus Christi, Texas during the drought of 1996.² This model consisted of a time-series regression model that uses a moving average index to model seasonality in water demands.³ As expected, it confirmed that rainfall and temperature were significant explanatory variables for water use.⁴ The findings emphasize the importance of three weather variables: evaporation, temperature, and precipitation.

This water conservation policy study seeks to

confirm that these variables are significant in the data compiled for this paper. The resulting model takes the form:

$$\gamma = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + \epsilon$$

where γ is the dependent variable; x_1, x_2, \dots, x_p are the independent variables; β_0 is the coefficient of the constant or intercept and $\beta_1, \beta_2, \dots, \beta_p$ are the coefficients of the independent variables; ϵ is the error term that accounts for the variability in γ that cannot be explained by the linear effect of the independent variables. The final form of the equation with weather and policy variables combined in the form of an index is:

$$\text{GPCD} = \beta_0 + \beta_1 [\text{Evaporation}] + \beta_2 [\text{Precipitation}] + \beta_3 [\text{Policy Index}] + \epsilon$$

where: $\gamma = \text{GPCD}$ (gallons per capita per month), $x_1 = \text{evaporation}$ in average inches per month, $x_2 = \text{precipitation}$ in average inches per month, and $x_3 = \text{a policy index variable}$ created from the sum of the yes/no categorical water conservation policy variables. The resulting regression analysis indicates:

$$\text{GPCD} = 105.47 + 13.35 [\text{Evaporation}] - 2.49 [\text{Precipitation}] - 6.15 [\text{Policy Index}] + 86.32$$

This model can be used as a guideline for examining the effect of conservation plans. It indicates that for each one-inch increase in average monthly evaporation, average monthly GPCD increases by 13.35. For every one-inch increase in average monthly precipitation, average monthly GPCD decreases by 2.49. For each entity with water conservation policies, average monthly GPCD decreases by 6.15. Of course, a few caveats are inherent in using this model to predict water use.

The regression results are consistent with the hypothesis that rainfall and evaporation affect water use. Cyclical characteristics of the data, however, prevent this model from being used for projection purposes. Evaporation, precipitation, and temperature are the variables that provide the basis for Data Envelopment Analysis (DEA). DEA does not require correlated variables to be excluded from analysis. DEA may include all variables in the form of ratios important to managers or analysts.⁵ Water conservation analysts have consistently used these variables to relate water use to weather variables.

INTRODUCTION TO DATA ENVELOPMENT ANALYSIS (DEA)

First developed in 1978, Data Envelopment Analy-

sis (DEA) evaluates the relative efficiency of decision-making units (DMUs) within organizations or in a region.⁶ Decision-making units take inputs and convert them with varying degrees of efficiency into outputs.⁷ DEA identifies an efficiency envelope or efficiency frontier similar to well performing residual outliers in a model estimated as a measure of central tendency. These good performers that reach the efficiency frontier are the "reference set" for the others. In DEA, the production possibility set is everything else except the most positive residual outliers. The efficiency frontier is the line connecting the most positive residual outliers from the origin to the region of interest in a linear regression. DEA creates the line connecting the most positive residuals by identifying the most positive residual frontier to form a composite DMU. The weighted average of the most positive residual outliers adjacent to the point of interest comprises the fictitious composite DMU. DEA uses the fictitious composite, made up of the most positive residual outliers to assess the other points. DEA scores the other points based on their distance from the efficiency frontier relative to the weighted average position of the most positive residual outliers, restricted to the region of interest.

Linear programming computed the weights assigned to each DMU being compared and to the group of DMUs in the region of interest. The software is constrained to find the weights that:

1. Equal one when added together;
2. When multiplied with the output coefficients of each DMU and added together are greater than or equal to the output for the DMU being compared;
3. When multiplied with each input coefficient and added are less than or equal to the input of the DMU being compared.

An unknown variable E is introduced. E identifies that amount of input needed by the composite to obtain the output of the DMU being compared. If, for example, a DMU E score is 0.90, the composite DMU can obtain the same amount of output as the DMU being compared using 90 percent of the input of the DMU being compared.

In the comparison to the central tendency line, this DMU would occupy a point at a distance of ten percent short of occupying a place on the frontier line connecting the most positive residual outliers. The DMU must remedy a ten percent shortfall to

reach the efficiency frontier. The city can look to those DMUs that occupy either side of this point on the efficiency frontier for guidance. These adjacent DMUs are the reference set for the DMU being compared. The inefficient DMU should investigate what the efficient DMUs are doing to reach that frontier line.

The analysis uses evaporation and maximum temperature ratios as outputs; precipitation and water use in GPCD ratios are the inputs. The model includes information on cities that have high temperature and high evaporation rates and therefore more reason to have a high GPCD. The software calculated which cities have low water use, by holding constant their evaporation temperature and rainfall. The best performing cities are those with an efficiency index score of 1.

In most cases DMUs control inputs and outputs. In this analysis, a city cannot hope to control the amount of evaporation, precipitation, or temperature. The GPCD can be controlled using specific water conservation strategies or policies. This formulation seeks to list in order of water use efficiency, those cities that are able to meet the challenge posed by the water conserving composite city—composed of DMUs with conservation plans in the region of interest—on a consistent basis. In other words, the software identified the low water using cities by holding constant evaporation, temperature, and precipitation.

RESULTS OF ANALYSIS

Data Envelopment Analysis software determined the most efficient water-using cities.⁸ The analysis examined each of twelve months for the years 1996, 1997, and 1998. It separated the months into base months, transition months, and peak months. Base months consist of November, December, and January. Peak months were June, July, and August. Transition months are neither base nor peak months. In Texas, most cities use the least water outdoors during November, December, and January. Water use during these months represents

mostly residential indoor use. Transition months are those months during the rainy season. Water use begins to increase gradually during transition months. June, July, and August are those months when it normally rains the least. The years 1996 and 1998 were drought years and experienced very little rainfall during peak months. The Palmer Drought Index for 1997 reveals somewhat of a reprieve from drought conditions.⁹ Naturally, residential consumers might water their lawns more frequently than necessary during these months, especially under threat of drought.

Cities selected for this study occupied the efficiency frontier (i.e., scoring a 1 on the efficiency index) on a consistent basis in each of the three categories (base, transition or peak months), with most emphasis placed on the peak months. The cities with the highest ratios of achieving the efficiency frontier,

based on the number of possible months in each category over a three-year period, became the criteria used to select cities for this study. If a city consistently scored 100 percent efficiency over each category of transition and peak months, that city was selected.

Over the three-year period, the analysis examines nine peak months, eighteen transition months and nine base months. Cities in the study include El Paso, Midland, Edinburg, Mission, Angleton, and Sanger. Two other cities deserve mention, though they are not examined in detail: Corinth and McAllen. Indeed, each city scoring an efficiency index of 1 was on the efficiency frontier and, therefore, could be used as a mentor for lesser performers. However, identification of the best performing cities is only the beginning; each city's program must be examined in detail for clues to their success. Analysis of every city is beyond the scope of this study.

WATER CONSERVATION BEST MANAGEMENT PRACTICES IN TEXAS

One useful source of information about a community's water conservation plan is the annual report, which is due approximately one year after the closing date of the entity's loan from the TWDB. The annual report provides system size descriptions

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through the number of master meters, number of commercial and residential meters, and the volume of water produced and sold as of 1998. The number of master meters reflects the number of water sources available to a community, and range from one master meter in Midland to 296 master meters in El Paso. The number of commercial meters in this group of cities varies from 65 in Angleton to 3,108 in El Paso. Residential meters range from 1,600 in Sanger to 138,925 meters in El Paso. The volume of water produced by city is between a low of 708,960 gallons per year in Angleton and 40.08 billion gallons per year in El Paso. The estimated 1998 population ranges from 4,671 in Sanger to 604,870 persons in El Paso in 1998.¹⁰ These indicators of size can be combined with strategies and used as indicators of policy success.

As illustrated in Figure 1, the average amount of literature distributed as a percentage of the 1998 estimated population range from zero in Angleton and Sanger to 64 percent in Midland. The number of average meters repaired or replaced as a percentage of total residential meters in the system extends from zero in Sanger to 36 percent in Midland. The average amount of recycled water as a percentage of water sold varies from zero in Angleton and Sanger to 53.6 percent in Edinburg. Unaccounted for water, a measure of water loss by percentage are all fairly low, ranging from 6.3 percent to 12.7 percent.

THE CITY OF EDINBURG

The City of Edinburg showed savings from 220,000 gallons per day in 1997 to 1,000,000 gallons per day in 1998 because of the activation of their Emergency Demand Management and Drought Contingency Plan. Their plan was active throughout the year on January 1 to December 31 during the 1997-1998 period.¹¹ Most cities do not deem it necessary to activate

the drought contingency plan until the peak months have arrived, and then they deactivate it after the peak months have passed. Edinburg's drought contingency plan was implemented for an entire year, which was an unusual step. Low river flow in the Rio Grande triggers the activation of the drought contingency plan according to the annual reports.

THE CITY OF MISSION

Mission operates year-round under its Emergency Water Demand Management or Drought Contingency Plan. They activate the plan on May 13 of every year and continue it throughout the year, as does the neighboring city of Edinburg.¹² The level of the Rio Grande also triggers this plan.

THE CITY OF ANGLETON

The City of Angleton implemented few of the specific strategies or water conservation policies. They attribute their success to rapid responses to calls of high usage, technical assistance fielded by office personnel over the telephone, a good meter change-out program, a computer system that monitors holding tank levels for gauging system leaks, and a relatively expensive increasing block water rate structure. Angleton charged \$8.00 for the first 2,000 gallons of water consumed, \$2.20 for each additional 1,000 gallons up to 10,000 gallons, and \$2.40 for each additional 1,000 gallons up to 15,000 gallons.¹³

THE CITY OF SANGER

Besides a strong literature distribution program, the City of Sanger attributes its success to a relatively expensive increasing block-rate water rate structure, even higher than Angleton's rate. The rate structure combined the monthly fee with the first 1,000 gallons, which constitutes the minimum charge. Each additional 1,000 gallons—up to a limit

Figure 1
City, Reported Strategy, and Ratio Analysis

City	Literature distributed as a percentage of the est. population	Meter repaired or replaced as a percentage of total residential meters	Reuse as a percent of total sales	Unaccounted for Water Percent, a measure of water accountability deficiency
Edinburg	10.6%	13.8%	53.6%	6.3%
Angleton	0	5%	0	12.6%
Mission	63%	1.5%	2.7%	12.2%
Sanger	58%	0	0	10%
Midland	64%	36%	50%	9.5%
El Paso	26%	13.3%	5.7%	12.7%

Source: TWDB Water Conservation Annual Reports for Edinburg, Angleton, Mission, Sanger, Midland, and El Paso, 1996-1998.

of 5,000 gallons—is \$7.80. Between 5,000 and 15,000 gallons, the cost to consumers is \$21.50 per thousand gallons. An additional 1,000 gallons up to a ceiling of 30,000 gallons costs \$38.25 per thousand gallons. Any water consumed over 30,000 gallons carries a hefty price tag of \$100.50 per thousand gallons. This increasing block-rate structure is the strongest example of a stiff rate structure among the five most efficient cities of the group.¹⁴

THE CITY OF MIDLAND

The City of Midland maintains outstanding literature distribution and meter replacement programs and recycles over 50 percent of its wastewater. The City also reports joining a partnership with the Midland Independent School District, placing information at the local library. They offer xeriscape tours to schools and clubs. They cite a mayoral proclamation of drinking water week held each year from May 3-9, which coincides with the federal drinking water week. The City became a charter member in the Water Wise Council of Texas, which is another contribution to their success. The goals of the Water Wise Council are to:

1. Establish an educational network to develop and disseminate water conservation information and activities to residential water users;
2. Provide financial and in-kind support for the development and execution of educational programs regarding landscaping based on the principles of sound water management;
3. Accumulate, develop, and produce educational materials;
4. Aid in the development of Water Wise Council guidelines for the public and private sector.¹⁵

Midland also credits its success to an extensive education and public awareness campaign, including the formation of a new citizen-driven Water Task Force with City representation.¹⁶

THE CITY OF EL PASO

El Paso attributes its successes in water conservation to extensive education and outreach efforts through radio, television, print media, and exhibits. El Paso prints and provides to customers a graph of their 13-month historical water use pat-

tern. The graphs clearly show the base, peak, and transition month pattern based on the customer's own usage patterns, and is designed to help customers understand their water use.¹⁷ El Paso maintains a strong toilet rebate program that offers up to \$75 for toilets up to \$100 in price.¹⁸ Through a grant from the Bureau of Reclamation, the city also has an extensive landscaping education program called Desert Blooms. El Paso conducts workshops in conjunction with the University of Texas at El Paso Centennial Museum, the Texas Agricultural Extension Service, and the West Texas Urban Forestry Council. El Paso developed a program to promote living in harmony with the Chihuahuan desert through xeriscaping techniques.

CONCLUSIONS AND RECOMMENDATIONS

Water conservation, like the weather, is usually more talked about than acted upon. If water conservation in Texas is important to its citizens, it is important to begin to identify best management practices, describe these programs, and disseminate the information to utilities. Many analysts have used statistics to document that conservation plans work. This approach can identify which plans work best. DEA can identify the best performing units of a group. A case study approach can then describe the details of these programs. These investigations should include those characteristics attributed to its success from the perspective of the manager(s) of the program.

As the repository of the necessary information needed to perform this type of analysis, the Texas Water Development Board and the Texas Natural Resource Conservation Commission should be actively involved in establishing best management practices and performance measures and disseminating this information to interest groups as well as utility operation conservation staff. Water utility practitioners will recognize which of the efficiency frontier cities can best serve as a mentor city. The reference set in Data Envelopment Analysis is important when identifying best management practices and considering mentor cities on the basis of similar characteristics. Reference-set cities identified by DEA are clearly the preferred method of assigning mentoring relationships. A small city cannot be expected to perform as well without the benefits of the size and budget of a large city. Small cities need to know which cities are currently using best management practices effectively before they devote scarce resources to conservation efforts.

FURTHER STUDY IN TEXAS IS NEEDED

Results show monthly efficiency frontiers to be composed of large, medium, and small cities. The cities studied are by no means an exhaustive list of cities with water conservation plans or those without water conservation plans. Some cities could very well have been included in this short list of the most efficient, but were not included because of a lack of data.

The inclusion of budgetary ratios also would have resulted in a different list. The inclusion of budgetary ratios would identify the most efficient and cost effective plans. This study could not determine cost effectiveness without the full time equivalent and budgetary ratios. Water conservation experts should work towards standardizing the necessary ratios in order to better incorporate cost effectiveness as part of their analyses.

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NOTES

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4. Ibid., p. 38.
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