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Special Project Report

The Consequences of Water Consumption Restrictions During the Corpus Christi Drought of 1996

Volume 1: Overview

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Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the nine-month policy research project, in the course of which two or more faculty members from different disciplines direct the research of 10 to 30 graduate students of diverse backgrounds on a policy issue of concern to a government or nonprofit agency. This "client orientation" brings the students face to face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special talents. It also illuminates the occasional difficulties of relating research findings to the world of political realities.

The Consequences of Water Consumption Restrictions During the Corpus Christi Drought of 1996 is the product of a year-long analysis of the city of Corpus Christi's drought management program, which was implemented in 1996 in response to a three-year drought that had dramatically altered in-stream flows and reservoir levels. The report presents a method for estimating the water savings and economic costs resulting from implementation of the drought management program. The approach combines an analysis of water savings and an economic impact assessment with focus group sessions, written surveys, and interviews with Corpus Christi water utility customers.

The curriculum of the LBJ School is intended not only to develop effective public servants but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope that the report itself will contribute to the second.

Finally, it should be noted that neither the LBJ School nor The University of Texas at Austin necessarily endorses the views or findings of this report.

Acknowledgments

The Lyndon B. Johnson School of Public Affairs wishes to thank the many individuals who assisted in various ways with a number of aspects of this project. The Texas Water Development Board and the city of Corpus Christi provided the funding to support this project. The project team wishes to thank James Dodson, Susan Cable, Ed Garana, and Hubert Hall of the city of Corpus Christi for their varied and helpful assistance. Susan Cable worked closely with the project team to implement focus group sessions and identify those issues which were most important to the city's design and implementation of its water management program. Ed Garana and Hubert Hall discussed the water supply system and provided the water supply records needed for forecasting and water savings analysis. The project team also wishes to thank Joe Rios and Omar Mendoza of Corpus Christi's Municipal Information Systems Department for their cooperation and assistance in developing the municipal utility database. Kay Hoover of the city of Corpus Christi assisted by contacting potential focus group participants. John Sutton and Bill Hoffman of the Texas Water Development Board provided useful guidance and assistance at several points during this project. Chandler Stolp of the LBJ School advised on development of the forecasting models.

Several individuals assisted with the economic impact assessment. Don Hoyt of the State of Texas Office of the Comptroller of Public Accounts discussed applications of input-output analysis to economic impact assessment. Sandra Martinez of the State of Texas Office of the Comptroller of Public Accounts assisted with collection of background information to characterize the Corpus Christi Metropolitan Statistical Area. Herb Grubb of HDR Engineering, Inc., and Mickey Wright of the State of Texas Office of the Comptroller of Public Accounts provided useful feedback on the application of input-output analysis. The Corpus Christi Board of Trade Technical Committee discussed economic impacts of water rationing in the ship channel industries.

The many individuals that participated in focus group and discussions of water savings analysis and economic impact assessment also deserve recognition. Several individuals assisted in this project through participation in a group discussion held in Austin that considered the approach and methods used in this study. Participants included John Sutton and Bill Hoffman of the Texas Water Development Board, Bruce Moulton of the Texas Natural Resource Conservation Commission, Mark Hughes of the Texas Workforce Commission, and Susan Cable of the city of Corpus Christi. The project team also wishes to thank the water utility customers that volunteered as focus group participants in the city of Corpus Christi for their active participation in this project. Their names are not listed to preserve the confidentiality of their responses.

The authors are solely responsible for any errors, interpretations, or omissions.

Executive Summary

Chapter 1. Introduction

The city of Corpus Christi began implementation of its drought management program on April 9, 1996, in response to a three-year drought that reduced reservoir inflows to a rate less than the "worst case scenario" of water supply planners. As of December 1996, the combined storage in the reservoirs was about 30 percent of capacity, twelve percentage points less than in December 1995, and capable of providing approximately 18 months of water supply with drought management efforts in place. The Lyndon B. Johnson School of Public Affairs of The University of Texas at Austin began an evaluation of Corpus Christi's drought management program in June 1996, with funding from the Texas Water Development Board and the city of Corpus Christi. The objective of this evaluation is to provide information on water savings in real time to provide feedback to water managers who must make decisions based on expectations of water savings, changes in utility revenues, and the effectiveness of alternative drought management strategies. Policymakers were also weighing the cost of drought management strategies against expected benefits to the region. An assessment of the economic impact of drought management could assist policymakers in comparing the cost of drought management with the cost of alternative supplies and any opportunity costs associated with long-term risks of water shortage.

This report presents a method for estimating the water savings and economic costs resulting from implementation of the drought management program during the drought of 1996. Chapter 2 provides a brief overview of the drought management program and water use in Corpus Christi. Chapter 3 provides an introduction to water savings analysis and a brief literature review. This analysis of water savings is based on the results of two water demand forecasting models. Chapter 4 presents a rainfall-temperature time-series regression model that could be used to accomplish the analysis. This rainfall-temperature time-series regression model is applied to analyze water demand at an aggregate level and in individual water user sectors. Price elasticities are calculated for residential, commercial, and industrial water users. Chapter 5 introduces a second time-series regression model that uses a moving average index to model seasonality in water demand. Results and performance of this model applied to treated and total water use are compared with those of the rainfall-temperature model. Chapter 6 uses customer-level records from the municipal utility database to identify changes in the distribution of water among single-family residential customers. The analysis tests whether water restrictions had a greater impact among high-volume residential water users than among low-volume residential water users.

Chapter 7 describes a method for estimating household income and employment effects of drought management in Corpus Christi's petrochemical manufacturing industries. The method could be extended to other production sectors. This is an application of a regional input-output model to quantify income and employment effects of water management decisions at the local level. First, the input-output model is described. Second, how to estimate direct, indirect, and induced income and employment effects given estimates of the output effect is discussed. Economic impacts such as these indicate how drought management decisions affect residents in the Choke Canyon/Lake Corpus Christi service area. This report argues that water rationing and water supply decisions should not be made by equating income and employment effects with economic costs alone, because those costs ignore service costs and incentives that govern supply and demand for water. A decision-making model for water rationing and water supply could be based on maximization of the total net value of water in the service area. Chapter 7 discusses problems with the use of income and employment effects to evaluate the costs of water rationing. The direct economic cost of water rationing is proposed as an alternative measure for cost assessment.

This project combined an analysis of water savings and an economic impact assessment with focus group sessions, written surveys, and interviews with Corpus Christi water utility customers. Results from the focus groups, surveys, and interviews provided water utility managers with feedback on customer practices, the potential effects of proposed policies, and attitudes toward specific water supply alternatives. Focus group activities included 18 sessions involving 9 residential customers and 63 representatives of 43 commercial and industrial utility customers. Most focus group participants completed written surveys. A total of 67 surveys were completed. Six industrial water utility customers from the petrochemical manufacturing industries also contributed to this project by agreeing to one-on-one interviews. Chapter 8 describes selection of participants and focus group methods. Also discussed is the input of commercial and industrial water customers, as well as the input of residential customers. Finally, this chapter combines responses from commercial and industrial customers to summarize information on attitudes toward water supply and drought management.

Summary of Project Results

Water Savings Analysis

Water demand forecasting is a well-established means of estimating water savings associated with drought management. Though such methods can work well, model selection is an important step toward developing credible results. A variety of models were considered for this project. Criteria for model selection required that the method (1) provide a reasonably precise estimate of potential water use without drought management given economic activity and weather patterns during the drought management period, (2) allow identification of water savings by water user sector, and (3) enable water managers to obtain feedback on drought management program effects in real time at minimum cost.

A time-series regression model that uses significant lagged error terms to correct for autocorrelation provided the most straightforward real-time solution to the forecasting problem. The method is logically interpretable and could be implemented by water utility personnel using spreadsheet software and monthly billing records. The speed with which rainfall-temperature models can produce feedback on water savings is limited by the time required to read all utility meters, approximately one month, and an additional one month lag in the availability of monthly billing records. Initial results are available about 60 to 90 days after implementation of a drought management program.

Information on water use was obtained from the city of Corpus Christi's monthly billing reports, which are produced by the city's accounting division and subsequently corrected and revised by water utility managers when necessary. These data are provided with monthly mean maximum daily temperature and aggregate rainfall in Appendix A (see Volume 2). Accounting reports include sufficient detail to allow aggregation of water use by residential, commercial, and industrial sectors. Identification of water savings by water user sector allows utility managers to better direct their drought management program if some water user sectors are not achieving water savings.

The forecasting and evaluation methods outlined in this report could be implemented by water utility managers using spreadsheet software. Instructions for applying the model are provided in Chapter 4. However, more sophisticated software would be required to reestimate the forecasting model or recalculate operational criteria used to evaluate water savings. Operational criteria for water savings, defined as a one-sided lower 95 percent confidence bound of predicted water use, may be identified for each month of the forecast and can only be calculated after rainfall and temperature in the forecast month are known. Although the model remains valid while Corpus Christi remains under its drought management plan, the quality of forecasts will deteriorate as the length of the drought management period continues. Chapter 4 discusses the deterioration of forecasts.

Results of Water Savings Analysis

Results of the water savings analysis show that actual water use is less than the water use forecast during the period May through November 1996. The analysis is designed to test the effects of mandatory water rationing as implemented through drought condition 2 beginning May 6, 1996. Results of the analysis of water demand for residential and commercial customers inside the city limits are illustrative of project results. Municipal per capita water demand is defined as residential and commercial water use inside the city limits expressed in gallons per capita per day (gpcpd). Population figures were estimated by the city of Corpus Christi Planning Department. Water savings by residential and commercial customers inside the city limits during the mandatory drought management period, May 6 through November 1996, are estimated to be 4.48 percent in May, 16.14 percent in June, 6.74 percent in July, 18.58 percent in August, 28.44 percent in September, 32.29 percent in October, and 16.04 percent in November. Not all differences between forecast and actual water sales meet statistical criteria for distinguishing between drought management effects and random errors of the forecast. Differences in estimates of water savings across months could be attributed to errors in the forecast, the differential effects of regulations on water uses, or both.

Figure 1.1 graphs municipal per capita water demand forecast and actual water use. Water savings is calculated as the difference between forecast and actual water use. The y-axis is gallons per capita per day and the x-axis indicates the numerical sequence of months, taking January 1986, as 25 and May 1996, as 197. The model estimation period begins in January 1986, and continues through April 1996. Ex-post forecasts for months within the estimation period are connected by a solid line. Model forecasts are represented by "x" and the 95 percent confidence bound of predicted values is shown by the faded dashed line.

The model produces similar results when applied to five other aggregations of water demand. These aggregations include total water sales (the sum of treated and raw water sales including sales to wholesale customers), treated water sales (including treated water sales to wholesale customers), and water sales to retail customers in three water user sectors: residential, commercial, and industrial. Results show that water savings have appeared gradually during this drought management period. For example, estimates of treated water savings are 3.48 percent in May, 15.34 percent in June, 8.63 percent in July, 10.3 percent in August, 24.6 percent in September, 18.79 percent in October, and 14.25 percent in November. Not all differences between forecast and actual water sales meet statistical criteria for distinguishing between drought management effects and random errors of the forecast. Details of the water savings analysis are provided in Chapter 4.

Table 1.1 describes some key results of this water savings analysis in general terms. Other results of the forecasting exercise include trends in water demand within the city's retail service area and estimates of the price elasticity of demand in water user sectors. This study found statistically significant increasing trends in per account water use in commercial and industrial sectors. The increases are 87 gallons per month per commercial account and 16,522 gallons per month per industrial account. There is no statistically significant trend in per account residential water demand within the city's retail service area. The water forecasting equation controls for changes in the number of water utility customers. However, because the forecasting equation does not include variables to control for changes in productivity over the estimation period, changes in per account water demand do not necessarily reflect increases or decreases in water efficiency. Trends such as these may not be used to evaluate long-term water conservation programs.

Price elasticity is the percent change in water demand that results from a 1 percent change in water price. Elasticities can serve as a tool for comparing the effectiveness of water rationing with hypothetical water utility price increases. Water price is included as a variable in the forecast of residential, commercial, and industrial demand. Parameter estimates for the price variable are used to calculate long-run point price elasticities for each sector. Only commercial water customers showed statistically significant responses to price changes. The price elasticity in that water user sector is -0.519. The interpretation is that commercial utility customers will reduce water use 0.52 percent in response to a 1 percent increase in the price of water. The interpretation of insignificant price elasticities is that residential and industrial water customers have not adjusted water use over the estimation period in response to price changes. Chapter 4 discusses why price elasticities may not be significant in the forecasting equation. Appendix B lists nominal prices for residential and non residential water customers from 1978 to 1996 (see Volume 2).

A set of evaluative criteria is presented for comparing rainfall-temperature model results with results of other water demand forecasting equations. Results of a moving average index time-series regression model applied to total water use and treated water use are compared with results of the rainfall-temperature model. Comparisons based on evaluative criteria show that the moving average index performs slightly better as a forecasting tool, but this results in no change in conclusions about the effectiveness of the drought management program during the period May through August 1996. Overall, the rainfall-temperature model is considered a better alternative to the moving average index model because it describes underlying processes rather than model the data and therefore better preserves the ability to interpret other variables that might be incorporated into the analysis.

Potential Improvements in Water Demand Forecasting

One of the efforts of this project has been to develop the customer-level municipal utility database for use in water demand forecasting. Some analysis of that database is included in this report (Chapters 2 and 6) as is a method for converting the city's accounting files to a format suitable for analysis by conventional statistical software (Appendixes E and F). A manual for converting the database to dBASE format is provided in Appendix E. A collection of FORTRAN programs used in this conversion process is provided in Appendix F (all Appendixes in Volume 2).

Monthly billing records are adequate for evaluating water savings. However, some improvements could prove useful in identifying water savings and interpreting model results. Benefits of using the customer-level utility records include replication of the water demand time series over 21 utility billing cycles and better specification of rainfall-temperature variables. Water utility customers are billed monthly on a rotational basis known as cycles. One cycle of customer meters is read and billed during each business day of each month. Using customer-level records allows aggregation of water customers by cycle as well as by water user sector.

Some advantages of using the customer-level database could include an increase in the number of observations during the forecasting period and a decrease in the lag time required before a water savings assessment is complete. The project team estimates that an installed system could reduce the lag time needed to obtain results from two or three months to one to four weeks. Another potential benefit of using customer-level data may be a decrease in the confidence interval width associated with predicted values. This could be the result of increasing the number of observations, the number of variables, or better definition of independent variables such as rainfall and temperature. One complication associated with increasing the number of observations is the need to account for additional variation in levels of water use between cycles.

Those cycles read and billed during the beginning of the month reflect water use primarily in the preceding month. Those cycles read and billed at the end of the month reflect water use primarily in the billing month. As this pattern occurs regularly and each cycle is read and billed on approximately the same day each month, specification of rainfall and temperature values for aggregate water billed misstates rainfall and temperature for the those cycles billed early in the month. Even though forecasts may be accurate, there may be an erroneous coefficient for the rainfall and temperature variables. Use of the municipal utility database resolves this problem by assigning rainfall and temperature for the water use period to each customer account.

Customer-level data can be aggregated by zip code as well as by cycle. This aggregation enables the analyst to use other data available by zip code to explain patterns in water demand. For example, personal income or other population and housing characteristics could be used in conjunction with the utility database. This is less true for commercial and industrial customers than for residential customers if single-family residential customers are treated as an homogenous group. In contrast, the characteristics and activities of commercial and industrial customers vary widely. It seems more information is needed about these customers in the utility database, including information on site-level activity and standardized industrial classification codes.

Utility of Database Screens

Another potential use of the customer utility database is the ability to create database screens. The utility database is designed to access information for specific accounts, but analysis of groups of accounts or aggregation of accounts by location, water user sector, water use, or other criteria requires a time-consuming programming effort. The converted database enables water managers to create up-to-date database screens in a short period of time. To demonstrate how database screens can be used, the project team created dBASE files listing commercial and industrial utility customers using 100,000 gallons of water or more each month. Alternatively, customers could be identified by other account characteristics such as meter information, billing history, or location. To preserve the confidentiality of water utility billing records, these results are not provided in this report.

Evaluating the Economic Impact and Costs of Water Rationing

This report presents a method for estimating income and employment effects of water rationing. Water rationing is defined as a system that restricts the timing, period, or volume of water use. This includes such things as limitations on the volume of water use, watering restrictions that specify the day or time of outdoor water use, or the length of the watering period. All are classified as water rationing because each system attempts to limit the volume of water used by each customer in a specific group. In contrast, water conservation is a long-term process that seeks to increase water efficiency by changing people's habits and promoting substitutes for water such as more efficient equipment or processes. The purpose of assessing the costs of water rationing is that water managers could weigh these costs against the benefits of proposed levels of water rationing or against the costs of alternative courses of action.

The input-output method used to assess economic impacts requires an independent projection of the change in output levels in commercial and industrial sectors. To demonstrate how the 1986 Nueces Mission-Aransas Estuary Input-Output Model can be used, estimates of income and employment effects of a 5 percent change in output are presented for the petrochemical manufacturing industry. Model coefficients indicate that, dollar for dollar, these two sectors have the largest potential impact of all input-output sectors on income and employment in Corpus Christi. Moreover, chemical and petroleum manufacturing accounted for 91 percent of the manufacturing output in Corpus Christi in 1992 (Bureau of the Census 1996).

A 5 percent decrease in production is used as a hypothetical output effect associated with proposed water rationing in the petrochemical manufacturing sector. This estimate, based on information obtained from industry representatives, is not indicative of what output change would be under any specific water rationing plan. Representatives would not release any estimates of what output effects might be. A 5 percent change in the output of each chemical and petroleum manufacturer results in a total direct, indirect, and induced decrease in employment of 1.54 percent. Similarly, a five percent change in the output of petroleum and chemical manufactures results in a total direct, indirect, and induced decrease in wage and salary income of 2.07 percent in the Corpus Christi Metropolitan Statistical Area. The term *direct effect* refers to the change among those employed in the industry, while the terms *indirect* and *induced effects* refer to changes in other industries.

Income and employment costs are useful measures of economic impact. However, income and employment effects of output change reflect only a portion of the total cost of water rationing. A decision criterion for water rationing and water supply investment should compare the total direct cost of water rationing with total direct benefits in the service area. Total direct benefit is measured by consumer surplus, which is related to the present value of water and its supply cost. The total value of a unit of water is equal to the value of that water used in production to commercial and industrial customers plus the utility of that water to residential customers, minus its acquisition and delivery costs. The cost of water rationing is the net change in economic value of water.

Price manipulation is an alternative means of controlling the volume of water use. This differs from water rationing because each water customer responds to price changes by adjusting water use according to an individual set of incentives and priorities. The effect is to minimize economic losses associated with a given quantity of water savings. Although noneconomic policy goals may suggest that minimizing economic losses is not the most desirable objective and institutional limitations may effectively prevent price manipulation in practice, the economic benefits of such a strategy are worth considering.

Focus Group, Survey, and Case Study Results

Input of Commercial/Industrial Customers

Between July and September 1996, representatives of 43 Corpus Christi commercial and industrial organizations discussed impacts of the water shortage and water consumption restrictions with project team members. Table 1.2 lists observations about patterns of water use drawn from focus group discussions, survey results, and case study interviews with commercial and industrial water customers. Observations listed in Table 1.2 are discussed in Chapter 8.

Condition 2 watering restrictions and the city request for voluntary water savings prompted changes in patterns of commercial/industrial water use. Participants report an increased awareness of how water is used, implementation of employee education programs, reduction of non-production related water use, increased equipment repair and maintenance costs, and alteration of production processes without capital investment. They also report capital investment in water saving equipment in anticipation of condition 3 water rationing.

Participating organizations express a preference for working to save water in a number of activities rather than focusing on a single activity. For example, after reducing non-production water use for safety and sanitation, they prefer to reduce water use across a variety of processes before eliminating water use in selected processes. In theory, organizations will reduce water use so that the last gallon of water used in production, cooling, sanitation, and other processes has equal value. Water uses should be restricted or eliminated in order of increasing marginal value. The city's request for voluntary water savings during conditions 1 and 2 was structured to allow water customers to independently identify and initiate the most cost-effective set of water saving measures possible. The ability to implement cost-effective water saving measures appears to assist implementation of drought conditions 1 and 2.

Implementation of condition 3 water rationing as proposed may create an incentive for customers to adopt water savings measures that are not presently cost-effective. Most study participants report they intend to comply with water rationing rather than pay surcharges and risk negative publicity or removal from the water supply system. However, customers that risk significant decreases in production may choose to pay surcharges in the short term. Aside from proposed restrictions affecting outdoor water use in industries like landscaping and building washing, condition 3 water rationing is also structured to enable water customers to adopt the most cost-effective water saving measures first. As long as total water use remains within a monthly water ration, customers will choose those water saving measures that best serve their interest. Firm-level case studies in Chapter 8 describe selected water saving decisions of industrial water customers.

Understanding the economic impacts of water rationing can help explain why patterns of water use change. Table 1.3 lists economic impacts identified through analysis of focus group discussions, survey results, and case study interviews. Chapter 8 describes economic impacts in commercial and industrial water user sectors, reflected in changes in revenue and cost, which affect employment, production, and expansion.

Smaller commercial enterprises did not report significant fixed or variable cost increases due to conditions 1 and 2, but larger industries did. Surveys and focus groups did not yield sufficient information that could be aggregated to estimate total costs. Customer-level case studies provide detailed examples of the variety and magnitude of capital water savings expenditures in local industries.

Most target sectors report that revenue and employment could be good indicators with which to measure the short-term impact of drought management. The city lacks a standard method for reporting revenue and employment information, so anecdotal information gathered through focus group and survey research cannot be corroborated. With the exception of landscape and building washing businesses, few participants report any effect on revenue and employment during conditions 1 and 2. Landscape and building washing businesses were restricted from using water freely in operations, and they were also affected by drought-induced reductions in demand for their services. Landscapers may have lost stock due to the watering restrictions, for example, but they have also been affected by residents' reduced demand for landscaping materials and services since implementation of condition 2 watering restrictions. Calculation of the revenue and employment effects of conditions 1 and 2 would be further complicated by the fact that the landscape industry can expect to regain some lost revenue replacing dead lawns, trees, and plants after the water shortage. Hotels, other manufacturers, and industrial customers report no revenue and employment effects in conditions 1 and 2.

Anticipation of economic impacts from proposed condition 3 water rationing is complicated because condition 3 program parameters are unclear. Few commercial/industrial customers were able to estimate the revenue and employment effects of condition 3 water rationing. Chemical and petroleum manufacturers estimated the potential revenue and employment effects of condition 3 at hypothetical levels of rationing (5, 10, 15, and 25 percent). These customers anticipate substantial decreases in employment and revenue at 15 and 25 percent reductions in water use. No firm conclusions about potential revenue and employment effects of proposed condition 3 water rationing could be drawn from focus groups, surveys, and interviews.

The cost of long-term water shortage is reflected in the investment and production decisions of existing and future utility customers. For example, landscaping and power washing businesses that depend on discretionary water use by Corpus Christi residents postponed long-term expansion plans in response to the water shortage. Most other participating water customers report concern about the opportunity costs of long-term water shortage, but few report any effect of the current water shortage on long-term production decisions. The Greater Corpus Christi Business Alliance conducts business recruitment and retention surveys, through which many large industrial water customers have indicated that inadequate long-term water supply is a significant disadvantage to the local business environment.

Input of Residential Customers

Between July and September 1996, nine residential utility customers in Corpus Christi provided focus group input on household-level impacts of the water shortage and water restrictions. Twenty-six residential water customers, including eight focus group participants, completed surveys. Table 1.4 lists observations about patterns of household water use drawn from focus group discussions and survey responses. Observations in Table 4 are discussed in Chapter 8. Overall, households report little difficulty complying with condition 2 outdoor watering restrictions and anticipate little difficulty complying with condition 3 water rationing. Residential participants express concern about long-term foundation damage if water rationing interferes with their ability to water foundations. Foundation watering can prevent cracks and costly repairs.

Residential water customers report maintaining or reimplementing many water saving practices adopted during the 1984-1985 water shortage, and a possible willingness to maintain current voluntary water saving measures beyond the water shortage. Like commercial and industrial customers, residential customers adopt water saving measures that are most cost-effective. Costs could be reflected in equipment costs or in the relative convenience of one water saving measure over another. Nonmonetary measures may better reflect incentives because dollar costs of household-level water savings seem small and many households have already invested in the necessary equipment.

Residential customers generally report implementing those water saving measures they consider to be most effective. In contrast to cost-effectiveness, described above, *effectiveness* refers to the largest potential volume of water savings. Residents should have access to information about how much water is used in common household activities and how much is saved through alternatives so that they can more accurately assess the effectiveness of each. For example, residents could be more water efficient if they were informed about optimal watering of different types of foundations and landscapes. However, liability issues may prevent the city from acting as the source of information about foundation watering.

Uninformed residential customers often express resistance to city drought management policies and the possibility of sharing the costs of additional long-term water supplies. Enhanced education about industrial, commercial, and residential water savings and city water planning could defuse resistance caused by a lack of accurate information.

Table 1.5 lists observations about marginal household water use drawn from focus group discussions and survey results. Observations listed in Table 1.5 are discussed in Chapter 8. Because outdoor water uses appear marginal relative to indoor water uses among residential focus group participants, condition 2 water restrictions on outdoor water use probably did not conflict with the water use decisions of most households. Given time to adjust to a program like condition 3 water rationing, which regulates the total volume of water each household uses, it is likely that residential water customers would reduce outdoor watering in the absence of specific regulations.

Residential customers, like commercial and industrial customers, report a preference for incremental reductions in water use. They prefer to limit water use for a variety of outdoor and indoor activities before eliminating specific water uses. This complicates the design of conditions 1 and 2 restrictions on water use, which regulate specific uses, but supports the idea that pricing or rationing may work more efficiently than regulation governing how water is used. This report also presents information that suggests pricing is more economically efficient than water rationing.

Assessment of Attitudes Toward Drought Management and City Water Policies

Focus group participants and survey respondents answered questions designed to assess their knowledge and perceptions of the water shortage, attitudes toward mandatory and voluntary water savings, confidence in city management of the water shortage, and long-term water supply preferences. Table 1.6 lists observations about these issues drawn from residential focus group results. These observations are discussed in Chapter 8.

During drought conditions 1 and 2, publicity about the long-term implications of falling reservoir levels and associated water quality problems focused residential customer attention on the water shortage and long-term water supply issues. Residential customers demonstrate reasonable perceptions regarding the causes and severity of the water shortage, but do not express a great deal of confidence in the city's ability to manage the water shortage. Public discussion of enforcement, commercial and industrial water saving efforts, and long-term supply negotiations and costs might increase residential confidence in city policies. Again, the lack of accurate information appears to have created some resistance to reducing water use. Residential customer attitudes appear to be strongly affected by perceptions of fairness. For example, residents do not object to saving water and contributing to long-term water supply costs, but they seek assurances that other customers are contributing in equal proportion. Further study would be necessary to determine aggregate residential attitudes toward long-term supply options. Residential customers did not express clear support for one long-term option over others.

The increased risk that water shortage may limit production and increase costs in the short term has helped commercial and industrial customers focus their attention on the water shortage. Perhaps because many commercial and industrial customers factor water availability and price into long-term capital investment decisions, most commercial/industrial participants are well informed about the causes and severity of the water shortage. Table 1.7 lists observations drawn from commercial/industrial focus groups. These observations are discussed in Chapter 8.

Commercial/industrial attitudes toward mandatory and voluntary water saving measures are shaped by how those measures affect customer-level capital and operating costs, production, and revenue. Study participants do report a willingness to participate in the citywide effort to reduce water use. To assist them in these efforts, customers report a need for consistent implementation and enforcement of city policies. Commercial and industrial customers make water use decisions and plans based on drought contingency ordinances, statements of city officials, letters, press releases, and other communications. Participants report that knowing condition 3 water rationing requirements with certainty well in advance of implementation could enhance their ability to plan a response to the water shortage and evaluate alternatives.

Commercial and industrial customers express greater confidence than residents in the city's ability to manage the water shortage. Like residential customers, they report that regular communication between the city and water utility customers could enhance their ability to plan and comply with drought restrictions. If water rationing is to become a strategy for coping with long-term water shortage, the city should establish its water restrictions before there is a need to implement water rationing. In addition, incentives that give credit to water customers who reduce water use over the long term are also needed. For example, monthly water rations based on an average of previous monthly water use tend to penalize water customers who have already achieved permanent water efficiency gains.

With regard to selection of long-term water supply options, reliability and price are the primary concerns of commercial and industrial customers. Although industrial customers express a strong preference for the Lake Texana pipeline in focus group discussions, most commercial and industrial participants suggest that the city should continue to investigate a variety of long-term water supply options. Many customers were unaware of the water supply studies already completed by the city.

Recommendations

This section presents several recommendations based on project results. In general, recommendations are limited to those for which project results provide substantial support.

Reassess or strengthen the combination of restrictions on water use in conditions 1 and 2. Analysis of water rationing effects shows that restrictions on water use in Corpus Christi have not achieved the goals established for each drought condition in the city's drought management plan. That plan establishes a goal of 10 percent reduction in total water use during condition 1, an additional 5 percent reduction in water use in condition 2, and another 10 percent in condition 3. The combined effect of conditions 1 and 2, can be seen in the period May through October. Estimated water savings exceed the savings goal in only two of those three months, September and October. The combined effects of conditions 1, 2, and 3 in November should be 25 percent, but the city achieved less than 11 percent water savings in that month.

Results of this water savings analysis show that aggregate water savings between May and November 1996 are below established goals for the drought management program. The approach used to estimate water savings is to compare water demand forecasts with actual water consumption. The ability of the method to detect water savings is demonstrated during the 1984-1985 drought management period.

A reassessment of program goals or strengthening of water restrictions is warranted. Lowering projections of how much water savings can be achieved through the drought management program as implemented makes expectations more realistic and better enables the city to plan its response to the water shortage. However, it may be more important that the city achieve its 15 percent goal during conditions 1 and 2 as described in the present plan. In that case, the city might consider strengthening the combination of restrictions or the enforcement of restrictions established in its drought management plan.

Information drawn from focus group input supports this recommendation. The perception among residents who report complying with outdoor water restrictions during condition 2 is that restrictions on outdoor water use may not have reduced their outdoor water consumption. Outdoor watering restrictions limited lawn watering to specific days of the week and hours of the day. More stringent limits on the frequency and timing of outdoor water use could improve condition 2 restrictions as a tool for reducing water consumption. Residential customers report little cost or inconvenience in achieving compliance with existing condition 2 restrictions. This suggests that restrictions could be tightened without imposing an undue burden on residential customers.

Formally adopt a method for evaluating water savings due to water rationing. A number of good statistical methods for evaluating water savings can be used. Unless a specific method for evaluating effects of water rationing, interpreting results, and using these results to identify program needs are established in advance, the city may not have confidence in conclusions drawn from analyses. For example, this analysis shows differences in water demand forecasts and actual water use. Some of these differences are not statistically significant, but this may reflect the sensitivity of this model to small water savings. Statistical criteria present an operational minimum for qualification of water savings. Unless a water savings is larger than the operational minimum, it cannot be distinguished from random error of the forecast. Although such criteria are conventional bounds in statistical theory, they may be arbitrary from a policy standpoint from which small water savings may be as important as large water savings. Water savings may be small, may fluctuate from month to month, or appear gradually after program implementation. The existence of this operational minimum is a limitation of any method based on statistical inference.

This report presents several criteria that could be used in model selection and evaluation. For example, the relative sensitivity of the model to water savings has already been discussed. The scope of parameters for which the analysis controls is also important. For example, this report uses a rainfall-temperature model, which compares actual water use to potential water use given variations in population, rainfall, temperature, and long-term trends. The implication is that water savings should be measured only after allowing for differences in water use related to these variables. In contrast, the model provides for no differences in water use related to changes in the productivity of water users. The implication is that water users may increase water use in response to temperature without jeopardizing compliance with program goals, but may not do so in response to increased production demands. Another way of stating this is that water savings are conditional on changes in temperature but not on changes in production. A production variable was excluded from this model for statistical reasons; it could not be justified as an independent explanatory variable. For any long-term model it would be argued that an output on production variable should be included.

The purpose of a real-time assessment of water rationing effects is to provide feedback to decision makers and water utility managers on how well the drought management plan has met established goals. Developing consensus on how the results of the analysis will be used provides insights into how to conduct analysis and communicate information. For example, this analysis uses a method that preserves the ability to identify how the program affects water user sectors. There may be a trade-off between preserving sectoral analysis versus some other characteristic, as the need for this information may preclude the use of some other method. Evaluation of this trade-off requires determination of what set of information is needed and how it will be used.

Another advantage of adopting a method in advance of program implementation is that data needed to carry out the analysis can be collected and in place before implementation of the drought management plan. However, the cost of conducting the studies and developing the consensus must be weighed against the potential benefits of the analysis. For example, a community like Corpus Christi, which faces a real risk of water shortage, could justify this cost, but a community that faces no risk of water shortage might not be able to justify this cost.

Improve communications, public information, and public relations with respect to both drought management and long-term water supply activities, alternatives, and comparative costs. Water utility customers report a need to improve public information programs regarding water saving methods, city drought management policies, and long-term water supply options. Communication from the city could increase the effectiveness of voluntary efforts to reduce water use in conditions 1 and 2. For example, residential customers report implementing many of the water saving measures they think will achieve the greatest volume of water savings. If the city made available information on the relative water savings of different measures, customers could make better informed decisions about water use and perhaps achieve greater water savings.

Focus group participants reported an apparent lack of other information as well. Many customers were unfamiliar with the city's four-stage drought contingency plan. Residential participants seemed unaware that commercial and industrial customers had been asked to reduce water consumption during conditions 1 and 2. Focus group participants reported little knowledge of city participation in the Trans-Texas Water Study. Focus group participants made statements that suggested the city had done nothing since 1984 to prepare for water shortage. The absence of a public information program may help to create resistance to the city's drought management efforts. For example, a lack of understanding on the part of customers about the alternatives, costs, and benefits of long-term water supply options could inhibit the city's ability to pursue the most practical and cost-effective options. Consider desalination, for which a number of residential and commercial/industrial participants expressed initial support over all other options. In focus group sessions, participants knowledgeable about the costs and by-products of desalination often convinced others that it was not the most cost-effective option. The city should consider improving access to information so it may play a lead role in the dialogue on long-term supply options.

Integration of rebate programs to offset the cost of water saving plumbing fixtures and retrofit kit distribution programs could enhance a citywide information program. These programs should be accompanied by information about equipment installation, use, and maintenance. For example, some school districts and other organizations capable of achieving substantial water savings with low-flow faucets and other fixtures reported problems with these devices. Problems related to installation, use, or maintenance can increase water use or make sustained use of equipment unlikely. If the city's retrofit promotion program also provided information on maintenance and use, that program might better achieve its goals.

Water utility customers also suggest that improvements in public information and communications could reduce the level of resistance to drought management policies. Public support for condition 3 water rationing among focus groups, survey, and interview participants seemed contingent on perceptions of equity. Convincing the public that the burden of water rationing is distributed equitably could be accomplished by the periodic release of appropriate information. For example, the California Department of Water Resources (CDWR 1991) suggests that pertinent information regarding water use and water supply should be published and disseminated at least weekly to maintain customer commitment to the water saving program. One factor that makes public information programs difficult to implement in Corpus Christi is a lack of funding (Cable 1996).

Examples of recent steps to improve public access to water shortage information include the city's "Weekly Water Update," which began in August 1996 and is broadcast on the local public access cable channel, and publication of answers to frequently asked questions, or Water FAQs, which began in October 1996. Other low-cost alternatives could include periodic utility bill inserts discussing water supply issues or the creation of a World Wide Web page. A web page could provide information on the water shortage, recognize customers who have implemented substantial or creative water saving measures, and carry up-to-date progress reports on how well the city is meeting water-saving goals. Regardless of the variety of instruments established to facilitate drought management communications, focus group participants expressed a need for city representatives to speak with one voice if public information programs are to be effective.

Adopt seasonal water prices and or drought conditional water prices. Prices create incentives for customers to allocate water to highly valued use. Seasonal and drought conditional water prices could help reduce water consumption by internalizing the social cost of water use in each customer's decision to apply water to specific uses. This shift in water price can eliminate the least-valued water uses and reduce aggregate water consumption when some customers' willingness to pay for water is less than the price. Because each customer allocates water to its most highly valued use, the economic losses associated with reduced water consumption are minimized. Seasonal water prices are surcharges for water used during the outdoor watering season. The fraction of water used for seasonal uses can be estimated by comparing water use during the seasonal period with water use during the winter period, which is defined as a customer's base level of water use. Drought conditional water prices are surcharges for water used specifically during drought periods. Although utility rate increases can be difficult to accomplish politically, price increases can accomplish goals similar to water rationing without imposing the same community-wide economic costs as specific regulations governing how customers use water or how much water each customer may use.

Unlike utility water rates that are designed to cover the cost of water supply, seasonal and drought conditional water prices are a kind of tax that reflect the social cost of water use. Seasonal water uses presently account for approximately 15 percent of annual water consumption and seasonal water rates work only to reduce seasonal water uses. The potential water savings associated with implementation of seasonal rate structures may be limited. In contrast, drought conditional water prices could achieve short-term water savings that exceed those of seasonal water rates. A drought conditional water price should reflect the risk of water supply depletion and could become effective as part of drought conditions 1 or 2. The limitations of a rate cap in Corpus Christi that restricts utility costs and water price increases to no more than 6 percent per year may not preclude use of seasonal water prices or drought conditional water prices.

The argument for use of market incentives to encourage water savings is based on the logic that conditional water prices can achieve water savings at a lower cost than regulation. However, noneconomic policy goals may suggest some adjustments to a flat conditional water price. For example, conditional water prices can be seen as a regressive tax on water consumption. When measured as a percentage of household income, the greatest impact may fall on lower income residential water users that may not use much water in the first place, and a conditional water price may have little effect on wealthier water customers who are responsible for a large percentage of residential water use. If it is not the objective to place a disproportionate amount of the burden for reducing water consumption on lower income residents, this effect could be moderated by providing assistance in paying conditional water prices to certain classes of customer. The city already maintains a similar assistance program called Heat Help. Alternatively, drought conditional water prices could be applied to water increments above a specified minimum.

How do conditional water prices compare with current proposed surcharges for water use above proposed allocations of water under drought condition 3 water rationing? Unlike proposed surcharges, there is no penalty for water use above a specified level. This preserves the economic benefits associated with using prices to create incentives that reduce water consumption. Another difference between proposed surcharges and drought conditional water prices is that the latter reflect the risk of water supply depletion. Conditional water prices may be relatively low initially but could increase as a water shortage continued or as the risk of water supply depletion increased. There is presently no apparent link between the social costs of water consumption in Corpus Christi and surcharges proposed for exceeding condition 3 water allocations. A third difference is that drought conditional water prices are in place before a water shortage occurs.

Adopt training programs for commercial water users to teach water conservation methods and strategies. This report describes several obstacles to water savings based on discussions with residential, commercial, and industrial customers. One obstacle expressed by commercial customers, especially smaller commercial customers, was a need for training programs that provide information on how to achieve water savings. Efforts at training could pay off by increasing the effectiveness of short-term water rationing and longer-term water conservation. Activity-based training programs rather than industry-based programs are recommended to reach the greatest possible number of participants. An effective training program could lower both the level and rate of growth in water demands in the future.

Table 1.1
Some Key Results of This Water Savings Analysis

- Water savings are apparent in aggregate total and treated uses between May and November 1996.
- Water savings are apparent in commercial and residential water user sectors between May and November 1996.
- All water user sectors respond to rainfall and temperature variables.
- Statistically significant price elasticities are apparent only in the commercial water user sector. When aggregated by sector, industrial and residential water customers show little response to price changes occurring between 1986 and 1996.
- Small but statistically significant increasing trends appear in aggregate per capita total water use. No significant increasing or decreasing trends appear in per capita treated water uses.
- Significant increasing trends appear in commercial and industrial water user sectors, but these estimates do not control for differences in productivity across years.
- Although per account residential water demand has decreased in absolute terms over the past 15 years, there are no apparent increasing or decreasing trends in the residential water user sector given model determinants of water demand.

Table 1.2
Commercial/Industrial Input: Observations about Patterns of Water Use

Production Related Water Saving Measures
- Businesses reported implementing measures to conserve water in production in advance of condition 3 water rationing.
- Businesses began saving water by repairing, maintaining, and altering current production processes to affect the greatest possible water savings before investing in new capital equipment or additional labor hours.
- Some organizations implemented voluntary water saving measures to avoid perception of water waste.

Non-Production Related Water Saving Measures
- Participants reported implementing non-production related efforts beyond those required by the city in drought conditions 1 and 2.
- Relatively few participating businesses implemented voluntary indoor water saving measures that do not relate to production.
- A majority of commercial/industrial participants formally encouraged their employees to conserve water.

Total Water Use
- Participants reported using less water in July 1996 than in July 1995.

Marginal Water Use
- Significant water use reductions may require an emphasis on reducing water use in production.
- Many commercial/industrial participants waited to learn the requirements of condition 3 water rationing to decide which processes to alter.
- Outdoor water use may be more marginal than indoor water use for non-production related processes.
- Organizations make water savings decisions based in large part on the relative cost-effectiveness of potential projects.
- Firms in which water is a minor expense generally plan to revert to previous water consumption behavior when drought restrictions and voluntary savings requests expire.
- Firms in which water is a major expense might keep in place investments made during the current water shortage that prove to be cost-effective.

Table 1.2 (cont.)
Commercial/Industrial Input: Observations about Patterns of Water Use

Obstacles to Water Savings

- Uncertainty about condition 3 water rationing and the baseline from which the city will calculate rations is a significant obstacle to increased voluntary water savings.
- Lack of information about methods of reducing water use is an obstacle to increased water savings among smaller commercial enterprises.
- Some commercial/industrial customers face the additional obstacle of reliance on their own customers' water savings to reduce water use.
- Facility and equipment constraints are obstacles to increasing voluntary water savings.
- Health, safety, and liability issues are obstacles to increasing voluntary water savings in some commercial/industrial sectors.
- Public resistance can prevent organizations from implementing voluntary water saving measures.
- Water quality problems resulting from the water shortage are an obstacle to increased voluntary water savings among larger industries.

Possible Substitution Effects

- Commercial/industrial participants are able to substitute other inputs for city water in some production processes.
- Where substitution of other inputs for city water is cost-effective, most of the city's largest industrial water customers have already invested in the necessary technology.

Table 1.3
Commercial/Industrial Input: Observations about Economic Impact

Indicators of Economic Impact

- Focus group and survey results indicate that revenue and employment would be appropriate indicators of the economic impact of the water shortage and city restrictions on most commercial/industrial sectors.

Perceived Short-Term Economic Impact

- Revenue and employment have been hurt in industries affected most directly by drought condition 2 mandatory water restrictions.
- Many participants experienced small increases in fixed costs to comply with condition 2 outdoor watering restrictions and with the city request for voluntary water savings.
- Many participants experienced small increases in variable costs to comply with condition 2 outdoor watering restrictions and with the city request for voluntary water savings.
- Many participants were unable to estimate the revenue and employment impacts of condition 3 water allocation.
- Anticipated impacts of condition 3 water rationing on revenue and employment are unclear.
- The revenue and employment effects of condition 3 water rationing depend on the reduction required by the city and the baseline from which the reduction is calculated.

Possible Long-Term Economic Impact

- A majority of commercial/industrial participants believed that the long-term risk of drought in Corpus Christi is high enough to justify the cost of water saving investments.
- The current water shortage affected few participants' long-term expansion plans.
- Industrial participants expected water shortage long-term risks to affect their ability to compete for resources from parent firms.
- Commercial/industrial participants expressed concern that the long-term risk of water shortage will harm the local economy.

Table 1.4
Residential Customer Input: Observations about Patterns of Water Use

Mandatory Water Savings

- Residential customers report compliance with drought condition 2 outdoor watering restrictions.
- Residents report that compliance with condition 2 watering restrictions is not costly.
- Households report that they will be able to comply with the short-term requirements of condition 3 allocation.
- Anticipated long-term foundation and landscaping costs may reduce residents' willingness to restrict outdoor watering under condition 3.
- The current surcharge plan for drought condition 3 may not discourage households' use of water beyond their allocation.

Voluntary Water Savings

- Residents report implementing voluntary outdoor water saving measures beyond those required by drought condition 2.
- Residents report implementing voluntary indoor water saving measures in conditions 1 and 2.
- Households report maintaining or reimplementing many water saving practices implemented in response to the 1984-1985 water shortage.
- Households report implementing many of the water saving measures they consider to be most effective.

Total Water Use

- Residents report that water saving efforts are reducing their total household water use.
- Residents report that compliance with mandatory water restrictions does not necessarily reduce outdoor water use.

Obstacles to Water Savings

- Cost, convenience, and lack of information are the three most commonly reported obstacles to household water savings.

Table 1.5
Residential Customer Input: Observations about Marginal Water Use

- Outdoor water use is marginal relative to indoor water use among residential focus group participants.
- Residents report greater willingness to reduce water use for a variety of purposes than to cease water use for selected purposes in the short term.

Table 1.6
Residential Customer Input: Attitudes toward Drought Management and City Water Policies

Knowledge and Perceptions of the Water Shortage
- Focus group participants consistently rank the water shortage among the most important city concerns.
- Residents demonstrate reasonable perceptions of the causes and severity of the water shortage.

Attitudes toward Drought Management and Water Savings
- Residents express positive attitudes toward mandatory and voluntary household water saving measures in conditions 1 and 2.
- Most residents perceive current plans for household water rationing under condition 3 to be adequately restrictive, but not timely.
- Most residents perceive condition 3 household water rationing to be fair, provided it is adequately enforced.
- Residential perceptions about the fairness of condition 3 rationing are influenced by perceptions of the extent to which business and industry have pursued water savings.
- Residents see a role for voluntary household water savings, but not mandatory restrictions on water use, in long-term drought management programs.

Attitudes toward City Management of the Water Shortage
- Many residents are unfamiliar with the city's four-stage drought contingency plan.
- Residents are divided over the city's ability to plan a solution to the current water shortage.
- Residents would like the city to provide information about how to save water and about city water policy on an ongoing basis.

Long-Term Water Supply Preferences
- Residents report the need for more information to identify preferred long-term water supply alternatives.
- Residents prefer a strictly proportional distribution of costs for long-term water supply solutions among water customers.
- Residents appear less willing to share the costs of long-term water supply solutions when responding to a specific cost scenario.

Table 1.7
Commercial/industrial Input: Attitudes Toward Drought Management and City Water Policies

Knowledge and Perceptions of the Water Shortage

- Most commercial/industrial customers are well informed about the causes and severity of the water shortage.

Attitudes toward Mandatory and Voluntary Water Savings

- Commercial/industrial attitudes toward mandatory and voluntary water savings are shaped by firm-level economic effects of water saving measures.
- Most commercial/industrial participants report that condition 3 and 4 drought management measures should be implemented as planned or in a manner less restrictive than planned.
- Commercial/industrial customers see a role for voluntary water savings, but not mandatory restrictions, in long-term city water management plans.

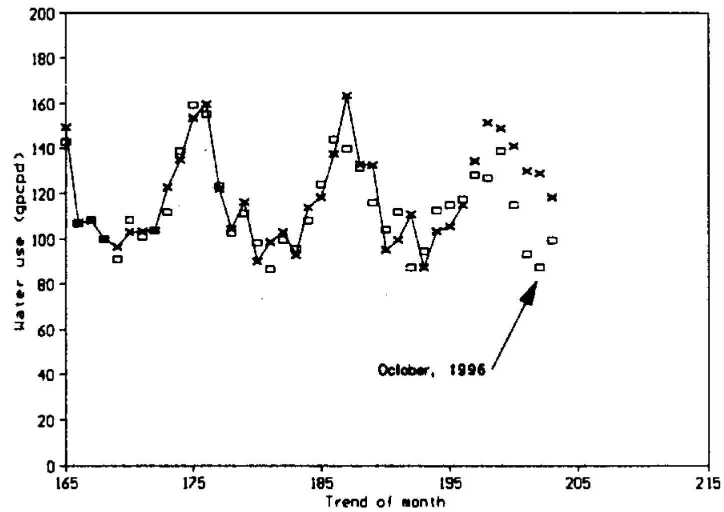
Attitudes toward City Management of the Water Shortage

- Most commercial/industrial customers are familiar with the city's drought contingency plan.
- Commercial/industrial participants express confidence in the city's ability to plan a solution to the current water shortage.
- Commercial/industrial participants identify consistent policy and enforcement as important elements of the city's drought management program.
- Participants report a need to improve the two-way flow of information between the city and commercial/industrial interests.
- Participants suggest that city drought management policies should incorporate incentives to save water in advance of mandatory restrictions.

Long-Term Water Supply Preferences

- Commercial/industrial participants report that preferences regarding long-term water supply options are based chiefly on the cost of water produced.
- Most commercial/industrial participants would prefer the cost of long-term water supply options be distributed in proportion to total water use.

Figure 1.1
Forecast of Municipal Per Capita Per Day Water Demand
(gallons per capita per day)



Chapter 2. Overview of Drought Management and Water Supply

Drought Management Program Summary

The city's drought management plan consists of four conditions which may be put into effect when reservoirs reach specified trigger levels. Condition 1 imposes a once-a-week limit on lawn watering and requests voluntary reductions in water use among customers with the goal of achieving a 10 percent water savings. The city Council began implementation of condition 1 measures on April 9, 1996. Condition 2 further restricts seasonal water uses such as building washing, car washing and other outdoor water uses with the goal of achieving an additional 5 percent water savings. Seasonal water use accounts for about 15 percent of annual water demands in Corpus Christi. Condition 3 requires residential customers to ration water. Water rations range from a minimum of 6,000 gallons per month to a maximum of 12,000 gallons per month, depending upon the number of household residents. Rations are enforced by surcharges to customers who exceed them. Residential customers who exceed the water ration by more than 4,000 gallons per month will be removed from the system and charged $50 and $500 for reinstatement after the first and second offenses, respectively. Customers that exceed their water rations more than twice during the drought management period will be permanently removed from the system until after the drought management period. Condition 3 also requires mandatory use reductions among commercial and industrial customers. The city began implementation of condition 3 drought restrictions on November 1, 1996, and was poised to begin water rationing when combined storage of the reservoirs reached 20 percent of capacity. The goal of condition 3 water restrictions is to reduce water use an additional 10 percent. Condition 4 further restricts water use by prohibiting new connections to the city's water supply system, revising industrial and commercial allocations, and establishing revised rate schedules for maximum monthly residential use.

When fully implemented, the drought management program is expected to reduce water consumption 35 percent. A 1988 study showed significant water savings associated with implementation of that program in 1984 (Shaw and Maidment 1988). However, there remains considerable uncertainty on the part of water managers about the effectiveness of this program in 1996. This project clarifies both the effectiveness and the cost of program implementation. This project also includes a significant public participation component that addresses economic effects of restrictions on water uses and behavioral changes in patterns of water use. Residents and business managers provided input through survey responses and a series of focus group sessions. Analysis of participant input provides a means to evaluate the effect of water use restrictions on investment decisions, operations, and residential water uses. Such information appears potentially more useful to policymakers than estimates of income and employment effects. City staff report that information about public attitudes gained from participants not ordinarily involved in local water issues has been a valuable product of this effort.

Water Supply

The city of Corpus Christi and surrounding communities in 12 counties depend on river flows in the Nueces, Frio, and Atascosa Rivers which drain into two reservoirs, Choke Canyon Reservoir and Lake Corpus Christi, before draining into the Gulf of Mexico. The city completed its dams at Lake Corpus Christi in 1958 and at Choke Canyon Reservoir in 1978. According to the 1990 census, the total population of the 12-county area is 530,878, with 65.9 percent of that population in the Corpus Christi Metropolitan Statistical Area (MSA). The MSA is defined as Nueces and San Patricio Counties. Three years of drought in the river basins resulted in a combined inflow to the reservoirs that was less than the rate of withdrawal. At the time this study began, steadily declining reservoir levels were at approximately 30 percent of capacity.

Water Use in the Corpus Christi Service Area

The city of Corpus Christi database includes information on water sales to both retail and wholesale customers. Of total water sales, 69.8 percent are treated water sales and 30.3 percent are untreated water sales (see Figure 2.1). Industrial raw water uses account for 10 percent of total water use. Wholesale customers that resell water for commercial, industrial, and residential uses outside the city's end-user area account for 26.3 percent of total water sales. Direct sales of treated water by Corpus Christi Water Division to commercial, industrial, and residential endusers account for 63.8 percent of total water sales. Figure 2.2 shows that 44.8 percent of this use is industrial, 25.4 percent is residential, and 17.6 percent is commercial (including apartments).

Average monthly per capita water use in the Corpus Christi area is listed by year in Table 2.1 for total water use and treated water use. Total water use is the sum of treated water sales to retail and wholesale customers plus the sum of raw water sales to wholesale and industrial customers. Treated water use is the sum of all treated water sales to retail and wholesale customers. Analysis of per capita water use controls for changes in water demand related to changes in population and identifies technological or behavioral trends in water use. Because population estimates do not correspond directly to the population served, the implicit assumption is that population growth in the MSA is equal to the population growth in the Choke Canyon/Lake Corpus Christi service area. This allows a comparison of water demand across years.

Population estimates do not correspond directly to the area served. The reason is that approximately 7.8 percent of the population served by the Choke Canyon/Lake Corpus Christi system is located outside the MSA. Similarly, HDR Engineering, Inc., estimates that only about 92 percent of the MSA population is served by the Choke Canyon/Lake Corpus Christi water supply system (HDR Engineering 1995). While this method serves the purpose of the analysis presented in this report, caution is advised in direct interpretation of (1) per capita water demands or (2) comparison of Corpus Christi per capita water demands versus per capita water demands in other cities.

Table 2.1 lists average water use per account for residential, commercial, and industrial customers in the Corpus Christi retail service area. Like per capita water use, per account water use controls for changes in water demand related to an increasing number of service connections. For example, an increasing level of commercial water use per account might suggest long-term changes in water efficiency or increased productivity of commercial and industrial customers. Short-term changes in the level of per account water use could be related to temperature and rainfall effects, or other factors.

Growth of Water-User Sectors

The residential water user sector is the strongest growing water user sector in Corpus Christi. The number of residential customer accounts increased by 16.66 percent between 1982 and 1996. The number of commercial and industrial customers fluctuated over the same 10-year period, but there was a net increase in the number of accounts between 1982 and 1996. The number of commercial accounts increased 5.6 percent and the number of industrial accounts increased 15.47 percent. Table 2.2 lists the number of customer accounts in each water user sector serviced by the city's retail water utility. Also listed in Table 2.2 is the number of residents in the Corpus Christi MSA. As described above, these population estimates include some residents in Nueces and San Patricio counties not serviced by the Choke Canyon/Lake Corpus Christi water supply system.

Focus on Residential Water Sales

Residential water sales, retail water sales to single-family residences and duplexes, account for approximately 25 percent of annual water demand. The residential water-user sector is the fastest growing water user sector in Corpus Christi. Figure 2.3 compares the distribution of residential accounts over a range of water volumes representing the mean monthly volume of water billed during a four-month period including May, June, July, and August in four separate years, 1993 through 1996. For graphical purposes, the figure makes no distinction between lines representing years 1993-1995. A special symbol has been added to the line representing the distribution in 1996 to show how it compares to those years prior to the drought management period. The figure shows little difference in this distribution between years and that a significant portion of residential water sales can be attributed to a small percentage of residential accounts. Figure 2.3 also shows the percentage of customers billed for a given quantity of water. For example, the average monthly water bill during the four-month period was 6,000 gallons or less for 30 percent of households.

The purpose of Figure 2.3 is to compare the distribution of residential water accounts in years preceding 1996 with the distribution of accounts during the drought management period, May-August 1996. A water savings could be reflected in a unique distribution. For example, this graph could show that drought restrictions or water rationing has a larger impact on high-volume water users than on low-volume water users. Although some change in the level of distributions can be attributed to rainfall and temperature effects, this analysis does not control for rainfall or temperature. Visual inspection of distributions across years suggests that program efforts produced little effect on the pattern of water sales between high- and low-volume water users in that period. No comparable analysis was completed for the period after August 1996. Figure 2.3 also suggests that a small percentage of residential water accounts are responsible for a large percentage of the residential water sales. Evidence of this fact is more pronounced in Figure 2.4 in which the x-axis represents a cumulative percentage of residential water accounts and the y-axis is the 1993-1995 average percent of residential water sales during the four-month period May through August. Figure 2.4 shows that the 25 percent of residential water accounts in the upper quartile was responsible for approximately 50 percent of all residential water sales between May and August. The 10 percent of residential water accounts in the upper decile account for 30 percent of residential water sales during that same period.

Water Prices

In theory, water price is a determinant of water demand. One goal of this report is to assess the potential effectiveness of price change as an incentive for encouraging customers to reduce water use. The city of Corpus Christi maintains separate rate structures for commercial and industrial customers and residential water customers. Commercial and industrial customers pay a decreasing block rate both inside and outside the city limits. Residential water customers pay an increasing block rate inside the city limits and a flat rate outside the city limits. Since 1990, nominal rate increases have averaged about 6 percent per year, which is the maximum rate allowed by the city's utility rate limit. In general, nominal commercial and residential water prices change at the same rate. For example, in 1995, the price of each rate block increased 6 percent. Appendix B lists nominal water prices by the year and month in which they became effective (see Volume II).

Nominal water prices were converted to real prices by dividing by a price index based on monthly series of producer and consumer price indexes obtained from the Bureau of Labor Statistics. Real marginal price in the residential water sector is defined as the price of the eighth thousand gallon delivered during the billing month divided by the consumer price index of the billing month (1982-1984 = 1.00). The consumer price index is for all urban consumers and all items (series identification number "cuur0000sa0"; Bureau of Labor Statistics 1996). Real commercial/industrial price is the marginal price of the next thousand gallons after the first 100,000 gallons during the billing month divided by an adjusted monthly producer price index. The producer price index is a national average price for all commodity categories relative to that price in another month. The average is weighted by the value of shipments (series identification number "wpu00000000"; Bureau of Labor Statistics 1996). The raw producer price index has a base year of 1982 = 1.00. It was converted to 1982-1984 = 1.00 for consistency with the consumer price index.

Figure 2.5 compares an index of real marginal price of water over time in the commercial/industrial and residential sectors. The index of marginal water price is the real price divided by the average real price during the period 1982-1984, which is the base year of the index. The purpose of Figure 6 is to show the cost of water today relative to the cost of water in the past, and in comparison to prices of other consumer products and producer inputs. Real water prices have fluctuated over the past 14 years but are higher today relative to other consumer products and producer inputs. For example, the net increase in real price of water between 1982 and 1996 is about 22 percent in the residential sector and 41 percent in the commercial and industrial sectors.

The city applies price increases equally in both commercial and industrial water sectors. For example, when residential prices increase 6 percent, commercial and industrial prices also increase 6 percent. Differences in the change in real marginal price between water user sectors shown in Figure 2.5 are related to differences in the consumer and producer price indexes used to standardize prices across years. The producer price index used to standardize commercial/industrial water prices has risen at a slower rate than the consumer price index, making water price increases in the commercial/industrial sector higher relative to other inputs.

Table 2.1
Mean Monthly Per Capita and Per Account Water Use (1982-1995)
(Corpus Christi Metropolitan Statistical Area)

	Choke Canyon Lake Corpus Christi System		Corpus Christi Retail Service Area		
	Per capita water use per month (thousand gallons)		Per account water use per month (thousand gallons)		
	Total	Treated	Residential	Commercial	Industrial
1982	7.52	5.25	9.55	50.61	11,036
1983	7.52	5.35	8.91	52.81	11,841
1984	7.16	5.01	7.51	47.09	11,186
1985	6.53	4.82	7.46	45.54	10,176
1986	6.91	5.10	8.03	50.00	10,589
1987	6.91	5.27	8.01	50.74	11,059
1988	7.70	5.66	8.64	56.10	11,664
1989	8.64	6.30	9.81	61.21	12,585
1990	8.07	5.88	8.86	60.33	11,135
1991	7.69	5.59	7.49	57.21	11,786
1992	7.59	5.63	7.55	58.25	12,265
1993	7.96	5.73	7.69	59.04	12,981
1994	8.02	5.60	7.78	58.83	12,785
1995	7.76	5.39	7.62	56.52	12,275

Table 2.2
Population and Mean Number of Retail Accounts Serviced Each Year (1982-1996)

	Mean Number of Retail Accounts Serviced by Month			Population	
	Residential	Commercial	Industrial	Statistical Area[1] (thousands)	City Limits[2] (thousands)
1982	58,744	6,946	84	343.80	236.82
1983	60,412	7,135	87	351.40	239.89
1984	61,690	7,352,	89	352.90	242.79
1985	62,088	7,521,	92	353.60	245.32
1986	62,664	7,509	92	356.60	247.95
1987	62,597	7,367	88	352.10	250.45
1988	63,012	7,279	87	350.30	252.65
1989	63,509	7,229	86	349.10	254.76
1990	64,139	7,180	93	350.70	256.89[4]
1991	64,769	7,146	92	356.20	260.07
1992	65,456	7,175	91	361.40	263.55
1993	66,384	7,180	96	375.70	267.08
1994	67,407	7,266	97	378.04[3]	270.52
1995	68,065	7,298	98	380.73[3]	274.01
1996	68,536	7,338	97	382.71[3]	277.49

Sources:
1. Bureau of Economic Analysis 1996
2. City of Corpus Christi Planning Department.

Notes:
3. Estimated by the authors
4. Adjusted to 257.45 for the period April-December 1990

Figure 2.1
Total Water Sales by the City of Corpus Christi, Fiscal Year 1995

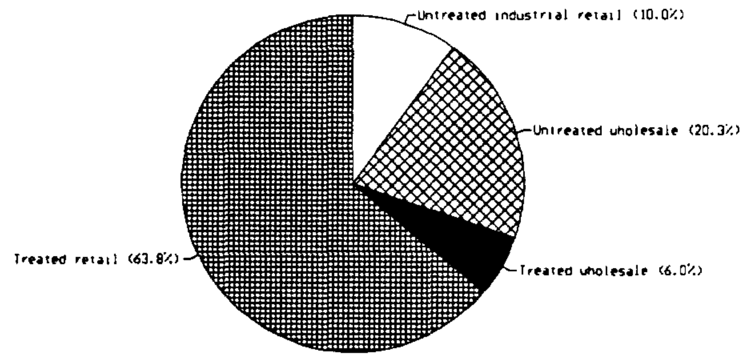


Figure 2.2
Treated Water Sales by the City of Corpus Christi, Fiscal Year 1995

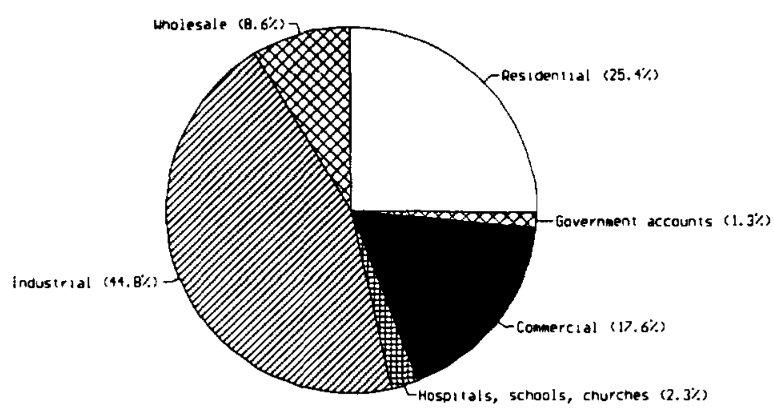


Figure 2.3
Cumulative Distribution of Average Monthly Residential Water Billed During the Period May-August by Year, 1993-1996

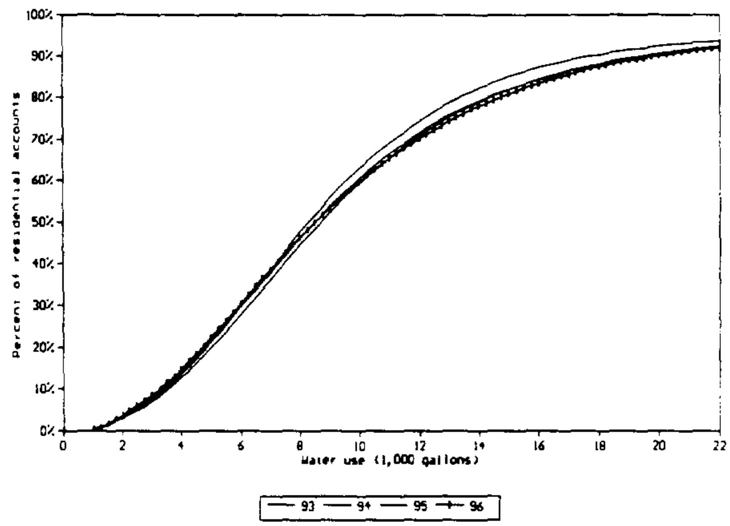
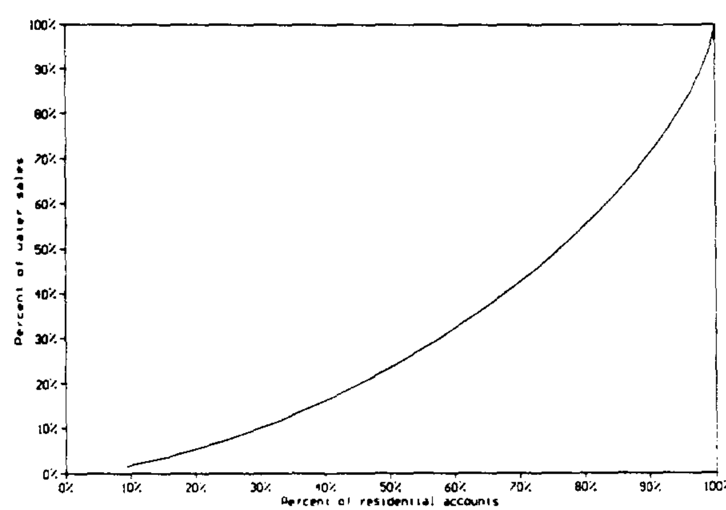


Figure 2.4
Average Percent of Residential Water Sales by Percent of Residential Customer Accounts, May-August, 1993-1995



Chapter 3. Water Demand Forecasting and Water Savings Analysis

When the purpose of the forecasting exercise is to evaluate water savings from drought management, the overall approach is to develop water demand forecasts over the drought management period as if no drought management program were in place. The difference between forecast values and actual water use is interpreted as water savings. Several methodological approaches to water demand forecasting exist. The utility of any one method may vary depending upon the scale of the time series. For example, the time series may be hourly, daily, weekly, or monthly. The purpose of the analysis is fundamental to selection of time series scale. Daily and hourly models may be most appropriate for utilities that frequently need to adjust production levels in response to highly variable demands. While monthly models are less useful for making short-term production decisions, they have proven to be entirely adequate for understanding the factors that affect water use, predicting demands in the months ahead, and detecting and measuring water savings.

Shvartser, Shamir, and Feldman (1993) used pattern recognition in conjunction with autoregressive integrated moving average (ARIMA) models to forecast hourly water demands up to several days ahead using the past 15 days of hourly water use data. Anderson, Miller, and Wshburn(1980) used regression to forecast daily water use and estimate water savings in Fort Collins, Colorado. Maidment and Miaou (1986) developed models of daily water use for cities in Texas, Pennsylvania, and Florida using time-series decomposition and Box-Jenkins transfer function noise models. These authors provide an overview of water demand forecasting methods used in the literature through 1984. Shaw and Maidment (1987) applied these methods using an intervention component in their transfer function noise model to estimate water savings during 1984-1985 in Austin and Corpus Christi, Texas. The Austin model is reviewed in Maidment, Miaou, and Crawford (1985). The Corpus Christi drought management study is reviewed in Shaw and Maidment (1988).

Hansen and Narayanan (1981) used time-series regression to estimate monthly water demands and interpret price elasticities in Salt Lake city, Utah. These authors explained over 90 percent of the variation in monthly water demands using regression procedures. Maidment and Parzen (1984) developed a time-series decomposition and climatic regression procedure for monthly water use in five Texas Cities and for Deerfield Beach Florida. That model explained 86 percent of the variance of the monthly series in Canyon, Texas. These authors suggest that multiple regression is suitable for annual and monthly data in slowly changing cities. Time-series works best in rapidly growing cities, and for daily and weekly water use data. The relatively high computational requirement of time-series analysis must be balanced with any expected increase in the forecasting ability of the model. Franklin and Maidment (1986) compared the use and performance of weekly and monthly time-series forecasts with forecasts based on a time-series decomposition and regression approach. Models of weekly water use performed only slightly better than their monthly counterparts.

Berk, LaCivita, Sredl, and Cooley (1981) used Box-Jenkins ARIMA models to estimate the effects of drought management programs on monthly water consumption in several California cities during the drought of 1976-1977. The study estimated water savings in different water user sectors including agricultural, commercial, industrial, and residential sectors. These authors list two reasons that the Box-Jenkins method might be preferred to regression corrected for autocorrelation (correlated residuals): (1) logical selection of autoregressive terms and (2) flexibility to use lagged dependent variables with autoregressive error terms to model delayed responses. The latter is necessary because the effect of drought management programs may not be immediate.

Some authors study the effect of alternative forms of climatic specification on regression results. Morgan and Smolen (1976) studied a set of variables including (1) simple temperature and precipitation variables; (2) potential evapotranspiration minus precipitation; and (3) monthly seasonal dummy variables. Evaluation of model results included the effect of regressors on price and family income variables as well as assessment of each model's forecasting power. The authors concluded that simple temperature and rainfall variables outperformed alternatives. Weber (1989) used regression of monthly water demand on a seasonal index and rainfall, temperature, and price variables to estimate price elasticities of water demand. His model incorporates a moving average index to model transitions in water use between winter and summer months.

The selected method should provide a reasonably precise estimate of what water use would be given economic activity and weather patterns during the drought management period. The utility of results to water managers was an important concern in selection of methods. The perception among utility managers has been that information on total water savings is more valuable when accompanied by identification of those water sectors in which savings are realized. Provided in real time, such information could identify water user sectors where more effort or alternative program designs are needed. Information about water uses by water user sector were readily available on a monthly basis from billing records. Thus, the project team settled on the analysis of monthly water use to forecast water demand.

Chapter 4. A Rainfall-Temperature Model of Water Use

Rainfall-Temperature Model Development

One difficulty with using ordinary least squares regression to forecast water sales it that the presence of serial correlation, a correlation between residuals of the regression model, violates one of the underlying assumptions of the method. Regression results may not be interpretable because of inefficient parameter estimates and inflated estimates of the R-squared statistic. Two rainfall temperature models have been developed to forecast water use in Corpus Christi. The first is a rainfall-temperature regression model that corrects for autocorrelation with an autoregressive error term. The second is a moving average index model that does not exhibit autocorrelation. In general, the latter performs slightly better as a forecasting tool, but the rainfall-temperature model is preferred for making inferences from parameter estimates.

The model uses monthly rainfall and temperature as independent variables to estimate per capita and per account water sales. Separate analyses have been developed using six aggregations of water sales. These are total, treated, municipal, residential, commercial, and industrial water sales. This chapter of the report uses an analysis of total water sales, treated water sales, and municipal water sales to inform the reader of the forecasting approach and interpretation of results. Per capita total water sales is calculated as the sum of all treated and raw water sales divided by the combined population of Nueces and San Patricio Counties. Per capita treated water sales are the sum of all wholesale and retail treated water sales by the city of Corpus Christi divided by the combined population of Nueces and San Patricio Counties. Both are expressed in thousand gallons per capita and include sales to wholesale customers serving the surrounding areas such as Alice, Beeville, Mathis, Port Aransas, and San Patricio Municipal Water District. *Municipal water sales* are defined as treated water sales to residential and commercial customers inside the city limits divided by the population inside the city limits and again divided by the number days in the month. Unlike the other aggregations, municipal water demand is expressed in gallons per capita per day (gpcpd).water use

The minimum data requirements needed to forecast demand using these methods include the year and month of water sales, volume of water sales, number of active accounts billed, population, the mean maximum daily temperature, and aggregate rainfall over the billing month. Specification of the dependent variable on a per capita basis eliminates changes in the total water use related to an increasing or decreasing number of residents, although it does not control for changes in water demand related to an inflow of tourists. Total water use and treated water use were analyzed using population to standardize across time because much water is sold to wholesale customers outside the city's water utility retail service area. Because population estimates do not exclude all persons outside the service area, standardizing the dependent variable by number of accounts is potentially more accurate. However, no data were available on the number of accounts beyond the city's immediate retail service area.

The explanation of equation 4.1 is that as temperature increases, per capita (or per account) water use increases as people begin summer activities such as lawn watering and car washing. Indoor water use may also increase as people take more showers and wash more clothing. There is also evidence that industrial demand for cooling water also increases as outdoor temperatures rise. The model also includes precipitation which reduces outdoor water demand. These variables describe short-run determinants of water use. If the series extends over more than a few years, the addition of a trend variable can capture long-run determinants of demand such as technological change. The equation states that per capita water use is a function of temperature, rainfall, and long-term determinants of water demand other than population:

$$\hat{W}_t = \hat{\beta}_0 + \hat{\beta}_1 T_t + \hat{\beta}_2 T_t^2 + \hat{\beta}_3 R_t + \hat{\beta}_4 t_t + v_t$$

$$v_t = \varepsilon_t - \phi_1 u_{t-1} - \phi_3 u_{t-3} - \phi_{10} u_{t-10} - \phi_{12} u_{t-12} \qquad [Eq. 4.1]$$

$$\varepsilon_t \_ N(0, \sigma^2)$$

where:

W = per capita water sales (thousand gallons)

T = mean maximum daily temperature (fahrenheit)

R = aggregate rainfall (inches)

v = an error term

$u_t = W_t - (\alpha_0 + \alpha_1 T_t + \alpha_2 T_t^2 + \alpha_3 R_t + \alpha_4 t_t)$= residuals of the structural equation

α = parameters estimated by a preliminary regression

β = parameters estimated by regression

ϕ = autoregressive parameters for error terms

t = an index of months i={1,2,3, . . .,n} (January, 1982 = 25)

i = the lag of significantly correlated residual errors

The error term corrects for autocorrelation. Autocorrelation is a positive or negative correlation between the difference in predicted and actual values of a regression and that difference at one or more lags in the past. Autocorrelation results in inefficient parameter estimates. Interpretation is more difficult than in the structural model and provides little in terms of understanding water use processes. However, the presence of the error term can improve the forecasting ability of a model and allow for separate interpretation of structural parameters. Model coefficients for per capita total and treated water sales are provided in Table 4.1.

This model forecasts monthly per capita treated water sales when estimated over the period January 1986 to April 1996. The 1996 drought management period May to August is excluded from the period over which parameters are estimated. The structural parameters of this model-temperature, rainfall, and trend-account for 70.36 percent of the variation in treated water use. The autoregressive error term accounts for an additional 16.39 percent of that variation. Overall, the model accounts for 86.75 percent of the variation in treated water use. Although the model of per capita total water use works well also, the R-squared statistic for structural parameters is relatively low.

The squared temperature term of the rainfall equation accommodates seasonality in water use. A nonlinear relationship is needed because water sales increase more rapidly in relation to temperature increases at higher temperatures and during late spring and summer months. Inclusion of a squared temperature term describes an increasing rate of water use relative to a 1° change in temperature. Although a negative coefficient for the temperature term implies decreasing water use with increasing temperature, this is balanced by a positive coefficient for the squared temperature term. The method outperformed seasonal dummy variables and logarithmic transformations that might also be used to describe these temperature effects.

Figure 4.1 plots the relationship between water use and temperature. There is an increasing rate of water use for each 1° change in temperature. These estimates represent water use over a range of temperatures while holding rainfall at 2.601 inches per month and other structural parameters constant. Interpretation of the precipitation variable is straightforward. One inch of rainfall reduces per capita treated water use on average 42 gallons per month. The parameter estimate for the trend variable is positive but small and statistically insignificant. This indicates no long-term change in per capita treated water use that might be attributed to changes in water use patterns or changes in technology.

Results for per capita total water use are slightly different. Although the temperature terms are almost identical to those estimated for treated water use, the parameter estimate for rainfall shows a larger effect. The trend variable which measures long-term change in water use is also positive and statistically significant, which suggests per capita water use is increasing at a rate of nine gallons per capita per month. Because analysis of per capita treated water use shows no statistically significant trend, this increase in total water use could be attributed to raw water users or increased demand for water outside the metropolitan statistical area.

Evaluation of the Rainfall-Temperature Model

This model can be evaluated on several bases. Among these are its ability to 91) explain those processes causing high or low water uses; (2) its ability to forecast accurately over the estimation period, or one or more months ahead; and (3) the precision of water demand estimates. The interpretation of model parameters to explain possible causes of high or low water use has already been discussed. Structural parameters account for 48 percent of the variation in total water use and 70 percent of variation in treated water use. One variable potentially missing from this model is related to economic causes of water use. Commercial and industrial customers account for 49.8 percent of treated and untreated water sales. It is likely that long-term economic growth or short-term changes in productivity and demand could be identified as causal factors of water demand. Income and employment variables tested during development of this forecasting model have been excluded because they produced inconsistent results. Price variables were difficult to specify for total, treated, and municipal water sales, but are evaluated in models of sectoral water demand.

The accuracy of forecasts over the estimation period can be evaluated by the average absolute relative error (AARE). This measures how closely the predicted values match the actual values of the time series over a period of one or more months ahead. AARE is the absolute value of the residual divided by the actual value of water use (Franklin and Maidment 1986). Equation 2 describes how the mean AARE is calculated over n time intervals:

$$AARE = \frac{1}{n}\sum_{t=1}^{n}\frac{|\varepsilon_t|}{W_t} \qquad [Eq.4.2]$$

where:

AARE = average absolute relative error

W = actual water use

ε = the error of the forecast

t = an index of time interval $\quad t = \{1, 2, 3, \ldots, n\}$

Table 4.2 lists the average AARE for models of per capita total and treated water sales during each year over the estimation period. For example, in 1986 the mean AARE of the treated water sales model is 7.3 percent. The overall mean AARE of that model during the estimation period, January 1986, through April 1996, is 4.3 percent and the range in monthly AARE is 0.06 percent to 17 percent. Unusually high errors occur in the first year due to adjustment of the error term, v_t in equation 4.1. After 1986, the monthly AARE exceeds 10 percent during only three months and has a maximum monthly error of 13 percent in one month.

A third measure of how well the forecasting model will detect water savings is precision of model estimates, measured by the relative width of the mean confidence interval around water demand forecasts. The confidence interval reflects the bounds in which the true mean estimate of the forecast would fall 95 out of 100 times, given the independent variables of the regression equation and the variability in the data. It is desirable to have a forecasting model with narrow confidence bands that is sensitive to small differences in water use. Confidence intervals expand at an increasing rate as one moves from the center of the estimation period to the beginning or end, and at a much faster rate when forecasting beyond the period over which the coefficients are estimated. Confidence intervals are bigger at the beginning of the series because there are no past error terms to use in making the early forecasts (SAS Institute 1993, p. 243).

Water demand forecasts are estimates of water sales in the absence of the drought management program because the model is estimated over a period of time during which no drought management plan was in place. Because there is an error associated with estimates, differences between forecast and actual water sales during the drought management program must exceed some criterion that is an operational definition of water savings before these differences can be distinguished from random error of the forecast. Confidence limits are one such criterion. Figure 4.2 plots the absolute difference between the lower two-sided 95 percent confidence bound and the treated water sales forecast from equation 4.1 as a percent of the forecasted value. Peaks in this operational criteria occur in winter months, when per capita water use is relatively low (Figure 4.2, A). For example, in July 1996, when t = 199, the minimum treated water savings that exceeds the criteria is 13.26 percent (Figure 4.2, B). If the difference in the water demand forecast and actual water use in that month exceeds the criterion, the estimate of water savings is the difference in forecast and actual values. If the difference is less than this criterion, the conclusion is that any apparent water savings are not large enough to distinguish between water savings and random error of the water demand model. This differs from the statement that no water savings is observed. Use of a two-sided 95 percent confidence bound is conventional, but in some cases there are legitimate reasons for adopting alternative confidence bounds.

Alternate Rainfall-Temperature Model Specification

Reliance on rainfall and temperature alone imply that equation 4.1 models "seasonal" water use while ignoring changes in water use related to productivity, income, or price. Better forecasts and more information about the economic impact of mandatory reductions in water use could be obtained by incorporating these variables into the analysis. Price variables are excluded from the analysis of treated and total water use. The reason for this is that given multiple water user sectors with different block rate structures, the marginal price of water is hard to define. Water prices and price elasticities are addressed later in the analysis of residential, commercial, and industrial water demand sectors.

Income, sales, and employment data were available for the Corpus Christi MSA. Total annual income and income by standardized industrial classification (SIC) code were obtained from the 1994 Regional Economic Information System (Bureau of Economic Analysis 1996). Monthly total employment and employment by SIC code were obtained from the Bureau of Labor Statistics on-line database (Bureau of Labor Statistics 1996). Monthly gross sales and sales tax revenue were available from the Texas Comptroller of Public Accounts. However, anomalies in reporting and tracking of sales data may make these data unsuitable for analysis.

Incorporation of income and employment variables into the analysis produced inconclusive results. Both are theoretically strong determinants of water use (Berk et al. 1981; Weber 1993; Carver and Boland 1980). The results of these preliminary analyses may reflect the quality and applicability of these input "economic" data for the intended use. For example, annual income data can, at best, be averaged over a 12-month period to estimate monthly income. Without monthly or spatial variation, the relationship to monthly water sales can be hard to identify. Although monthly employment data provide the strongest results of all economic variables tested, these data estimate only the total number of jobs held on the 12th day of each month.

Some alternative specification of rainfall and temperature variables may be in order. Aggregate billing records represent the volume of water for which customers were billed during a particular month. These data are produced by the utility operations division by aggregating for each sector the volume of water billed. Although the city reads all water meters each month, reported water use cannot be accurately assigned to monthly rainfall and temperature values because only 60 to 70 percent of water use occurs in the reporting month. Some customers' water use could be attributed to climatic factors during the previous month. This implies a misspecification related to the assignment of rainfall and temperature values, and these parameter estimates may not be interpretable despite accuracy of monthly forecasts. This will not affect the ability of the method to estimate water savings. However, there may be some question about when the savings occurred. For example, savings observed in August billing records may have occurred in July, and savings occurring in August may not be detected until September.

Water Savings Analysis: Demonstration over the 1984-1985 Drought Period

The rainfall-temperature model works well as a means of detecting and measuring water savings. To demonstrate how the method works, water savings during the 1984-1985 drought period can be estimated by forecasting backward ("backcasting") over the most recent period during which the city implemented its mandatory drought management program, which included water rationing to residential customers. Model parameters are estimated between January 1986 and April 1996 and water use is estimated for prior months using rainfall and temperature data. The solid line in Figure 4.3 shows the first year of the **ex-post** forecast over the estimation period. The symbol "x" represents predicted values outside the estimation period. Faint dashed lines above and below the predicted values are the two-sided 95 percent confidence limits. The estimate of water savings during the mandatory drought management period is the difference between forecast water use and actual water use. The effectiveness of that program can be seen in Figure

4.3. It shows water savings beginning with implementation of condition 3 water rationing in July 1984 and continuing over several months. Water rationing ended in November of that year.

In this example, the estimated savings is approximately 18.5 million gallons per day. This is less than the 27.2 million gallons per day reported in a study by Shaw and Maidment (1987), but this difference can be attributed to "backcasting" In this example, backcasting is expected to underestimate potential water use during the 1984-1985 drought management period. Because the forecasting equation is estimated after that water shortage, when less water-intensive processes and practices had been adopted and new equipment installed, it does not portray the predrought management water use processes against which water savings should be measured. This discussion has demonstrated that backcasting with this model detects water savings in 1984 despite these problems, and, therefore, forecasting with this model should be able to detect the presence of water savings in 1996.

Water Savings Analysis: Measuring Aggregate Water Savings in 1996

A forecast of treated water use on a per capita basis can be developed for the future using rainfall and temperature data from the Corpus Christi International Airport. Forecasts are developed by substituting rainfall, temperature, and time into equation 4.1 with the coefficients listed in Table 4.3. For example, the forecast of per capita treated water sales for May 1996 (Y_{197}) is:

$$\hat{Y}_{197} = 16.649 \bullet 0.363(87.6) + 0.0027(87.6\ )^2 \bullet 0.042(1.14) + 0.003(197) + v_{197} = 6.09$$
$$v_{197} = 0.372\, u_{196} + 0.211\, u_{194} \bullet 0.132\, u_{187} + 0.409\, u_{185} \qquad [Eq.4.3]$$

The mean maximum temperature during May was 87.6° Fahrenheit and there were 1.14 inches of rain at the Corpus Christi International Airport. The trend variable for May is defined by the numerical sequence of months in the data series when January 1982 is taken to be 25. While the assignment of indices is somewhat arbitrary because the series could begin at any point in time, changes in the initial assignment of indexes must be completed before estimation of model parameters. The second equation is the autoregressive error term. A series of coefficients is multiplied by the difference in predicted and actual values at significantly correlated lags.

When a forecast of water use is created for more than one time period over the drought management period or after the drought management period has begun, the residuals of lagged forecasts will not be available. The reason is that there is no measurement of water use in the absence of the drought management program. This problem is resolved by substituting the value of the error term at each lag for which the lagged residual is missing. For example, a forecast for August 1996 is missing the first and third lagged residual.

$$\hat{Y}_{200} = 16.649 \bullet 0.363(94.21) + 0.0027(94.21)^2 \bullet 0.042(6.26) + 0.003(200) + v_{200} = 6.59$$
$$v_{200} = 0.372\, v_{199} + 0.211\, v_{197} \bullet 0.132\, u_{190} + 0.409\, u_{188} \qquad [Eq. 4]$$

The effect of the error term on the forecast decreases as the number of successive months in the forecast increases.

Figure 9 shows a forecast of water use from July 1993 through November 1996. The x-axis denotes the numerical sequence of months such that 175 represents June 1994 185 represents April 1995 and 197 represents May 1996. The bands around the forecast line reflect the two-sided 95 percent confidence interval. The lower bound of the two-sided 95 percent confidence interval could serve as an operational definition of water savings. The difference between the forecast and the bound ranges from approximately 885 to 949 gallons per capita between May and November, 1996. That is approximately 14 percent of forecast water sales. With this confidence bound as a criterion for distinguishing between random error and water savings, only differences between forecast and actual water use larger than that difference could be interpreted as an effect of efforts undertaken during drought conditions 2 and 3. Figure 4.4 shows that this condition is met in June, September, and October. However, Figure 4.4 also shows a strong pattern overall that suggests effects of the program each month. Other criteria exist for interpreting water savings. These criteria are discussed later in the text.

Application of Rainfall-Temperature Model to Water User Sectors

The rainfall-temperature model may also be applied to residential, commercial, and industrial water user sectors. Specification of the model and interpretation of results are similar to analyses of treated and total water use. Two differences distinguish these estimates from those generated using equation 4.1. Equation 4.3 includes a marginal price term and is specified on a per account basis rather than a per capita basis. It is applied to three water user sectors. Residential water use consists of all retail water sales to meters at single-family homes and duplexes. Commercial water use includes retail sales of treated water to meters servicing nonindustrial and nonresidential establishments including hospitals, schools, and churches, but not governmental accounts. Industrial water use is retail sales of treated and raw water to industrial customers.

Real marginal prices are specified for water user sectors but were excluded from equation 4.1. The logic for this is that prices vary across users and locations. For example, in the city retail service area there are four different rate structures, including two commercial/industrial rate structures and two residential rate structures. Inside the city limits, residential rate structures are an increasing block rate, while commercial/industrial rates are a decreasing block rate. Outside the city limits, residential prices are a flat rate and commercial/industrial prices are a decreasing block rate, although these prices are higher than inside the city limits. Marginal prices in equation 4.3 are defined for residential customers as the real price of an additional 1,000 gallons when the average customer has already consumed 7,000 gallons in one billing month. Marginal prices for commercial/industrial customers are defined as the real price of an additional 1,000 gallons when the average customer has already consumed 100,000 gallons during the billing month.

The explanation and interpretation of this model are the same as described for equation 4.1 with the exception of the price term. The price term measures customer responses to changes in the real marginal water price. The equation for this sector-specific water demand forecast is

$$\hat{W}_t = \hat{\beta}_0 + \hat{\beta}_1 T_t + \hat{\beta}_2 T_t^2 + \hat{\beta}_3 R_t + \hat{\beta}_4 t_t + \hat{\beta}_5 P_t + v_t$$

$$v_t = \varepsilon_t + \sum_{i=1}^{k} -\phi_i u_{t-i} \qquad [Eq. 4.5]$$

$$\varepsilon_t \_ N(0, \sigma^2)$$

where:

W = per account water use (thousand gallons)

T = mean maximum daily temperature (fahrenheit)

R = aggregate rainfall (inches)

P = real marginal price of water (dollars)

u = residuals of the structural equation

v = an error term

β = parameters estimated by regression

φ = autoregressive parameters for error terms

t = an index of months t={1, 2, 3, . . ., n} (January 1982 = 25)

i = the lag of significantly correlated residual errors

Model coefficients and t-statistics are presented in Table 4.3. AARE values are listed in Table 4.4. Rainfall and temperature coefficients are similar in sign and significance to those in equation 4.1. The value of coefficients is larger because they reflect change on a per account basis rather than a per capita basis. For example, equation 4.1 showed that 1 inch of rainfall over the period of the month reduces treated water use 42 gallons per capita. Equation 4.3 shows that 1 inch of rainfall reduces treated water use in the residential sector 151 gallons per residential account, and in the commercial sector 468 gallons per commercial account. The rainfall coefficient in the column labeled Industrial Water Use is -35.102. This suggests that rainfall has a negative effect on industrial water demand; however, the t-statistic is less than the critical value of 1.96. That suggests the slope coefficient is indistinguishable from zero. The interpretation is that rainfall has no measurable effect on industrial water use.

Trends in Water Demand in Water user Sectors

There are statistically significant increasing trends in per account water use in commercial and industrial sectors (Table 4.3). The increases are 87 gallons and 16,522 gallons per account per month in the commercial and industrial sectors respectively. A slight decreasing trend in per account water use, 9 gallons per month, appears in the residential water sectors. However, this trend in the residential sector is statistically insignificant.

These trends may be compared to those obtained from equation 4.1 applied to total, treated, and municipal water use. Those trends describe changes in per capita water use, not per account water use. Those results showed a 9-gallon per capita per month increase in per capita total water use, but no significant increase in treated water use. One logical conclusion is that water use by commercial and industrial customers has increased and there has been no change in the amount of water used by residential customers. However, several caveats accompany the interpretation of these trend estimates.

Trend must be distinguished from random drift. The longer the time series under analysis, the less likely that random drifts in the data will appear as trends. Analysis of subsets of a time series is likely to result in as many different estimates of the trend coefficient. In addition, estimates of the trend coefficient are sensitive to beginning and ending values of the dependent variable and to outliers (McCleary and Hay 1980). As with random drift, these effects diminish as the length of the series increases.

Positive trends in per account water consumption do not necessarily reflect decreases in the efficiency of water use. For example, increases in per account water use may be offset by increases in the level of production. Controlling for the number of commercial and industrial accounts serviced each month helps clarify the estimate of trend, but better estimates of trend could be obtained by including a variable that better reflects production in the forecasting equation. Trend over the long-term might also be interpreted as a performance measure reflecting the success of a long-term water conservation program. However, conservation programs should be evaluated on the difference between actual water use and potential water use, which reflects what water use would have been without conservation. Trends say nothing about potential water use in the absence of water conservation.

Significant Temperature Effects in Each Water User Sector

Temperature emerges as a statistically significant determinant of aggregate water use in all three water user sectors. On average, residential water demand increases approximately 2 percent for every 1° increase in temperature between 60° and 96° Fahrenheit, and commercial water demand increases approximately 0.9 percent. On average, aggregate industrial demand increases about 0.51 percent for every 1° increase in temperature between 60° and 96° Fahrenheit. Figure 4.5 plots the response of industrial water demand to temperature. This supports the hypothesis that industrial water demand increases in response to increased cooling needs.

Calculation and Interpretation of Price Elasticities

Price elasticities measure the percent change in demand that results from a 1 percent change in price. Price elasticities close to zero indicate inelastic demand. The more negative the price elasticity, the more a price increase will reduce water demand. Water prices can be included in the forecasting model to estimate price elasticities. Elasticities can be used to evaluate customer response to historic changes in water prices. Results could also be used to evaluate price as a water conservation or drought management tool. For example, Weber (1993) recommends using price elasticities to estimate the impact of a new block rate structure or summer-winter rates on water demand. Ordinarily, price elasticity is estimated while controlling for income as a causal factor of water demand because theory suggests water demand increases with income. For example, Agthe and Billings (1980) found income elasticities of water demand to be positive and greater than one. However, the use of variables representing income led to consistently poor results and were therefore dropped from the forecasting model. This problem may be related to the use of annual income data. Berk et al. (1981) also calculate price elasticities without specifying income in their demand equation. Price elasticity is best calculated using cross sectional data because patterns in the data are repeated over a variety of customer types. The aggregate monthly data from which these elasticities are calculated are not cross sectional.

Specification of marginal price variables is often problematic when increasing or decreasing block rate structures are used to calculate user fees because each customer has a marginal price unique to his or her own water increment. One approach has been to divide total water utility revenue by total water used and calculate an average price (Morgan and Smolen 1976). Billings and Agthe (1980) show that this leads to incorrect results because average price can decrease while marginal prices increase. These authors also show that use of marginal price to analyze price elasticity in block rate structures, as in a study by Howe and Linaweaver (1967), also leads to erroneous conclusions unless intramarginal prices have changed at a constant rate. Intramarginal prices are those prices for all water increments less than the marginal increment and greater than zero. Billings and Agthe recommend dissaggregating the elasticity to calculate one price elasticity coefficient which measures only income and substitution effects and one elasticity coefficient which measures the income effect of changes in intramarginal rates. Berk et al. (1981) use the marginal price for the average consumer at each point in time to identify the marginal price in a decreasing block rate structure. That price is also defined as "the average consumption that identified the marginal block in the rate schedule" (p. 91). Prices used later in this analysis of Corpus Christi water demand follow this model; however, the authors of this report thought it made more sense to observe the effect of price increases while holding identification of the average rate block constant.

Interpretation of price elasticities is sometimes unclear as it is uncertain how much of the elasticity is manifest in the short run and how much is delayed or manifest in the long-run response. In the long run, price elasticities tend to be more negative because customers have more opportunity to develop and install technological alternatives to water. Carver and Boland (1980) specify a water demand model to estimate both short- and long-run price elasticities. Time-series rather than cross sectional data are needed to estimate these elasticities. The authors note that if the change in marginal and intramarginal prices has been stable, a single elasticity approximates the long-run elasticity. Intramarginal rate increases in Corpus Christi have been relatively constant since 1986. In addition, since these data span a 10-year period, these elasticity estimates may be interpreted as long-run elasticities.

From equation 4.3, the price elasticity is calculated as the slope coefficient of the price term times the price divided by the predicted water use:

$$\_ = \hat{\beta}_5 \frac{P}{\hat{W}}$$

where _ is the point price elasticity of water demand.

Price elasticities are tabulated in Table 4.5 for each Corpus Christi water user sector. However, only the commercial sector shows a statistically significant price elasticity. Results show that commercial water demand decreases 0.51 percent in response to a 1 percent increase in the price of the marginal rate block. Water demand is inelastic in the residential and industrial water user sectors. All estimates of price elasticity are based on prices and forecasts for August 1996.

The limits of the elasticity range in Table 4.5 are calculated by substituting the 95 percent confidence limit of the estimate for β_5 in equation 4.4. These represent upper and lower elasticity estimates. The better the estimate of price elasticity, the narrower this range. When the range of elasticities overlaps zero, elasticities are considered insignificant, or not statistically different than zero. Residential and industrial elasticities are not significantly different than zero, suggesting that price plays little role as a determinant of water demand in these demand sectors.

There are several reasons that price may not appear to be a significant determinant of water demand, as is the case in these residential and industrial water user sectors. The price of water may be so low that demand may truly be inelastic at prices and quantities modeled. For example, this could be the case if the cost of altering production technologies to use less water in response to water price increases is more expensive than paying the new water rates. Howe and Linaweaver (1967) and Berk et al. (1981, p. 98) note that water prices are a function of water consumption because price is established by dividing the production costs by the volume of water sales. Marginal prices therefore do not reflect the marginal value of water to consumers. Another reason for insignificant elasticity estimates is a potentially delayed customer response to price changes. That is a statistical problem that might be resolved with lagged price variables, although some independent means of establishing that lag is needed to incorporate delayed response into the model. Other reasons, such as specification of the price variable, for example, have already been discussed.

It should be noted that water prices used in calculating these elasticity estimates reflect only the cost of water supply. Wastewater disposal costs might also be included in estimates of marginal water price. For example, residential water customers pay a minimum $9.404 for wastewater disposal plus an additional $1.899 for every thousand gallons of water over the first 2,000 gallons. If wastewater charges increase at the same rate as water prices, the effect could be to increase elasticity estimates.

Water Savings Analysis: Measuring Water Savings by Water User Sector

Differences between forecast and actual water use can be attributed to random error of the forecast or to water savings resulting from implementation of drought conditions 2 and 3. The confidence with which random error is distinguished from water savings increases with the difference between actual and forecast values. Confidence limits are often two-sided. However, when there are strong reasons to suspect that differences are unidirectional, a confidence bound can be one-sided. A one-sided confidence bound tests whether the actual water use is less than the forecast. The logic for using a one-sided confidence bound is that, if there are water savings, actual water demand will not be greater than the forecast. Table 4.6 lists one-sided confidence bounds for forecasts during the drought management period. When actual values of water use are less than the value listed as the one-sided confidence bound, differences could be interpreted as water savings. For example, Table 4.6 lists actual and forecast values for treated water sales in thousand gallons per capita. Per capita water use is calculated by dividing all wholesale and retail treated water sales in a given month by the population of the Corpus Christi MSA.

Actual treated water sales are not less than the one-sided 95 percent confidence bound until September 1996, when actual treated water sales were 4.57 thousand gallons per capita. In September, therefore, the percent difference, -24.6 percent of forecast water sales, is an estimate of water savings. No conclusions about whether small water savings occurred during the period May-August are possible. A lower level of confidence could also be used to distinguish random error from water savings. For example, a 90 percent confidence bound could be used to evaluate whether water savings occurred during the drought management period, June through September 1996. If actual water sales are less than the lower confidence bound, percent differences can be interpreted as water savings. Similar logic could be used in adopting a one-sided 80 percent confidence bound as a criterion for detecting water savings. However, these tests of water savings are slightly weaker than the 95 percent confidence bound and their use increases the risk of interpreting random variation as water savings.

What guidance exists for determining which confidence bound is appropriate for detecting water savings? One measure is to compare the performance of the forecast before the drought management period (January 1986-April 1996) with its performance during the drought management period (May-November 1996). Table 4.7 lists the number of months and the percentage of months in which actual water use exceeds proposed confidence bounds over the entire series. For example, over the entire water use period January 1986 through November 1996, actual treated water sales fall below the one-sided 95 percent confidence bound 5 out of 124 times. That represents 3.82 percent of observations in that period. Before the drought management period, 2 observations fall below the one-sided 95 percent confidence bound. That number represents 1.61 percent of these observations. During the seven-month drought management period, 3 observations fall below the confidence bound. That represents 42.86 percent of observations. The pattern shows a stronger tendency for water sales to be less than the confidence bound during the drought management period. That suggests a systematic change in the level of water use that may be related to the drought management program. The rest of Table 4.7 can be read in a similar manner for each water user sector and each confidence bound. Figures 4.6 through 4.11 display graphically the one-sided confidence bounds, water demand forecasts, and actual water use during the drought management period. Graphics are presented for all aggregations of water sales used in this study including per capita total, treated, and municipal water sales and per account residential, commercial, and industrial water user sectors.

How Far into the Future Can Forecasts Be Created?

The purpose of this water demand forecast is to estimate potential water use during the drought management program so that actual water use may be compared with forecasts and water savings may be estimated. The forecasting method makes use of an autoregressive term, lagged errors of the structural model. Therefore, the quality of forecasts will deteriorate as the number of time intervals from the end of the estimation period increases. The reason is that during forecast months there is no information on potential water use in the absence of drought management. Therefore, the lagged residuals cannot be calculated and the accuracy of the forecasts is not known.

This section evaluates the ability of the model to forecast water use beyond the estimation period. Implementation of the forecasting model was simulated by estimating the model over four time periods and evaluating the forecasts against actual water use during nondrought management months. Results are evaluated in terms of the average absolute relative error. Table 4.8 describes the four runs. Trial 1 was completed by estimating the model over the entire available period and calculating a mean AARE for the estimation period. Trial 1 provided a baseline absolute relative error of forecasts against which to compare the performance of 12-, 24-, and 36-month forecasts. Trial 2 was completed by estimating the model over the period January 1986 through April 1995 and forecasting over the remaining 12 months for which actual water use in the absence of drought management is known. An AARE was then calculated for the estimation period and for the forecast period. Trials 3 and 4 were completed in a same way as trial 2, but with each successive trial the last 12 months of the preceding estimation period were transferred to the forecast period.

Table 4.9 lists the AARE of each forecast and estimation period. With the exception of trial 1, all means and standard deviations are for forecasts after the estimation period only. For trial 1, the mean and standard deviation are for the AARE of **ex-post** forecasts during the estimation period. Water managers in Corpus Christi may use these results to gauge the accuracy of their forecasts as they implement the forecasting model. Results of these trials are also presented in Figures 4.12 and 4.13. Figure 4.12 plots the 12-month moving average of the absolute relative error for each trial. The vertical distance between moving average lines is a measure of how the AARE changes with definition of the estimation period and how much forecasts deteriorate in the future. Trial 3 exhibits the highest AARE during the estimation period. This can be attributed to the relatively short period over which parameter estimates are calculated, 88 months. The lowest moving average AARE line occurs during the estimation period of trial 1. Those parameter estimates are based on 124 months of data. That could be considered a minimum error for the model. At 12 months into the forecast period there is little deterioration of the forecast. This is measured by the vertical distance between lines for trial 1, marked "0," and for trial 2, marked "12." Numbers reflect the number of months between the end of the estimation period and the last forecast. However, trial 3 shows that at 24 months into the forecast there is an increase in the 12-month moving average error. At 24 months, the 12-month moving average AARE for the last 12 months of the forecast increases to about 10 percent.

Figure 4.13 displays the mean absolute relative error (ARE) for each month into the forecast period. Mean ARE differs from AARE in that it is calculated across trials for some given number of months beyond the estimation period. Points in Figure 4.13 represent the mean absolute relative error for each successive month into the forecast period. For example, the fifth month into the forecast there are three water demand forecasts and three estimates of the absolute relative error. The mean absolute relative error for the fifth month is approximately 5 percent, not much more than the AARE over the estimation period, 4.3 percent. At 21 months into the forecast there are two estimates of water demand. The mean absolute relative error of these two forecasts is approximately 7 percent. After 24 months, there is only one estimate of water demand and the absolute relative error of the forecast because only trial 4 is used to estimate water demand that far into the future. The greater spread of mean absolute relative error beyond 24 months reflects this small sample. The line in Figure 4.13 represents the best linear fit of these points and can be used to estimate the mean absolute relative error of forecasts during the drought management period.

Table 4.1
Parameter Estimates for Total, Treated, and Municipal Water Sales (Equation 4.1)

	Coefficient	Variable	Total Water Sales[1]	Treated Water Sales[1]	Municipal Water Sales[2]
Structural Parameters					
	β_0	Intercept	15.994	16.649	338.566
	β_1	T	-0.335	-0.363	-7.329
			(-2.871)*	(-5.778)*	(-3.869)*
	β_2	T^2	0.0027	0.0027	0.057
			(3.599)*	(6.798)*	(4.784)*
	β_3	R	-0.067	-0.042	-1.588
			(-3.407)*	(-3.648)*	(-4.991)*
	β_4	t	0.009	0.003	-0.018
			(2.790)*	(1.048)	(-0.310)
Autoregressive Error Terms					
	ϕ_1	v_{t-1}	-0.338	-0.372	-0.414
			(-4.244)*	(-4.904)*	(-4.807)*
	ϕ_2	v_{t-3}	-	-0.211	-
			-	(-2.762)*	-
	ϕ_3	v_{t-6}	-	-	-0.1188
			-	-	(-1.452)
	ϕ_4	v_{t-10}	-	0.132	-
			-	(1.658)	-
	ϕ_5	v_{t-12}	-0.349	-0.409	-0.462
			(-4.254)*	(-5.220)*	(-5.173)*
	ϕ_6	v_{t-13}	-	-	0.297
			-	-	(3.098)*
	Model R^2		0.8145	0.8675	0.8532
	Structural Parameters R^2		0.4819	0.7036	0.6608
	Number of observations		124	124	124

Notes: (1) Coefficients in thousand gallons per capita per month; (2) Coefficients in gallons per capita per day; (*) Indicates significance of parameter estimates at the 95 percent confidence level.

Table 4.2
AARE Values for the Rainfall-Temperature Forecast of Water Use

	Year										
Aggregation	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996***
Total Water	0.089	0.037	0.053	0.069	0.044	0.033	0.059	0.050	0.049	0.059	0.023
Treated Water	0.073	0.025	0.034	0.055	0.032	0.027	0.045	0.045	0.035	0.062	0.031
Municipal Water	0.069	0.035	0.055	0.073	0.044	0.063	0.071	0.036	0.038	0.099	0.052

Note: * 1996 mean AARE based on estimates from January through April 1996.

Table 4.3
Parameter Estimates for Rainfall-Temperature Model in Water-User Sectors

	Coefficient	Variable	Total Water Sales[1]	Treated Water Sales1	Municipal Water Sales[2]
Structural Parameters					
	β_0	Intercept	32.407	171.466	18962.000
	β_1	T	-0.743	-2.998	-283.840
			(-4.393)*	(-3.543)*	(-2.555)*
	β_2	T^2	0.006	0.0023	2.279
			(5.129)*	(4.275)*	(3.576)*
	β_3	R	-0.151	-0.467	-35.102
			(-5.288)*	(-3.183)*	(-1.336)
	β_4	t	-0.003	0.086	16.875
			(-0.593)	(-6.058)*	(3.363)*
	β_5	t	-0.118	-29.026	-1289.098
			(-0.048)	(-3.595)*	(-0.497)+
Autoregressive Error Terms					
	ϕ_1	v_{t-1}	-0.335	-	-0.235
			(-3.914)*	-	(-2.637)*
	ϕ_2	v_{t-3}	-	-	-0.253
			-	-	(-2.677)*
	ϕ_4	v_{t-4}	-	-	-0.187
			-	-	(-1.942)
	ϕ_6	v_{t-6}	-	-	0.287
			-	-	(3.037)*
	ϕ_7	v_{t-7}	-	-	-0.215
			-	-	(-2.311)*
	ϕ_{12}	v_{t-12}	-0.361	-	-
			(-4.238)*	-	-
	Model R^2		0.8342	0.7896	0.6875
	Structural Parameters R^2		0.5481	0.6344	0.4691
	Number of observations		124	124	124

Note: (*) Indicates significance of parameter estimates at the 95 percent confidence level.

Table 4.4
AARE Values for the Rainfall-Temperature Forecast of Water Use

	Year										
Sector	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996***
Residential	0.082	0.046	0.072	0.083	0.052	0.087	0.087	0.056	0.057	0.092	0.067
Commercial	0.048	0.033	0.050	0.060	0.026	0.033	0.060	0.033	0.027	0.111	0.044
Industrial	0.058	0.048	0.035	0.040	0.063	0.048	0.053	0.061	0.038	0.041	0.075

Note: (*) 1996 mean AARE based on estimates from January through April 1996.

Table 4.5
Point Price Elasticities for Water-User Sectors, August 1996

	Water-User Sector		
	Residential	**Commercial**	**Industrial**
Price Elasticity Estimate	-0.014	-0.519*	-0.119
95% Confidence Interval†	±0.565	±0.289	±0.476
Real Marginal Price ($/1,000 gal)	1.108	1.255	1.255
Demand Forecast (1,000 gal/account)	9.554	70.082	13,493.700

Note:

* statistically significant elasticity estimates

† Range based on 95 percent confidence interval of β_5

Table 4.6
1996 Forecasts, Actual Water Use, Percent Difference, and One-Sided Confidence Intervals

Total Water Sales (all treated and raw water sales, 1000 gal per capita)

Month	Actual Water Use	Forecast Water Use	Percent Difference	One-sided CI 95 percent	90 percent	80 percent
May	8.64	8.86	-2.48	7.84	8.07	8.34
June	8.37	9.58	-12.62	8.53	8.77	9.05
July	9.10	9.99	-8.91	8.90	9.15	9.44
August	8.63	9.40	-8.20	8.32	8.56	8.85
September	6.57	8.86	-25.81	7.82	8.05	8.33
October	7.04	8.51	-17.29	7.48	7.71	7.98
November	6.83	7.67	-10.89	6.63	6.86	7.14

Treated Water Sales (wholesale and retail sales, 1000 gal per capita)

Month	Actual Water Use	Forecast Water Use	Percent Difference	One-sided CI 95 percent	90 percent	80 percent
May	5.88	6.10	-3.48	5.36	5.52	5.72
June	5.73	6.77	-15.34	6.01	6.18	6.39
July	6.42	7.03	-8.63	6.24	6.42	6.63
August	5.91	6.59	-10.30	5.80	5.97	6.19
September	4.57	6.07	-24.61	5.29	5.46	5.67
October	4.66	5.74	-18.79	4.96	5.13	5.34
November	4.38	5.11	-14.25	4.33	4.50	4.71

Municipal Per Capita Water Demand Inside City Limits (gallons per capita per day)

Month	Actual Water Use	Forecast Water Use	Percent Difference	One-sided CI 95 percent	90 percent	80 percent
May	128.15	134.17	-4.48	110.89	114.93	119.786
June	126.85	151.26	-16.14	134.30	138.71	144.024
July	138.85	148.88	-6.74	134.16	138.57	143.881
August	114.94	141.18	-18.58	118.10	122.53	127.864
September	92.86	129.77	-28.44	110.22	114.68	120.046
October	87.23	128.83	-32.29	101.38	105.674	110.831
November	99.23	118.18	-16.04	93.25	97.70	103.058

(Continued)

Table 4.7 (cont.)

Month	Total Water Sales (All treated and raw water Sales, 1000 gallons per capita) Actual Water Use	Forecast Water Use	Percent Difference	95 percent	One-sided CI 90 percent	80 percent
May	9.49	9.22	2.91	7.73	8.06	8.46
June	9.05	10.47	-13.55	8.92	9.27	9.68
July	10.48	11.23	-6.65	9.62	9.98	10.41
August	7.87	9.55	-17.61	7.97	8.32	8.75
September	5.72	8.56	-33.25	7.04	7.38	7.79
October	5.79	8.25	-29.88	6.75	7.08	7.49
November	6.63	7.08	-6.33	5.56	5.90	6.30

Month	Total Water Sales (All treated and raw water Sales, 1000 gallons per capita) Actual Water Use	Forecast Water Use	Percent Difference	95 percent	One-sided CI 90 percent	80 percent
May	62.44	61.27	1.91	54.43	55.96	57.79
June	59.82	70.23	-14.81	63.28	64.83	66.69
July	65.40	68.38	-4.37	61.24	62.83	64.74
August	61.84	70.09	-11.77	63.01	64.59	66.49
September	53.29	64.43	-17.29	57.55	59.08	60.92
October	49.93	63.22	-21.03	56.36	57.83	59.73
November	51.60	62.19	-17.03	55.30	56.84	56.68

Month	Total Water Sales (All treated and raw water Sales, 1000 gallons per capita) Actual Water Use	Forecast Water Use	Percent Difference	95 percent	One-sided CI 90 percent	80 percent
May	12,540.43	12,997.55	-3.52	11,537.51	11,862.68	12,253.81
June	11,039.03	12,803.90	-13.78	11,275.79	11,616.12	12,025.48
July	12,368.11	13,979.74	-11.53	12,420.58	12,767.83	13,185.51
August	13,934.06	13,496.15	3.24	11,894.21	12,250.99	12,680.12
September	11,556.13	13,589.61	-14.96	11,998.39	12,352.78	12,779.04
October	12,019.15	13,058.58	-7.96	11,460.10	11,816.10	12,244.31
November	10,965.41	12,063.95	-9.11	10,446.74	10,806.91	11,240.14

Table 4.8
Number and Percent of Times Actual Water Use is Less than the Lower One-Sided Confidence Interval

Water Use Aggregation and Period	Obs	Number and Percent of Observations less than Confidence Interval					
		95% CI		90% CI		80% CI	
Total Water Sales		Number	Percent	Number	Percent	Number	Percent
1/86 – 9/96	131	5	3.82	13	9.92	29	22.14
Pre-drought management	124	2	1.61	8	6.45	23	18.55
drought management	7	3	42.86	5	71.43	6	85.71
Treated Water Sales							
1/86 – 9/96	131	5	3.82	8	6.11	17	12.98
Pre-drought management	124	2	1.61	3	2.42	11	8.87
drought management	7	3	42.86	5	71.43	6	85.71
Municipal per capita per day inside city limits							
1/86 – 9/96	131	9	6.87	12	9.16	23	17.56
Pre-drought management	124	4	3.23	7	5.65	17	13.71
drought management	7	5	71.43	5	71.43	6	85.71
Retail Residential Water Sales							
1/86 – 9/96	131	6	4.58	12	9.16	21	16.03
Pre-drought management	124	3	2.42	8	6.45	17	13.71
drought management	7	3	42.86	4	57.14	4	57.14
Retail Commercial Water Sales							
1/86 – 9/96	131	8	6.11	10	7.63	19	14.50
Pre-Drought management	124	3	2.42	5	4.03	14	11.29
Drought management	7	5	71.43	5	71.43	5	71.43
Raw and Treated Industrial Sales							
1/86 – 9/96	131	8	6.11	12	9.16	26	19.85
Pre-Drought management	124	5	4.03	9	7.26	21	16.94
Drought management	7	3	42.86	3	42.86	5	71.43

Table 4.9
Description of Trial Per Capita Treated Water Demand Forecasts

Trial	Estimation period	Months in estimation period	Forecast period	Months in forecast period
1	1/86 to 4/96	124	None	0
2	1/86 to 4/95	112	5/95 to 4/96	12
3	1/86 to 4/94	100	5/94 to 4/96	24
4	1/86 to 4/94	88	5/93 to 4/96	36

Table 4.10
Mean and Standard Deviation of AARE Observed in Per Capita Treated Water Demand Trial Forecasts

Trial	Number of Observations	Mean AARE	Standard Deviation
1	124	0.04305*	0.03211*
2	12	0.06523	0.04101
3	24	0.08395	0.05624
4	36	0.09366	0.05782

Note: * Mean and standard deviation for *ex post* forecasts during the estimation period.

Figure 4.1
Model Estimates of Per Capita Treated Water Sales Over Different Temperatures

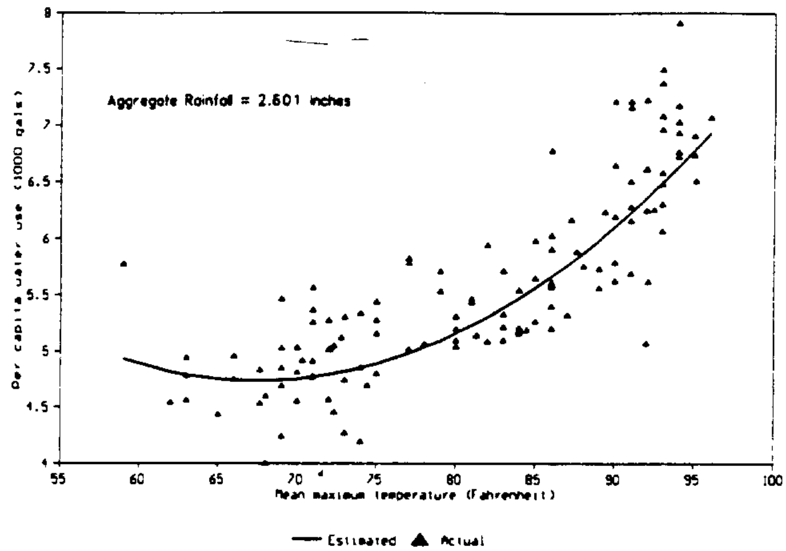


Figure 4.2
An Operational Criteria for Water Savings as a Percent of the Per Capita Treated Water Sales Forecast

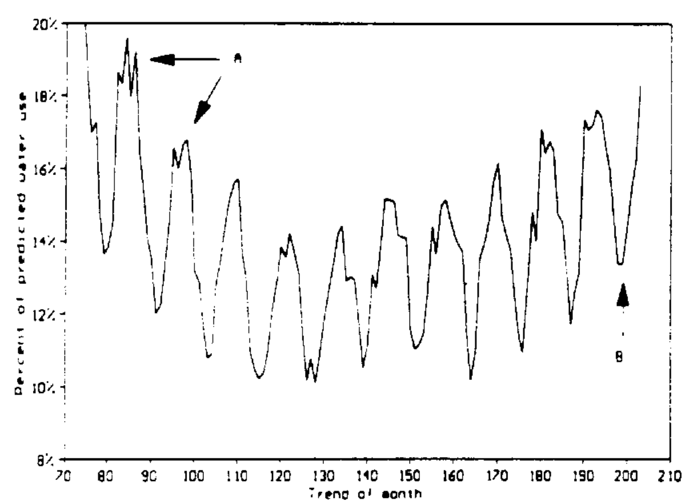


Figure 4.3
Backcasting Treated Water Use over the 1984-1985 Drought Period
Percent of the Per Capita Treated Water Sales Forecast

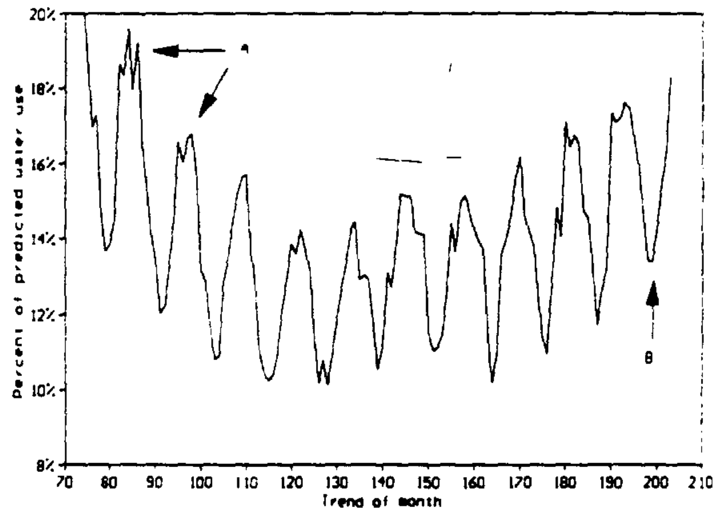


Figure 4.4
Per Capita Treated Water Use Forecast, July 1993 - November 1996

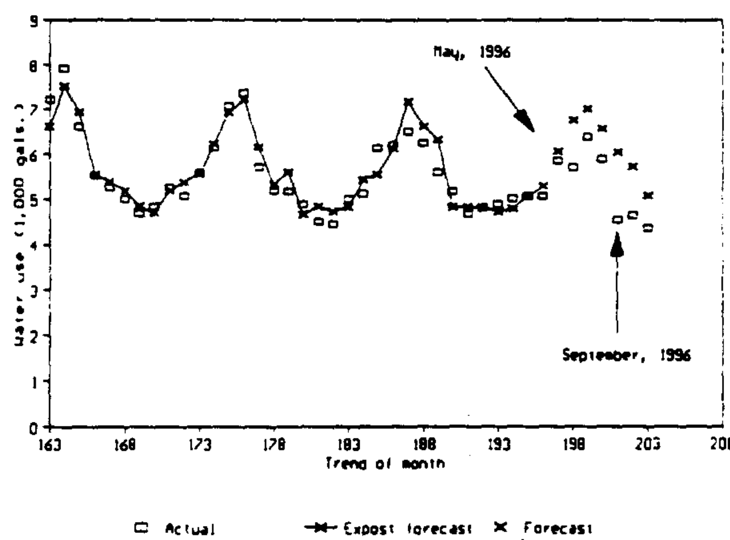


Figure 4.5
Response of Industrial Water Demand to Temperature

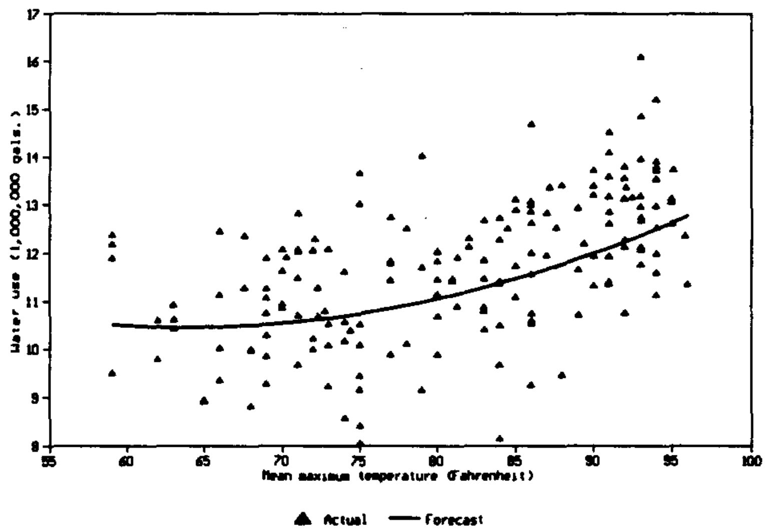


Figure 4.6
Per Capita Total Water Use Forecast with Confidence Bounds

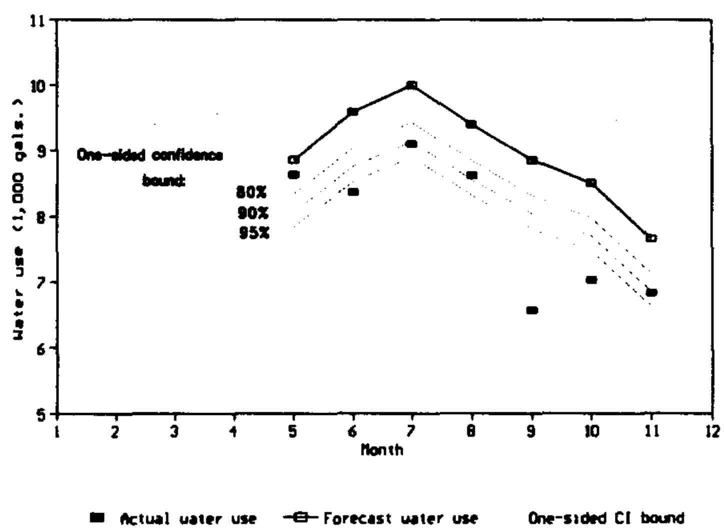


Figure 4.7
Per Capita Treated Water Use Forecast with Confidence Bounds

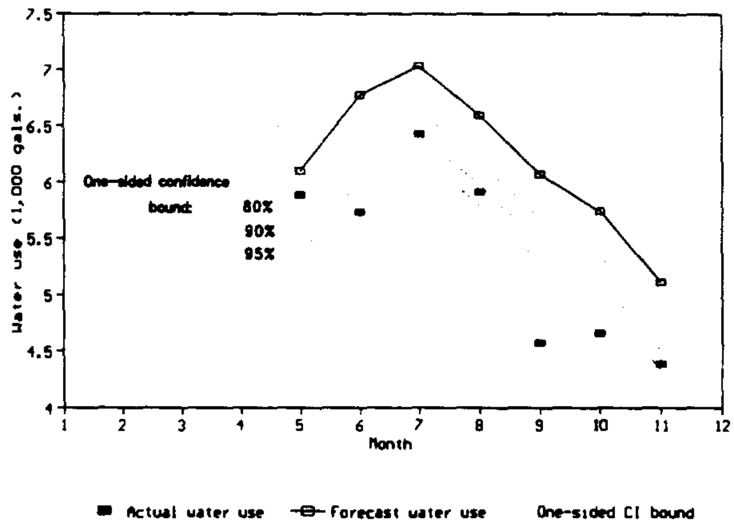


Figure 4.8
Per Capita Municipal Water Sales Inside City Limits with Confidence Bounds

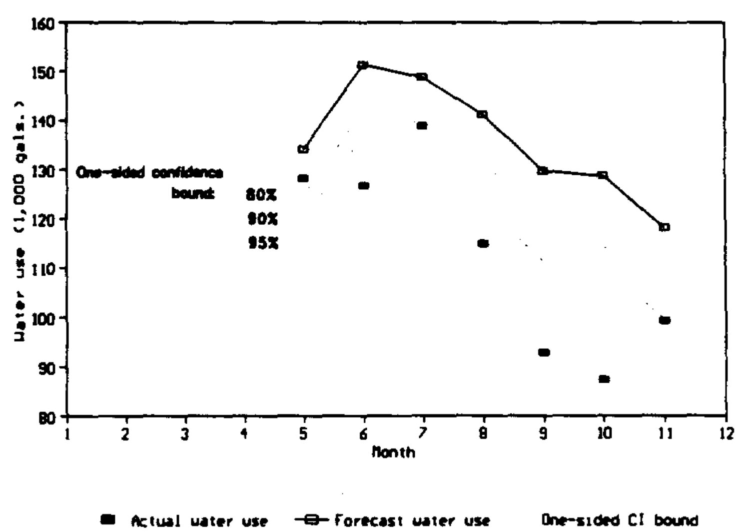


Figure 4.9
Per Account Residential Water Sales Forecast with Confidence Bounds

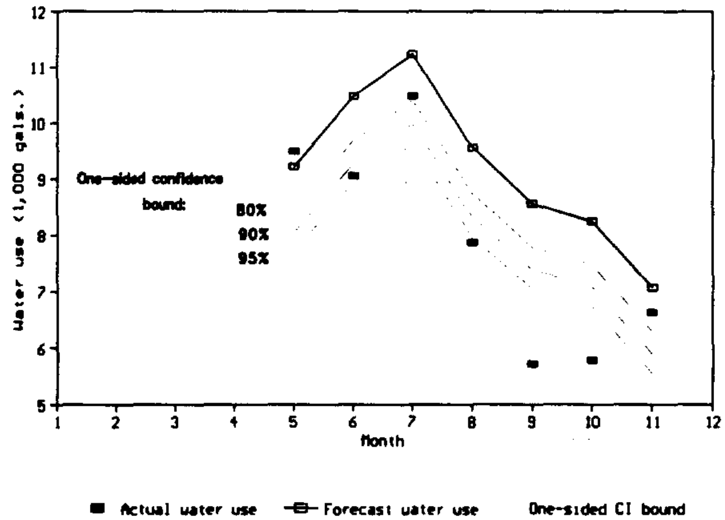


Figure 4.10
Per Account Commercial Water Use Forecast with Confidence Bounds

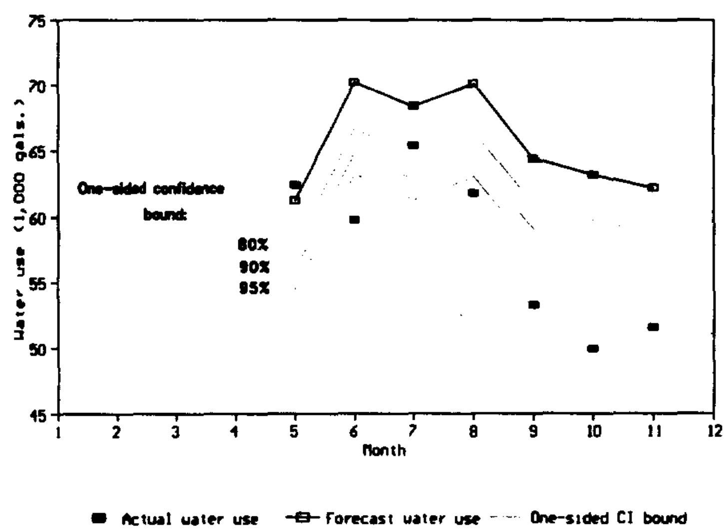


Figure 4.11
Per Account Industrial Water Use Forecast with Confidence Bounds

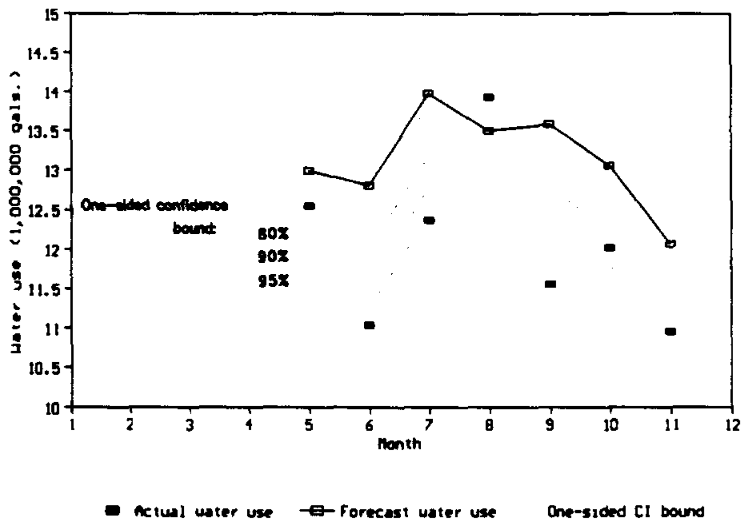


Figure 4.12
12-Month Moving Average Absolute Relative Error of Trial Treated Water Demand Forecasts

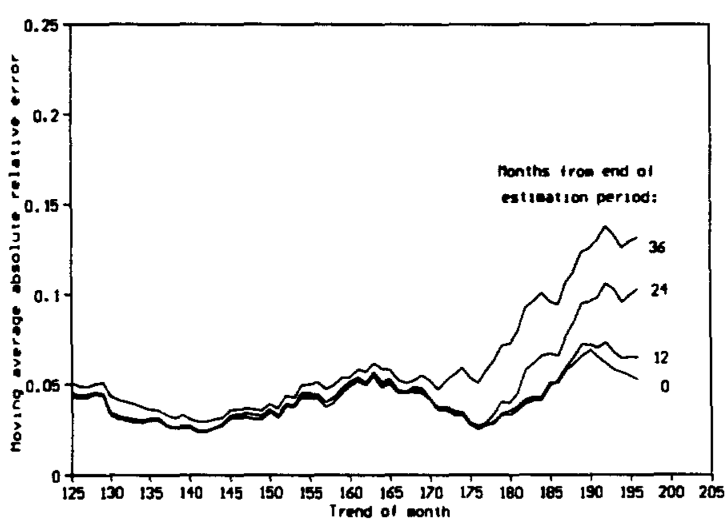
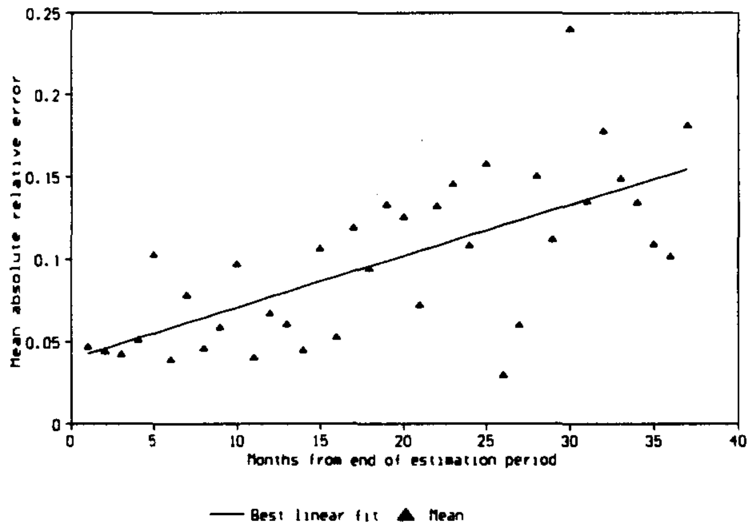


Figure 4.13
Mean Absolute Relative Error of Trial Treated Water Demand Forecasts



Chapter 5. A Moving Average Index Model of Water Demand

Moving Average Index Model Development

The moving average index model is described by Weber (1989) in a water demand forecasting study for East Bay Municipal Utility District, Oakland, California, and further described by Weber (1993). It is the purpose of this section to present the moving average index model as an alternative to the rainfall-temperature model. These results are compared with results of the rainfall-temperature model described in Equation 4.1. The moving average index estimates seasonal variations in water use. According to Weber, the logic for selecting this approach is that seasonality alone can account for much of the variation in monthly water use and the monthly index can model the transitions from seasonal to nonseasonal water use better than climatic variables. The purpose of the moving average is to capture long-term trends and exclude these effects from the index. The moving average index is calculated as the mean ratio of water use in a particular month to a 13-month moving average:

$$\theta_i = \frac{1}{k}\sum_{i=1}^{k} W_{ij}\, overomega_{ij} \qquad for\ all\ i$$

$$\omega_{ij} = \frac{1}{13}\sum_{t}^{t-13} W_{ij} \qquad for\ all\ i,j \qquad [Eq.5.1]$$

where:

θ_i = monthly index of water use

W = monthly per capita water use

i = an index of the month of the year i={1, 2, 3, . . ., 12}

j = an index of year j={1, 2, 3, . . ., k}

t = an index of the numerical sequence of months i = {1, 2, 3, . . ., n}

Figure 5.1 graphs the moving average index of treated water use. The faint line is per capita treated water consumption. The dark line tracking actual water use is the 13-month moving average of that series. The moving average index ranges from 0.8 to 1.2. Table 5.1 lists the index for each month of the year calculated based on data from January 1986 to April 1996. For example, the moving average index for treated water use in August is 1.208, and the standard deviation of that mean is 0.0587. The minimum ratio was 1.131 and the maximum ratio was 1.328. The mean moving average index less one can be interpreted as the percent difference in per capita water use in one month relative to an annual average of a detrended water demand time series. For example, treated water use in August is, on average, 20.8 percent higher than the annual average monthly water demand. The last line of Table 5.1 lists the mean ratio of treated water use to the moving average water use for the entire series and the standard deviation of that mean. Minimum and maximum are the minimum ratio of any month in the series, and n is the number of observation in the series. Table 5.2 lists information on the moving average index for total water use.

Although a monthly index accounts for the seasonality in water use, climatic variables are still needed to explain departures from the seasonal index. The forecasting model uses departures from a 30-year average rainfall and temperature to account for differences in climate across the same months in different years. Average rainfall and temperature are calculated using monthly data collected between 1960 and 1990. As in Equation 4.1, autocorrelation is removed using an error term. The model states that water demand follows a defined seasonal pattern, and that departures from this pattern are a function of departures from normal climatic patterns and long-term trends:

$$\hat{W}_t = \hat{\beta}_0 + \hat{\beta}_1\theta_t + \hat{\beta}_2 DT_t + \hat{\beta}_3 DR_t + \hat{\beta}_4 t_t + v_t$$

$$v_t = \varepsilon_t + \sum_{i=1}^{k} -\phi_t u_{t-i} \qquad [Eq.5.2]$$

$$\varepsilon_t \sim N(0, \sigma^2)$$

where:

W = per capita water use (thousand gallons)

θ = moving average index

DT = departure from normal mean maximum temperature (Fahrenheit)

DR = departure from normal aggregate rainfall (inches)

v = an error term

u = residuals of structural regression estimates

β = parameters estimated by regression

ϕ = autoregressive parameters for error terms

t = an index of time, the numerical sequence of months $t=\{1, 2, 3, \ldots, n\}$

i = the lag of significantly correlated residuals

Results of this model applied to per capita total and treated water use are provided in Table 5.3. The signs of rainfall and temperature coefficients are in the expected direction. For example, treated water use decreases 55 gallons per capita for every inch of rain above the 30-year average. Total water use decreases 73 gallons per capita for every inch above the 30-year average. AARE values, listed in Table 5.4, show that the model fits these data fairly well. The average absolute relative error for Equation 4.6 applied to treated water use between January 1986 and April 1996 is 0.040, or 4 percent. AARE for total water use over the same period is 4.7 percent.

Comparison of Moving Average Temperature Model with Rainfall-Temperature Model

The moving average index model can be compared with the rainfall-temperature model using the evaluative criteria described above. When estimated over the same data series, the moving average index model results show similar rainfall and trend coefficients as the rainfall-temperature model (Equation 4.1). Because of differences in the definitions of variables between Equation 4.1 and Equation 4.6, the temperature coefficients cannot be compared directly. The R-squared statistic measures the fraction of total variation explained by each model. The structural and error components of the moving average index model explain more variation in the data series. In addition, AARE values are lower for the moving average index model, suggesting forecasts of water use are more accurate than those using the rainfall-temperature model. AARE for the moving average index model applied to treated water use between January 1986 and April 1996 is 0.3 percentage points lower over the estimation period than AARE for the rainfall-temperature model.

The two remaining evaluative criteria are logical interpretability and confidence interval width. In the rainfall-temperature model, temperature coefficients were not directly interpretable. Both rainfall and temperature coefficients of the moving average index model are directly interpretable. However, the coefficient of the moving average index is difficult to interpret. From an interpretability standpoint, the risks associated with using the moving average index model are related to interpretation of potential covariates. This index may not account for variation due to nonclimatic determinants of water demand that may also be seasonal. For example, if coefficients of price or income are later estimated in this model, it is not certain that some of this variation has not been assigned to the moving average index, which models the data rather than the process. Examining the data for multicollinearity before estimating coefficients could help prevent misinterpretation.

If the sole purpose of estimating water demand is to generate forecasts of water use, a moving average index model may provide a better solution. Estimates produced by the moving average index model are more efficient than those of the rainfall-temperature model, and this is reflected in the narrower confidence intervals around predicted values. The moving average index model produces two-sided 95 percent confidence intervals for predicted values during the drought management period that are 5 to 10 percent smaller than the rainfall-temperature model. Over the first four months of the forecast (May-August 1996), the differences in the water savings needed to exceed the lower confidence bound is between 45 and 150 gallons per capita. For example, in July 1996, treated water savings must reach 51 gallons per capita more than the moving average index model to exceed its lower confidence bound.

The homoscedasticity assumption of the regression model requires constant error variance. That means the variance of the residual should not be more or less at the beginning of the series than at the end of the series. If the variance of residuals changes, confidence intervals may be inflated. Results of Portmanteau's Q Test and Engle's Lagrange Multiplier Test indicate that the moving average index model is heteroscedastic (SAS Institute 1993). Heteroscedasticity will not bias parameter estimates, but will inflate the confidence interval widths of parameter estimates and water demand forecasts. Correcting this problem by modeling the error variance should reduce confidence interval width in the moving average index model and improve the efficiency with which the model detects water savings. Portmanteau's Q Test and the Lagrange Multiplier Test showed no heteroscedasticity in the rainfall-temperature model.

Overall, the moving average index model seems to provide a slightly better forecast of per capita water use than the rainfall-temperature model. It explains a larger percentage of the variation and it has lower AARE. The main reason for selecting the rainfall-temperature model over the moving average index is the logical interpretability of the latter. The rainfall-temperature model was selected over the moving average index model because it preserved the ability to interpret the coefficients of new variables that might later be incorporated into the analysis. Selection of one model over the other has no effect on the outcome of this evaluation of water savings during the period May-August 1996.

Table 5.1
Monthly Moving Average Index for Treated Water Use

Month	Index	Standard deviation	Minimum	Maximum	n
January	0.84081	0.04696	0.75046	0.92027	12
February	0.83816	0.04565	0.74860	0.91485	12
March	0.93435	0.04964	0.83986	1.02049	12
April	0.95491	0.04794	0.86570	1.03894	12
May	1.02225	0.05270	0.93564	1.11408	11
June	1.10606	0.05551	1.02379	1.21086	11
July	1.17922	0.05520	1.10219	1.28748	11
August	1.20814	0.05871	1.13116	1.32809	11
September	1.04540	0.05082	0.97819	1.14020	11
October	0.97729	0.04742	0.89962	1.05873	11
November	0.91981	0.04574	0.83729	0.99606	11
December	0.91497	0.04514	0.82764	0.98243	11
Series	**0.99143**	**0.12568**	**0.74860**	**1.32809**	**136**

Table 5.2
Monthly Moving Average Index for Total Water Use

Month	Index	Standard Deviation	Minimum	Maximum	n
January	0.85201	0.05901	0.75898	0.95193	12
February	0.82786	0.05575	0.73863	0.92484	12
March	0.94113	0.06065	0.84796	1.05370	12
April	0.97161	0.05984	0.88577	1.09053	12
May	1.02998	0.06643	0.94355	1.15319	11
June	1.09037	0.07371	1.00390	1.23471	11
July	1.16326	0.07592	1.08606	1.31588	11
August	1.21962	0.08249	1.14229	1.40040	11
September	1.05346	0.07123	0.98361	1.21266	11
October	1.00369	0.06575	0.91983	1.14904	11
November	0.93357	0.06172	0.84455	1.06853	11
December	0.90452	0.05545	0.81942	1.02340	11
Series	**0.99565**	**0.13060**	**0.73863**	**1.40040**	**136**

Table 5.3
Parameter Estimates for Moving Average Index Model of Total and Treated Water Use (Equation 4.6)

	Coefficient	Variable	Total Water Sales[1]	Municipal Water Sales[2]
Structural Parameters				
	$ß_0$	Intercept	-1.997	0.937
	$ß_1$	θ	8.549	6.115
			(12.638)*	(16.921)*
	$ß_2$	DT	0.041	0.013
			(-2.399)*	(1.349)
	$ß_3$	DR	-0.073	-0.055
			(-4.041)*	(-5.023)*
	$ß_4$	t	0.009	0.003
			(2.363)*	(0.880)
Autoregressive Error Terms				
	ϕ_1	v_{t-1}	-0.483	-0.508
			(-5.227)*	(-6.553)*
	ϕ_2	v_{t-2}	-0.076	-
			(-0.830)	-
	ϕ_3	v_{t-3}	-	-0.166
			-	(-2.091)
	ϕ_4	v_{t-4}	-0.176	-0.183
			(-2.217)*	(-2.341)*
	Model R^2		0.8504	0.8903
	Structural Parameters R^2		0.6246	0.7397
	Durban Watson Statistic		1.9755	1.9642

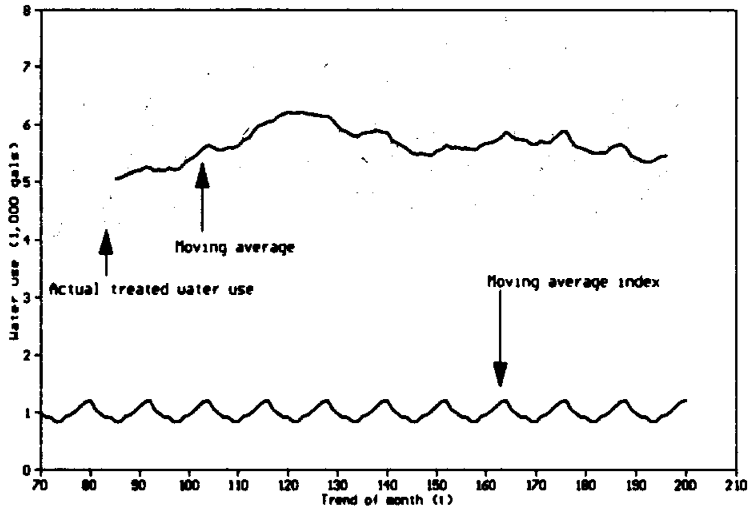
Note: * Significance of parameter estimates at the 95 percent confidence level.

Table 5.4
AARE Values for the Moving Average Index Model of Water Use

Avg Absolute Relative Error	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996*
Total Water	0.082	0.046	0.072	0.083	0.052	0.087	0.087	0.056	0.057	0.092	0.067
Treated Water	0.048	0.033	0.050	0.060	0.026	0.033	0.060	0.033	0.027	0.111	0.044
Industrial	0.058	0.048	0.035	0.040	0.063	0.048	0.053	0.061	0.038	0.041	0.075

Note: * 1996 mean AARE based on estimates from January through April 1996.

Figure 5.1
Moving Average Index of Per Capita Treated Water Use, January 1986 - August 1996



Chapter 6. Evaluation of the Distribution of Water among Residential Customer Accounts

The drought management program may have had little effect on the total volume of water demand until August 1996. However, that program may have had other effects on the pattern of water use. How strongly did restrictions on water use affect the distribution of water among users in the residential water user sector? In the absence of restrictions on water use, the distribution of water among residential customers is a function of household size, lot size, soil and vegetation types, wealth, willingness to pay, and other variables. Some water restrictions may eliminate some of these variables as factors affecting the distribution of water. If so, a unique distribution of water is expected under programs that place restrictions on either how water is used or the volume of water sales to each customer account.

In the extreme case of condition 3 water rationing, the distribution of water among residential customer accounts is a function primarily of household size. Condition 3 water rationing limits monthly water sales to each residential customer account to 6,000 gallons per resident with an additional 1,000 gallons for each one or two residents thereafter. No residential account may purchase more than 12,000 gallons of water each month without paying surcharges and facing possible removal from the water supply system.

The condition 3 water rationing goal is to limit water use to a maximum quantity and distribute it among residential accounts on the basis of household size. The distributional goal of water rationing can be estimated as the distribution of persons per housing unit reported in the 1990 U.S. Census (Table 6.1). For example, the number of housing units with exactly two persons represented 28.36 percent of all Corpus Christi housing units. Under condition 3 water rationing, this group could be expected to consume a maximum of 115,860 thousand gallons during one month. This represents 25.89 percent of potential water use in the residential sector under condition 3 water rationing. Potential water use, 453,898 thousand gallons, is the amount of water used in one month if each customer uses the maximum volume of water allowed. Although the U.S. Census includes apartments as housing units and the Corpus Christi Water Utility excludes apartments from its residential customer count, this population and housing distribution provides a rough approximation of the distribution of residents by residential customer account and the approximate distributional goal of Corpus Christi's condition 3 water rationing program.

Were there no allowance in the rationing plan for household size, each residential account would account for an equal amount of residential water use. This hypothetical distribution of water is shown by line 1 in Figure 6.1. Line 2 represents the distributional goal under proposed condition 3 water rationing. Figure 6.1 also shows how the water rationing goal (line 2) compares with the empirical distribution of residential water sales during the four-month period May through August, 1993-1995 (line 3). Line 3 represents a typical distribution of water among residential customers without water rationing. The goal represents a more even distribution of water among residential accounts. For example, the 25 percent of residential accounts that use the most water were responsible for 50 percent of water use during 1993-1995. Under condition 3 water rationing, the 25 percent of residential accounts using the most water are responsible for only about 30 percent of all residential water use. Those users in the top 25 percent are qualified by the number of people per household rather than wealth, lot size, or other factors.

The distribution of housing units by persons per household approximates the distribution of water under the proposed condition 3 water rationing program. The distribution of water is approximated by an exponential equation which states that the fraction of water used by each group is a function of the number of people per household and the number and size of other households:

$$Y_j = aX^b = aZ^b \qquad [Eq. 6.1]$$

where:

Y = fraction of water use by housing unit in persons per housing unit increment j

X = fraction of housing units by people per housing unit

Z = fraction of residential water use by volume of sales under condition 3 water rationing

b = a slope coefficient estimated by regression

j = an index of household size increment (j = 1, 2, 3, . . ., k)

Household size increment is defined by water rationing program parameters. For example, the increment j =1 includes housing units with one or two people per household and the increment j=2 includes housing units with three or four people per household. The functional form of equation 7 was selected fo condition 3 water rationing (Figure 6.2, line 2). The closer slope parameters are to each other, the more similar the distributions.

Did Water Restrictions in 1996 Affect the Distribution of Water among Residential Customer Groups?

Because drought restrictions regulate how water is used, regulations can have a disproportionate effect on customers that use water in specific ways. For example, the use of water by customers that use a large portion of their water for lawn watering could be constrained by these water restrictions. Customers who use little or no water outdoors would not be affected. The share of total water use by customers who usually use little water will increase, because customers who have used water for lawn watering would decrease their use due to city restrictions. This alters the distribution of water by reducing the slope of the transformed empirical distribution. A large difference between the pre-drought management slope and the slope during drought management could be interpreted as an effect of the drought management program. Conversely, little difference between the slope parameters could lead an analyst to conclude the water restrictions had little effect on the relative distribution of water among residential customers.

This analysis shows no statistically significant change in the distribution of water among residential customers resulting from water restrictions during the period May-August, 1996. The estimate of b during the drought management period is 1.74. The estimate of b during the period May-August, 1993-5 is 1.76. The 95 percent confidence interval of the pre-drought management slope is $1.730 \leq b \leq 1.792$. The drought management estimate of b between May and August, 1996, is 1.747. This estimate lies between the upper and lower bounds of the confidence interval suggesting little distributional effect associated with water restrictions.

Is the Distribution of Water Consistent with the Distributional Goals of Water Rationing?

A similar analysis could be completed to evaluate performance of a water rationing program with explicit distributional goals. Suppose a condition 3 water rationing program were implemented during the drought management period and one goal of that program were to achieve a predetermined distribution of water. In the case of Corpus Christi, that goal is to distribute water strictly by the distribution of people per household. The slope coefficient for the goal represented by line 2 and an empirical slope coefficient could be compared to test whether the drought management program reached its goal. The 95 percent confidence interval around the slope of line 2 is $1.142 \leq b \leq 1.207$.

Table 6.1
Distribution of People Per Housing Unit and Potential Distribution of Water During Proposed Condition 3 Water Rationing

Persons Per Housing Unit	Percent of Housing Units	Approximate Water Use Under Condition 3 Water Rationing* (1,000 gal/month)	Water Use as a Percentage of Water Use Goal
1	22.52	92,015	20.27
2	28.36	115,860	25.53
3	18.01	85,847	18.91
4	16.26	77,503	17.08
5	8.66	47,180	10.39
6	3.66	19,961	4.40
7 or more	2.53	15,530	3.42
Total	**100.00**	**453,898**†	**100.00**

Note: * Assumes 68,100 residential customer accounts. (†) May not add to 100 percent up due to rounding.

Table 6.2
Coefficients Estimated for Equation 4.4

Coefficient	Variable	Prior to Drought Management 1993-1995 (line 3)	During Drought Management 1996	Condition 3 Water Rationing Goal (line 2)
Intercept	a	-0.051	-0.048	-0.026
Slope	b	1.761	1.747	1.175
		(111.34)*	(120.59)*	(59.81)*
R^2		0.992	0.994	0.998

Note:

T-statistics in parenthesis

* Significance at the 95 percent confidence level.

Figure 6.1
The Distribution of Water Use by Percent of Number of Accounts

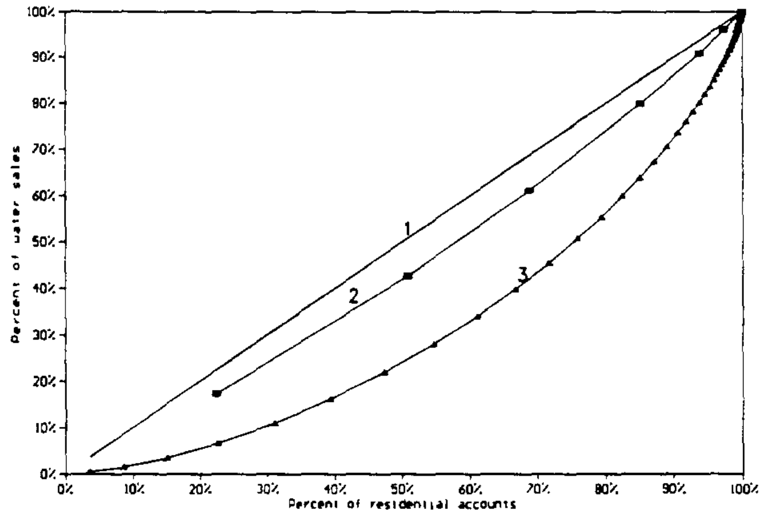
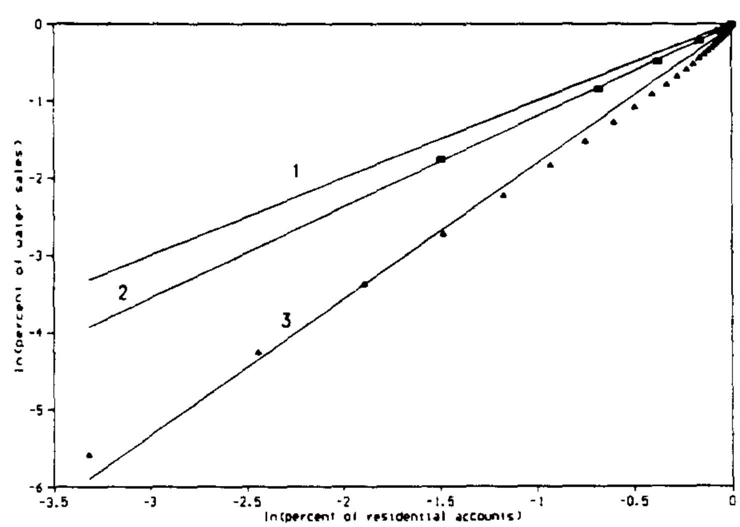


Figure 6.2
Logarithmic Transformation of Equation 4.1



Chapter 7. Economic Impact Assessment: What Are the Costs of Drought Management?

There are costs associated with the implementation of mandatory reductions in water use, the persistent risk of water shortage, and the selection of drought management strategies. This chapter describes types of costs and information needed to evaluate water supply investments and drought management alternatives. An example of how to estimate income and employment effects of water rationing using an input-output model is provided for the petrochemical manufacturing industry. This chapter concludes with a discussion of how local policymakers and state officials might apply concepts of economic value to evaluate costs of water rationing.

Imposing mandatory limits on the volume of water used or the types of water uses allowed implies some form of water rationing. *Water rationing* is defined as a limit on the timing, rate, or volume of water used by each customer in some customer groups or as restrictions on water uses. Volume limits may or may not be explicit. For example, a program that restricts the volume of water delivered to households each month is obviously a form of water rationing. A program that restricts the times of day that outdoor watering is allowed may also be classified as a water rationing program. Reducing the length of the watering period could restrict the maximum volume of water delivered in a water supply system, although the volume of water use allowed is not stated.

Economic impacts of drought management programs such as employment and income effects arise from constraints on the volume of water used in commercial and industrial enterprise. These effects occur when water rationing limits production capacity. Output effects are defined as a change in the volume of production related to water rationing. These output effects associated with mandatory reductions in water inflows could reduce the demand for labor, cause a net decrease in local income levels, and reduce profits among commercial and industrial interests. Output effects are extremely difficult to measure due to limitations in the availability of suitable data at local and regional levels.

Water rationing can increase production costs without creating output effects. For example, some commercial and industrial interests may find that the production strategy that maximizes profits under water rationing is to maintain output levels, make no changes in the production process, and pay the prescribed surcharges or fines for violating water rations. This "use it and pay for it" strategy would not be viable for the firm if the city were to enact a regulation that a customer would be removed from the water supply system if she/he violates water rations during more than two billing cycles.

Commercial and industrial interests may be able to increase water efficiency by altering the production process without creating output effects. A firm could reduce water consumption for uses other than production, such as lawn watering or washing. The purchase of new capital may become rational in the face of water rationing. If the firm is a price taker, these production costs are borne by the producer. If prices change to reflect local production costs, the cost is borne by consumers. In other cases, a combination of production cost and output effects may result and the cost is borne by both consumers and producers.

The need to implement drought management is an acute symptom of persistent water shortage, and the social expectation of water shortage has real costs. This cost may exist when water users perceive a risk of water rationing and may increase as the risk of water rationing increases. For example, there may be a reluctance among potential commercial and industrial interests to make long-term investments and there may be a migration of existing plants and commercial activity to water-rich sites.

There are other costs associated with drought management that cannot be measured directly. Drought management programs that impose limits on water use are by nature command-and-control approaches to regulation. Program outcomes are potentially less efficient than market-based incentives. The cost of a drought management program may also depend upon the mix of program elements, and the analysis of program costs is relevant to design of drought management programs.

An Input-Output Model Approach to Economic Impact Assessment

The economic impact of water shortage and drought management is a question for regional economic analysis. The purpose of this chapter is to describe how costs of drought management can be estimated when the effect of water rationing is to reduce output. The input-output method measures costs in terms of household income and employment effects. The regional model used in this study is a 1986 input-output model developed for a six-county area including Aransas, Bee, Jim Wells, Nueces, Refugio, and San Patricio Counties. Although this area does not correspond directly with the study area, the population and economic activity centers are located in Nueces and San Patricio Counties where most of the Choke Canyon/Lake Corpus Christi water supply is used.

Input-output models describe sales and revenues between commercial and industrial sectors, governments, and households. Input-output models are perhaps best used to describe industrial linkages. More complex applications are sometimes burdened by several model assumptions. For example, these models assume a linear and homogenous production function in each input-output sector. That implies no economies or diseconomies of scale and no substitution of inputs or technological innovation. Other assumptions include no joint production, no limits to production capacity, and perfect elasticity of supply (there is no change in prices as demand increases). Despite this range of assumptions, input-output models have been in use since 1936, and the applications of input-output models have increased rapidly since the 1960s, especially at the national level. The development of regional input-output models is a less well-developed field, in part because of the difficulty in acquiring the necessary data.

The transactions matrix consists of rows of producing sectors and columns of output sectors. Table elements describe the purchases of one sector from another. This matrix is converted to a direct requirements table that describes the ratio of purchases from one sector to another to total purchases. These table elements represent the amount of input required to produce one unit of output, and the vector of coefficients can be thought of as a linear production function for that producing sector. The direct requirements matrix is then inverted to express gross output as a function of final demand. This is the Leontief inverse matrix, and the table elements of this matrix are known as interdependence coefficients. These represent the direct and indirect input requirements needed by the producing sector to produce one unit of output.

One application of the input-output model as a forecasting tool is to use income and employment multipliers generated from the model to estimate the total effect of a change in the output of one sector. No modifications to the interindustry transactions matrix are needed if changes represent expansion or rundown of industrial sectors and there is no attempt to model the entry or exit of firms (Richardson 1972).

Type II income or employment multipliers are the ratio of total impact (direct, indirect, and induced effects) to direct impact resulting from changes in the level of output within an industrial sector. Direct impacts are those income and employment changes occurring within the input-output sector in which the output change occurs. Indirect effects are income and employment changes in sectors supplying and purchasing from the sector in which output change occurs. Induced effects represent "flow-on" income and employment changes in remaining sectors. Total income effects are estimated as the product of the Type II income multiplier and the household row coefficient from the direct requirements table times the change in output value. An employment impact is calculated as the product of an employment-production coefficient and the interdependency coefficient from the Leontief matrix times the value of an output change (Hewings and Jensen 1986; Richardson 1972). Output change must be adjusted for inflation when the employment-production coefficient is based on data from some prior year. The main requirement in addition to multipliers is a forecast of output change. Changes in the output of industrial sectors can be estimated using informed judgment gained through interaction with focus group participants.

Estimates of economic impact described below are based on multipliers generated from the 1986 Nueces Mission-Aransas estuary input-output model. This model was developed at Texas A&M University by updating the 1979 Texas input-output model using nonsurvey methods and regionalizing by wage-based regional control totals and the location quotient method. Table 6.3 lists Type II income and employment multipliers as they are presented in the report on the model (Fesenmaier et al. 1987). SIC major groups are assigned by logical interpretation of input-output sector titles. Table 6.4 describes how estimates are developed for the economic impact of water rationing in the petroleum refining and chemical industries defined as SIC major groups 28 and 29. These sectors were selected because chemical and petroleum manufactures were responsible for 91 percent of the total value of manufacturing output in Corpus Christi in 1992 (Bureau of the

Census 1996). Table 6.4 also disaggregates income and employment effects to describe both direct effects and indirect and induced effects.

Given assumptions about the rate of decrease in output associated with limiting water supplies to some percentage of past use, the economic impact of output change resulting from water rationing can be calculated. At this time, the output effect of water rationing is not known, but it seems clear that the rate of output change will be less than the rate of change in water use. For example, 9 out of 16 Board of Trade members reported no decrease in throughput resulting from a 10 percent decrease in water use over the short term. Only modest decreases in output at 15 percent decrease in water use are expected. Estimates of the output effect were said to be much higher in relative terms at 20 and 25 percent of water use (Smith 1996). This reflects a nonlinear relationship between changes in water consumption and output. Board of Trade members did not disclose estimates of throughput change (Smith 1996). Since estimates of the output effect have not been disclosed, this study uses a hypothetical 5 percent change in output as a response to water rationing to demonstrate the method. That level seems reasonable given the information provided, and may over- or underestimate the actual output change

Illustrative Example of the Household Income and Employment Costs of Output Effects

Input-output models are static because time is not a factor in the analysis. However, the transactions table from which multipliers are calculated are constructed using annual data on sales and purchases between sectors. The implication is that income and employment losses occur over the period of a year. Therefore, full realization of the income and employment forecast would require a 5 percent change in the annual output level. For this reason, model results are perhaps most easily interpreted as percent change in total employment and household income. Total personal income in 1992 dollars in the MSA was $5,943.352 million. Wage and salary income was $3,331.579 million (1992 dollars) and total wage and salary employment in 1992 was 148,847 jobs (Bureau of Economic Analysis 1996). The total value of manufacturing output measured by the value of shipments in 1992 dollars was $8,625 million and the total manufacturing value added was $1.818 million (Bureau of the Census 1996).

Note that the employment multiplier used to estimate employment effects in the petrochemical sector in Table 26 differs from the employment multiplier derived from the 1986 Nueces Mission-Aransas Estuary Input-Output Model listed in Table 25. The 7.69 value in Table 26 originates from the 1986 Texas Input-Output Model developed by the Texas Comptroller of Public Accounts. Grubb (1996) recommends substituting 7.69 for 12.013 because he believes the latter is too high and may therefore overstate employment effects. The reasoning is that most crude oil is shipped into Corpus Christi rather than generated in a local production base. There is no logical explanation as to why employment effects of decreased output should be more in Corpus Christi than the value forecast for the state as a whole.

Table 6.4 shows estimates of the impact of a 5 percent change in chemical and petroleum production. The value of total shipments from chemical and petroleum manufactures was $7.88 billion (Bureau of the Census 1996). The total output of 19 chemical manufactures employing 3,000 workers in the Corpus Christi MSA was $1,716 million in 1992. A 5 percent decrease in the output of this industrial sector would produce a total economic impact (direct, indirect, and induced) that reduces household income $15.39 million. That represents 0.25 percent of total personal income in 1992, or 0.46 percent of total 1992 wage and salary income in the MSA. The total effect can also be expressed in employment terms. Approximately 223 jobs in the MSA would be lost as a result of the output change (74 direct jobs and 148 jobs in other input-output sectors). That was 0.14 percent of total wage and salary employment in 1992.

In 1992 the output of 12 petroleum manufactures employing 2,800 workers totaled $6.1735 billion (Bureau of the Census 1996). A 5 percent decrease in the output of this industrial sector would produce a total economic impact (direct, indirect, and induced) that reduces household income $48.351 million. The total employment effect is estimated to be 2,066 jobs (269 direct jobs and 1,797 jobs in other input-output sectors). Using the alternative multiplier, 12.013, the employment effect is estimated to be 3,227 jobs (268 direct jobs and 2,959 jobs in other input-output sectors).

When the modeled change consists of output effects in more than one input-output sector, the sum of effects in each sector can misstate the total impact. This problem is avoided by estimating an aggregate multiplier that is an average of sectoral income and employment multipliers weighted by the ratio of the output change to the total output change in the combined sector. The change in employment resulting from lost production represents approximately 1.54 percent of employment in Corpus Christi. The change in income represents approximately 2.07 percent of wage and salary income.

The cost of output effects is best estimated when the output effect is known. If output effects are not known but there is a need to estimate costs, output effects may be estimated using informed judgement. In such cases it may be best to estimate a maximum and a minimum cost. Because the input-output model assumes a linear production function, the cost remains constant across output changes. In the above example, the cost of output effects is estimated for the petrochemical manufacturing sector. Using 1992 wage and salary income in the MSA as a base, wage and salary income decreases 2.07 percent for a 5 percent change in petrochemical manufacturing output. The first five percent change in petrochemical manufacturing output represents a $68.9 million decrease in wage and salary income. A 10 percent change in petrochemical manufacturing output causes a $137.92 million decrease in wage and salary income.

Evaluating the Cost of Water Rationing

The income and employment measures described above clarify the negative direct, indirect, and induced effects of proposed courses of action. However, income and employment effects of output change are only a portion of the cost of water rationing and ignore the potential benefits of loss-mitigating activities. Examples of other costs include capital expenses, increased production costs, drought damage to residential and commercial landscapes, reduced tourism, and damage to building foundations. Loss-mitigating activities could include opportunistic income-generating employment in nonwater-intensive industries. For example, resources left idle by water rationing might be employed in the best production alternative. The net economic loss is the difference in the value of the products. What is needed is a better measure of the economic value of water and the net costs of water rationing. The purpose of this chapter is to present consumer surplus as a better means of evaluating economic costs than income and employment effects.

Accounting stance is also an important concept in evaluating the costs of water rationing. Accounting stance describes the perspective of the decision maker and what he/she considers to be a net cost or a net benefit. For example, water rationing may reduce the demand for traditional landscape vegetation, but this cost could be balanced by an increase in demand for xeriscape vegetation. A landscape nursery selling both traditional and xeriscape vegetation may experience no net losses. A landscape nursery with no interest in xeriscape vegetation may experience a net loss. A different landscape nursery offering only xeriscape vegetation may gain from the shift in demand with no losses. Individually, this transfer of benefits from one party to another is considered a gain or a loss.

If a policymaker thinks in terms of the aggregate welfare of residents, there is no net economic cost associated with the transfer of sales from one landscape nursery to another and no basis for preferring one course of action to another. As Whittlesey (1990) states, "The argument becomes one of distribution or political constituency but not economic value." Similarly, a policymaker in Corpus Christi may see only economic costs while a policymaker at the state or national level may see those losses being offset by economic gains in other places. As a practical matter, it is accepted that local policymakers should make decisions that maximize net benefits within their areas of responsibility.

The preceding discussion reveals two flaws associated with using income and employment measures of economic impact to evaluate water rationing. One flaw with using income and employment costs associated with projected output effects is that these describe only the negative economic consequences of water rationing. There is no statement of trade-off or measure of net economic loss. Another flaw with using income and employment costs is that these reflect the accounting stance of the individual measuring economic costs and benefits. Maximization of net economic benefits is a potential Pareto optimal decision criterion that ignores the distribution of costs among residents. Pareto optimal decisions are economically efficient because they result in trades that maximize the productive output of water. NonPareto optimal decisions require value judgements on the part of a policymaker. For example, water price increases may be more economically efficient than water rationing, but price increases may distribute the burden of water shortage disproportionately on low-income residents or some other group, a consequence that may not be consistent with other public policy goals.

Consumer Surplus is the Economic Value of Water

The *aggregate economic value of water* is defined as the value that water utility customers derive from access to water less the cost of supplying that water to users. This concept, also called *consumer surplus,* is the difference between maximum willingness to pay for water used and the cost of water supply. Saliba and Bush (1986) and Gibbons (1987) provide discussions on ways to assess economic values of water. The relative costs of two courses of action can be evaluated by estimating the net change in the level of consumer surplus. Choosing the alternative that results in the highest net economic value should minimize income and employment effects (Whittlesey 1990). Unlike input-output analysis, demand analysis incorporates information about opportunity costs and production alternatives.

Total direct benefit is measured by consumer surplus, which is a function of the present value of water and its supply cost. The total value of a unit of water is equal to the value of that water used in production to commercial and industrial customers plus the utility of that water to residential customers. Consumer surplus is equal to the total value of water minus its acquisition and delivery costs:

$$CS = \int_0^{q^*} f(q) - p^* q^*$$

[*Eq*.7.1]

where:

CS = consumer surplus

f(q) = a demand function for water

q* = equilibrium quantity of water demanded

p* = average cost of water supply

Water rationing and water supply decisions should maximize consumer surplus while recovering the costs of water supply. As the price of water increases, consumer surplus decreases. As the level of demand increases or decreases, there is a change in consumer surplus.

Figure 6.3 describes consumer surplus in graphical terms. The area below the demand curve and above the price line represents, consumer surplus (CS). This is the net benefit of water supply in the service area. The variable q^* is the equilibrium quantity of water demanded at a price, p^*. Line AC is the average cost function of the water utility (assume that price is determined on a cost-of-service basis). This discussion will ignore complications related to estimating consumer surplus under the city's current pricing strategy. The assumption is that all water customers pay a single price, and that this price is determined by average cost. In practice, there are different water price schedules for different water user sectors. One way to address this problem would be to carry out separate analyses of consumer surplus and then aggregate benefits and costs in a final analysis.

Using Consumer Surplus to Evaluate the Cost of Water Rationing

The relevant cost of water rationing is the change in consumer surplus less any transfer of consumer surplus to the water utility. Designing or manipulating a water rationing program based on information about income and employment effects does not work toward minimizing the economic burden of water rationing and water shortage. Economic cost is measured by the change in consumer surplus; to measure it, the analyst must obtain information about the direct fixed and variable costs associated with increasing water efficiency and the direct opportunity costs of lost production. Costs may be borne by residential or commercial water customers. While noneconomic policy goals can be equally valid, from an economic perspective these are competing environmental, social, political, or financial goals that have economic costs.

To demonstrate how water rationing can reduce consumer surplus, consider the following discussion. Assume there is an equilibrium in the supply and demand for water. Water utility customers purchase q^* units of water at average cost, p^*. If a water rationing program requires each customer to reduce water use to a percentage of past water use, q'/q^*, water demand shifts to the left, q'/q^* percent. The slope of the demand curve also increases because each user allocates water to its most highly valued uses. A change in water consumption necessitates a change in price so that water sales cover the cost of service. This price change will probably not be immediate, but any utility deficits associated with difference between revenues during the rationing period and actual costs will be recovered over the long run. Because prices increase, some of the lost consumer surplus is captured by the water utility. Transfers such as these are excluded from the calculation of cost. The change in consumer surplus is the difference between the old consumer surplus and the new consumer surplus plus any surplus transferred to the water utility:

$$C_{WR} = \left(\int_0^{q^*} f(q) - p^* q^* \right) - \left(\int_0^{q'} g(q) - p'q' \right) + q'(p' - p^*) \quad [Eq. 7.2]$$

where:

C_{WR} = immediate cost of water rationing

$g(q)$ = a demand function for water under water rationing

p' = average cost of water supply under water rationing

q' = quantity of water demanded under water rationing

Figure 6.4 shows how this change in consumer surplus can be evaluated graphically. Demand for water under water rationing, D′, lies to the left of the original demand curve. Assuming increasing returns to scale in the water supply system, the average cost of service increases to p′. A portion of the loss measured by the area $q'(p'-p^*)$ represents a transfer from consumer surplus to utility expenditures. Given a potential Pareto optimal criterion, this change in consumer surplus is not counted as net loss.

Price Manipulation is More Economically Efficient than Water Rationing

Theory suggests that price manipulation is a more economically efficient tool for reducing water consumption than is water rationing. Raising prices allows each consumer to use water according to its contribution to production or the user's willingness to pay. Because each user allocates water to the most highly valued uses, the productive output of water is maximized. If the water utility raises water price from p^* to p', then demand decreases from q^* to q'. The economic cost of the price change is the shaded area.

Figure 6.5 demonstrates how price effects water consumption differently than water rationing. Because water rationing affects each user by reducing water use a certain percentage, water rationing results in a shift in the demand curve. In contrast, price manipulation ensures that the productive output of water is maximized by allocating water to those residential, commercial, and industrial users with the highest willingness to pay. The shaded area in Figure 6.5 is a deadweight loss, a loss of consumer surplus due to water rationing in Corpus Christi. Comparison with Figure 6.45 shows that this loss is potentially much less than lost consumer surplus associated with water rationing for a given quantity of water.

As discussed above, the best solution is not necessarily the most economically efficient solution. Noneconomic policy goals may suggest an economically inefficient allocation of water is a desirable outcome. However, explicit goals of water rationing should be evaluated with a knowledge of the potential costs, and those costs are best measured by changes in consumer surplus rather than changes in income and employment. An appropriate goal of water rationing may be to maximize the change in consumer surplus subject to social, environmental, political, and financial conditions. Such conditions could include income and employment effects and the affordability of water to low-income residents.

Table 7.1
Type II Income and Employment Multipliers

Sector	Name of Sector	SIC Major Group	Type II Income Multiplier	Type II Employment Multiplier
1	Irrigated agriculture	01	1.745	1.311
2	Dryland agriculture	01	1.550	2.003
3	Livestock and products	02	1.655	3.789
4	Agricultural services	07	1.725	1.424
5	Forestry	08	1.736	3.019
6	Fisheries	09	1.534	1.101
7	Petro & NL, NGL	13	1.292	1.638
8	Other mining	10,12,14	1.508	2.049
9	Construction	15,17	1.499	1.675
10	Food and kindred products	20,21	2.105	1.903
11	Textiles and apparel	22,23	1.348	1.230
12	Lumber and paper products	24,26	1.625	1.361
13	Printing and publishing	27	1.390	1.277
14	Chemicals	28	2.506	2.984
15	Petroleum refining	29	4.297	12.013
16	Rubber, leather, plastic	30,31	1.601	1.366
17	Glass, stone, clay	32	1.768	1.361
18	Primary metal products	33	1.732	2.661
19	Fabricated metal products	34	1.440	1.389
20	Nonelectrical machinery	35	1.399	1.498
21	Electrical machinery	36	1.318	1.517
22	Transportation equipment	37	1.394	1.133
23	Instruments	38	1.485	1.473
24	Misc. manufacturing	39	1.421	1.393
25	Transportation	40,47	1.418	1.819
26	Communications	48	1.344	1.339
27	Utilities	49	2.179	3.299
28	Wholesale trade	50,51	1.408	1.493
29	Eating and drinking places	58	1.569	1.325
30	Other retail trade	52,57,59	1.397	1.094
31	Financial, insurance, real estate	60,67	1.269	1.596
32	Health service	80	1.373	1.223
33	Education service	82	1.294	1.186
34	Other service	70,79,81,83,87	1.340	1.154

Source: 1986 Nueces Mission-Aransas Input-Output Model (Fesenmaier *et al* 1987)

Table 7.2
Impact of Petroleum and Chemical Output Losses, Corpus Christi MSA

		Input-Output Sector	
	Chemicals	Petroleum	Combined Sector
Area data for chemical and petroleum sectors			
Value of output ($ million – 1992)[1]	1,716.3	6,173.5	7,889.8
Inflation-adjusted output ($ million – 1986)	1,493.7	5,372.9	6,866.6
Number of firms	19	12	31
Number of employees	3,000	2,800	5,800
Input-output multipliers and model coefficients[2]			
Type II income multiplier	2.506	4.297	3.907
Household direct requirements coefficient	0.0715586	0.0372036	0.044677
Type II employment multiplier	2.98	7.69	6.665
Estimated impact of five percent change in output			
Estimated change in output ($ million – 1992)	85.815	308.675	394.49
Total change in household income ($ million – 1992)	15.393	49.352	68.876
Total change in employment (number of jobs)	222.56	2,065.89	2,288.45
Total income change as a percent of income			
As a percent of total personal income	0.258	0.830	1.159
As a percent of household wage and salary income	0.462	1.481	2.067
Total employment change as a percent of employment			
As a percent of wage and salary employment	0.149	1.388	1.537
Indirect income and employment effects			
Indirect and induced income effect ($ million – 1992)	9.252	37.868	51.252
Indirect and induced employment effect (number of jobs)	148	1,797	1,945
Direct income and employment effects			
Direct income effect ($ million – 1992)	6.141	11,483	17.7625
Direct employment effect (number of jobs)	74	269	343

Source: (1) Bureau of the Census 1996; (2) Fesenmaier *et al* 1987.

Figure 7.1
Consumer Surplus as a Measure of the Benefits of Water Suppl

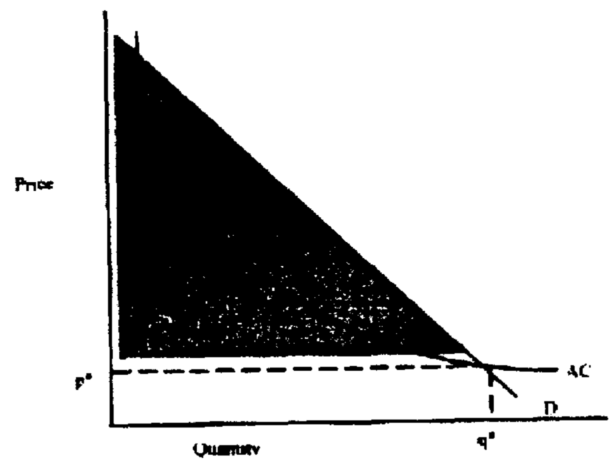


Figure 7.2
Measuring the Change in Consumer Surplus Resulting from Water Rationing

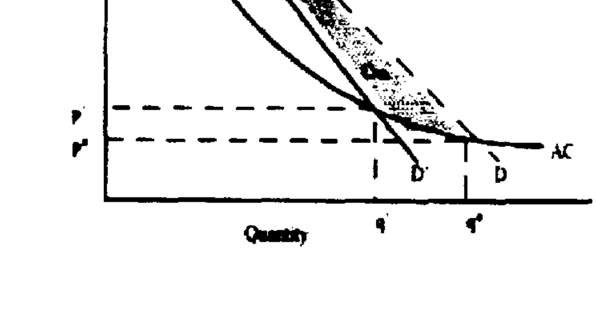
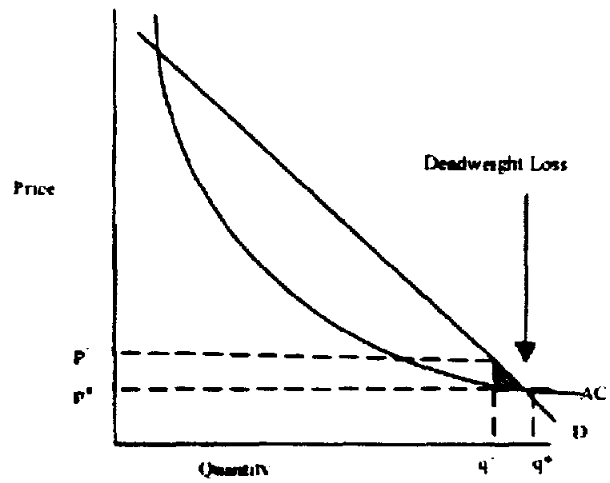


Figure 7.3
Economic Cost of Price Manipulation



Chapter 8. Economic and Behavioral Responses to Water Shortage and Drought Management

Methodological Approach to Surveys, Focus Groups, and Interviews

A series of meetings with residential water customers and representatives of six target commercial and industrial sectors addressed qualitative issues of drought impact to supplement the quantitative portions of the study. Focus group participants described changes in patterns of water use, anticipated the consequences of drought management alternatives, and provided public input on city water management and water supply policies. Table 8.1 briefly describes the composition of each focus group.

As Table 8.1 illustrates, residential and commercial/industrial groups met twice, and state and local government groups met once. During the first meeting of each group, completed between July 17 and August 8, 1996, participants answered a survey consisting of 40 questions related to water consumption, drought management preferences, and opinions about current and potential city policies. Results of the commercial/industrial and residential surveys are provided in Appendixes C and D, respectively. Following the survey, focus group moderators asked a series of discussion questions. The second meetings of each group were completed between August 14 and September 5 and were used to clarify issues addressed in the first meetings.

Focus group moderators used a series of questions as an interview guide. Questions addressed four main issues, which are listed in Table 8.2. Questions related to each of the four main issues were ordered by relative importance to the research agenda and, as often as possible, from the general to the specific. University and city staff moderated focus group sessions. The first meeting with each focus group was recorded and transcribed. Focus group results were processed and combined with results of survey data. In addition, university staff supplemented this information with interviews of petrochemical and ship channel industry representatives.

Recruitment of Participants

The city recruited residential focus group participants by requesting nominations from 24 neighborhood associations throughout Corpus Christi. Neighborhood associations were asked to nominate three members. Nine residential customers representing six different neighborhood associations participated in the focus group sessions. Seventeen residential customers who did not participate in focus groups completed surveys distributed through neighborhood associations and an apartment management company. A total of 26 residential customers completed surveys. Because participants were self-selected, the group was not a random cross section of water utility customers.

Commercial and industrial focus groups represented six target commercial/industrial sectors. Focus group participants were selected by managers from within selected organizations. The city asked top managers in selected organizations to nominate participants. Nominees were then contacted by mail and phone to recruit a suitable number of participants. Commercial/industrial focus groups comprised 63 participants representing 43 different organizations. Forty-one commercial/industrial organizations completed the survey. The project team did not offer any incentives for focus group participation. As with residential customers, participants did not represent a random cross section of water utility customers.

Surveys

The project team designed two surveys, one for residential participants and one for commercial and industrial participants, to collect detailed information about water use, drought management, and attitudes toward the drought and city policies. Information gathered through surveys supplemented information on behavior and attitudes gathered through focus group sessions. Completed surveys provide a basis for aggregation, comparison, and contrast of behaviors and attitudes among participants. Survey responses are tabulated in Appendixes C and D (see Volume 2).

Analysis

The following sections analyze results of the focus group and survey research. Sections 8.2 and 8.3 describe some economic effects of the water shortage. The information contained in these sections was generated through six commercial/industrial focus groups and interviews with large water utility customers. Section 8.4 addresses the behavioral effects of the water shortage using information generated by the two residential focus groups. Section 8.5 combines the contributions of both the commercial/industrial and the residential focus groups with regard to attitudes about the water shortage, city drought management policies, and similar issues.

Focus Group and Survey Results: Commercial and Industrial Water Utility Customers

The project team conducted focus group sessions and interviews with commercial and industrial water customers in Corpus Christi to describe economic effects of the water shortage and city water restrictions. This information is presented in three parts: patterns of water use, economic indicators of the effects of drought management, and case studies.

Patterns of Water Use

The term *patterns of water use* in this study refers to an observed set of features characterizing the ways in which residential and commercial/industrial customers use water. The project team used surveys, focus group discussions, and case study interviews to identify changes in patterns of production related and non-production-related water use that might be attributed to the water shortage or city water restrictions. Production related water uses are those that are integral to a production process, such as cooling or cleaning. Non-production-related water uses refer to activities such as janitorial water or outdoor watering by commercial and industrial customers. Research on patterns of water use also helped to identify marginal uses of water, obstacles to drought management, and potential substitutes for city water among commercial and industrial participants.

Production-Related Water Use

The city may eventually implement mandatory restrictions on commercial/industrial water use in production or operations. However, as of December 1996, the city's only action had been to request voluntary reductions in water use of 10 to 15 percent by members of the Board of Trade, Corpus Christi's 16 largest industrial water customers. In addition, mandatory outdoor watering restrictions have affected production related water use in the landscape/nursery and government/schools sectors. Table 8.3 describes production related drought management measures implemented since the city declared drought condition 1 in April 1996.

Businesses have begun repairing, maintaining, and altering current production processes to affect the greatest possible water savings before investing in new capital equipment or additional labor hours. According to focus group discussions, cost-effectiveness is the most common reason that organizations delay investing in water saving capital equipment. However, uncertainty about the length of the water shortage, city plans for water allocation, and their own ability to complete capital projects within the drought management period are all factors in this decision.

Some organizations are implementing voluntary water saving measures to avoid perception of water waste. Commercial enterprises in which water use is highly visible to the public, including hotels, landscaping businesses, and building washing businesses, wish to avoid the appearance of wasting water. This concern has caused them to implement some water saving measures either at customer request or to avoid negative publicity. For example, commercial building washers have reported recapturing water to use on customers' landscapes and transported groundwater in tank trucks for some clients who wish to avoid the appearance of wasting city water. In this case, the adoption of both water saving measures were prompted by customer requests. One power washing business even stopped all washing of private homes, an activity that generated about 40 percent of its revenue. In response to the same incentive, participating hotels have repaired malfunctioning sprinklers and other outdoor equipment in order to avoid visible noncompliance with mandatory city restrictions. Focus group participants mentioned several times the fear of bad publicity in local news broadcasts. The incentive to avoid the appearance of wasting water seems less relevant for businesses that use water in a less visible manner.

Non-Production Related Water Use

Table 8.4 summarizes participants' responses to a survey question that assessed measures taken to decrease non-production related water use in response to the water shortage and city restrictions.

Participants report implementing efforts not related to production to achieve water savings beyond those required by the city in drought conditions 1 and 2. Participating commercial/industrial organizations report compliance with mandatory watering restrictions. In addition, they report implementing voluntary water saving measures not related to production. Measures listed in Table 8.4 might be considered marginal relative to those described in Table 8.3, because these measures do not affect production. Businesses report that water saving measures not related to production are less costly than production related measures. However, businesses do not report implementing more efforts not related to production than measures related to production. Businesses have implemented production- and non-production-related water saving measures in approximately equal proportion.

Relatively few participating businesses have implemented voluntary indoor water saving measures that do not relate to production. Three of the four most common non-production related measures reduce outdoor water use. A relatively small number of participants report retrofitting indoor plumbing fixtures. This may be due to either perceived or real costs related to such a project. Lack of information about retrofit options may be another cause. Many focus group participants had not considered the possibility of retrofitting and were unaware that some kits may be available from the city water department.

A majority of commercial/industrial participants formally encourage their employees to save water. Sixty-three percent of participating organizations are educating employees about how to reduce water use. In some cases, participants' education efforts reach beyond their own employees. One city department, for example, is educating local restaurants about safe ways to reduce water consumption during the shortage. In the landscape and hotel industries, participants' ability to reduce their total water use depends upon their ability to influence their customers' water consumption. Informing customers about potential water saving measures is therefore an important part of these organizations' overall drought response.

Total Water Use

Commercial and industrial participants also answered a number of questions designed to gauge their perceptions of how total water use might have changed due to the water shortage and water restrictions. Participants were asked to assess the impact of their own drought management efforts on their total water use. Table 8.5 summarizes participants' assessments of their water use in July 1996 relative to their water use in July 1995. No water restrictions were in place in July 1995. By July 1996, the city had been in condition 2 of the drought contingency plan for approximately two months.

Participants report using less water in July 1996 than in July 1995. Sixty-one percent of commercial and industrial participants estimated that they used less water in July 1996 than in July 1995. Focus group discussions generally reinforced this perception, except in the landscape/nursery industry. For example, landscape industry representatives discussed the possibility that their customers might be watering more since the city implemented restrictions.

This does not imply that customers are not observing city water restrictions. Rather, it implies that complying with restrictions does not necessarily lead to a reduction in overall water use. In contrast, when landscape maintenance comprises a large portion of production related water use, water restrictions have greatly reduced overall water use. One school district reported using 25.5 percent less water in June 1996, than in June 1995, and approximately 50 percent less in July 1996, than July 1995. The district attributes this to its compliance with mandatory outdoor watering restrictions on its many athletic fields.

More pronounced changes in water use can be expected if the city limits water sales to commercial and industrial enterprises as prescribed in condition 3 of the drought contingency plan. Focus groups, surveys, and individual case studies all included a number of questions that asked participants to describe the water savings measures that they would implement at the onset of condition 3 and to estimate the costs of those measures. Participants' answers to these questions contribute to the following discussion of marginal uses of water in commercial and industrial enterprise.

Marginal Water Use

Conclusions about the marginal uses of water in Corpus Christi commercial and industrial enterprises can be drawn from the information on changes in production- and non-production related water use in Tables 8.2 and 8.1. It would be reasonable to assume that organizations' current curtailments in water use, made in response to a request for voluntary water savings and the possibility of limitations on water sales, have been made in areas of relatively marginal water use. In order to identify more precisely marginal commercial and industrial water uses, participants were asked what changes they might make if the city allocates water in later stages of the shortage and what changes they would consider keeping in place after the shortage.

Table 8.6 lists responses to a survey question that presented participants with a hypothetical water allocation scenario similar to that in the city's drought contingency plan. The project team did not ask a question directly related to the city allocation plan because the city had not yet determined the extent of commercial and industrial water consumption restrictions in drought conditions 3 and 4. Only 28 of 41 survey respondents answered this question. Responses are grouped into common categories and aggregated across commercial/industrial sectors.

Significant water use reductions may require production related water saving efforts. Forty-one percent of respondents reported they would reduce production related water use as the first step toward compliance with water restrictions. If non-production-related water uses are more marginal than water uses in production, these results seem contrary to the expected response. Production-related water savings should be implemented only after less costly water savings are achieved. This response can be explained by a number of factors. Most firms have already reduced water consumption in marginal processes, especially non-production-related processes, in response to mandatory outdoor watering restrictions and a request for voluntary water savings. More than half of the respondents who would reduce production related water use are firms in the petrochemical and ship channel industries. Of the 10 petrochemical firms that answered the question, 5 would increase water recycling in production and 5 would reduce production if they were required to reduce water use by 25 percent.

Both survey and focus group results indicate that reducing production is the least preferred drought response among commercial and industrial customers. This implies that reducing water use in specific production processes is a necessary step to achieving proposed water savings. Most petrochemical and ship channel participants report they have already scaled back non-production-related water uses. Some examples of the "next most marginal" uses of water in these firms can be found in the case studies in section 8.3. Water utility customers who agreed to provide anonymous information through interviews for the case studies were asked to identify the specific water savings measures they were implementing in response to the water shortage and in anticipation of city restrictions.

Many commercial/industrial participants are waiting to learn the requirements of condition 3 water rationing before determining which processes to alter. Marginal uses of water in production may be more apparent when the city implements condition 3 water rationing. Although most organizations report projects under way in anticipation of restrictions, both the required change in water use and the benchmark against which these changes will be measured could influence firm-level responses to water restrictions.

Outdoor water use may be more marginal than indoor water use for non-production-related processes. The relative cost of outdoor and indoor non-production related water saving measures is apparent in the response to this survey question. Only one respondent reported plans to reduce indoor water use upon implementation of drought restrictions. Obstacles to water savings described in the following section might also influence firm-level decisions about indoor and outdoor water use.

Organizations make decisions about how to reduce water use in part on basis of the relative cost-effectiveness of potential projects. The relative cost-effectiveness of water saving measures points to the relative marginality of the water uses that the projects seek to alter. Firms in all target sectors have implemented water saving efforts for their associated cost savings or efficiency. For example, two of the three local electric utility plants use seawater for power generation. Petrochemical and other large firms recycle water through cooling towers. In industries in which water is a major expense, cost-effective water savings are already in place.

Firms in which water is a minor expense generally plan to revert to previous water consumption behavior when drought management requirements and voluntary water savings requests expire. When water is not a major production input, reducing water use may not produce significant firm-level cost savings. Firms that do not save money as a result of their efforts during the drought will most likely revert to previous patterns of water use after the water shortage. Some firms noted an exception to this general rule. If their customers specifically request continuance of water saving efforts, there would be an incentive keep these in place indefinitely. For example, power washers who began using groundwater at customer request during the water shortage do not plan to continue to use groundwater after the shortage unless their customers request it.

Firms in which water is a major expense might keep in place cost-effective investments made during the current water shortage. Measures that require no capital investment and positive or insignificant change in variable costs are likely to be permanent if production, safety, and, in some cases, convenience do not suffer. In order to avoid reducing production, firms may attempt measures that require capital investment but do not generate sufficient savings in variable costs in the short term. Most firms that have implemented water saving measures with these qualities will lease the necessary equipment in the short term and plan to revert to past practices when restrictions are lifted. Reductions in water use that require capital investment that is not cost-effective, even in the short term, are likely to drive facilities and parent firms to consider reducing production in the short term. In the long-term, if firms cannot conserve enough water by implementing cost-effective projects, they and their parent corporations are likely to reconsider the long-term economic feasibility of potential expansions or continued operations in Corpus Christi.

Obstacles to Water Savings

In order to identify some of the obstacles to water savings in Corpus Christi commercial and industrial organizations, focus group moderators asked whether participating businesses had implemented as many water saving measures as they would like, and if not, what was preventing them from doing so. Table 8.7 lists the most common answers to this question. Cost is the primary barrier to increased water savings among Corpus Christi commercial and industrial enterprises, but the other obstacles listed in Table 8.7 were frequently mentioned across sectors.

Uncertainty about condition 3 water rationing and the baseline from which the city will calculate rations is a significant obstacle to increased voluntary water savings. According to the drought contingency plan, in July 1996, the water allocation to commercial and industrial customers was to be a percentage of water use in the same month of the prior year. Such a limitation would not reward voluntary water saving efforts undertaken prior to the enactment of restrictions. This disincentive to reduce water use in advance of drought restrictions is paired with a classic "free rider" problem. If one firm voluntarily reduces water use through long-term water conservation, it might be penalized by receiving a smaller monthly water allocation under drought restrictions than another firm in the same industry. Firms report no perceived benefits to water conservation if they have no assurance that other firms are behaving similarly or that they will receive credit for voluntary water savings when the city implements water restrictions. These views were expressed by representatives of the larger industries as well as those from smaller commercial enterprises.

Lack of information about how to achieve additional water savings is an obstacle to increased water savings among smaller commercial enterprises. Organizations like hotels and landscaping businesses, which might conserve significantly by plumbing modification, gray water reuse, and other indoor measures, often lack the necessary information. This did not seem to be a significant obstacle to increased water savings among larger industries. Many focus group participants suggested that availability of information on methods of reducing water use would enhance their own employee education and awareness efforts.

Some commercial/industrial customers face the additional obstacle of reliance on their own customers' water use to reduce water consumption. Landscapers, for example, could reduce overall water use if more of their residential and commercial customers agreed to water-wise plant selection, irrigation systems, and landscape designs. Most customers, however, are concerned less with improving the drought tolerance of landscapes than with compliance with a city ordinance that regulates landscaping around new buildings. That ordinance establishes a point system for water-wise materials and designs and requires a minimum number of "points" at each construction site. This ordinance does include incentives for selecting drought-tolerant landscape materials, but costs often deter customers from selecting them. Similarly, the behavior of guests can restrict a hotel's ability to achieve water savings.

Facility and equipment constraints are obstacles to increased voluntary water savings. Low water pressure and aging properties can prevent businesses from installing water saving plumbing devices or reducing the level of water in existing toilets, for example. In addition, school districts and other focus group participants that might achieve significant water savings by retrofitting faucets have experienced numerous difficulties with water saving valves. One school district is replacing these valves with traditional faucets due to excessive water waste. City departments and other organizations concerned with groundskeeping fear that reducing outdoor watering any further than current levels will irreversibly damage watering equipment, an expensive capital investment. Keeping systems minimally operational can avert this problem. Organizations facing this obstacle are therefore unlikely to further reduce water consumption voluntarily.

Health, safety, and liability issues are obstacles to increased voluntary water savings in some commercial/industrial sectors. These issues have limited the extent to which some organizations have voluntarily reduced landscape watering, dust control, facility washing, and other non-production related water consumption. In some cases, further reduction in these areas conflicts with local, state, or federal environmental or safety regulations. For example, one military facility is required to wash helicopters at a minimum frequency for corrosion control. Another is required to flush fire hydrants at a minimum frequency. Some focus group participants who have considered using effluent as a substitute for city water are prevented from doing so by liability issues and city rules. In some cases, regulatory issues generate a firm-level trade-off of one environmental side effect for another. For example, one local refinery installed a wet gas scrubber to control sulfur dioxide emissions. This technology has increased water consumption in the company's cooling process relative to other firms and complicates water recycling; this could be interpreted as an obstacle to voluntary water savings. One local manufacturer may consider increasing its percentage of solvent-based products relative to water-based products if water restrictions threaten to reduce production.

Public resistance can prevent organizations from implementing voluntary water savings measures. For example, city departments and school districts face public outcry over the deteriorating condition of parks and athletic fields. This may prevent these customers from altering water use patterns. Likewise, petrochemical industries that would consider recycling city wastewater effluent streams for use in production face public resistance to the depletion of wetlands and birding areas currently fed by those streams.

Water quality problems resulting from the water shortage are an obstacle to increased voluntary water savings among larger industries. As the level of the city's reservoirs has declined, water quality has declined, requiring both additional chemical and mechanical treatment and, in some cases, increased use of water in production among larger industries. Low quality of initial water inputs also poses an obstacle to maximizing water recycling.

Potential Substitution Effects

Commercial/industrial participants are able to substitute other inputs for city water in some production processes. Substitutes for water discussed by focus groups include city effluent, internally recycled water, groundwater, and seawater. A few other sector-specific substitutes for city water were mentioned in focus group discussions. For example, one landscaping business is promoting turf painting as a substitute for sod, one manufacturer would consider substituting distilled water or solvent for city water in some production processes, and one hotel has devoted extra labor hours to stairwell-sweeping instead of washing with water.

Where substitution of other inputs for city water is cost-effective, most of the city's largest industrial water customers have already invested in the necessary technology. For example, one Board of Trade member designed two of its Corpus Christi facilities to use seawater for cooling. Another invested $500,000 in two groundwater wells in response to the 1984-1985 water shortage. The cost-effectiveness of substitution of other inputs for city water might increase if city water restrictions remain in place for any length of time or if city water rates for commercial and industrial customers rise significantly.

The obstacles to substituting other inputs for city water are almost identical to the obstacles to voluntary water savings listed earlier. Cost and technology are the biggest obstacles to substitution among larger industries. Health and safety risks are obstacles to substitution of effluent for city water in most sectors. Lack of information about city effluent availability and gray water reuse is an obstacle for smaller commercial enterprises. Conflicts with local, state, or federal environmental regulations are obstacles to using effluent in some processes and also make recycling water more complicated. Effluent streams and recycled water cannot be used if use of such wastes would conflict with regulatory standards.

Economic Indicators

Economic impact estimates presented in Chapter 7 address the impact of the current water shortage on the Corpus Christi economy. The second major function of the study's commercial and industrial focus groups was to identify sector-level indicators of economic impact and to assess firm-level perceptions of how those indicators may be affected by the water shortage and city restrictions. Firms' perceptions of economic impact are not necessarily accurate, nor can they be aggregated to calculate total economic impact. They are, however, a barometer of how firms may act in response to water restrictions and how the water shortage may influence their long-term plans for production in Corpus Christi.

Indicators of Economic Impact

Indicators of economic impact vary by sector. The project team met with a group of local and regional government representatives to identify potential measures of the water shortage's aggregate economic impact. The local government working group suggested a number of indicators, listed in Table 8.8, that might measure the long-term impacts of the water shortage and city restrictions on aggregate economic conditions in Corpus Christi.

Focus group and survey results indicate that revenue and employment would be appropriate indicators of the economic impact of the water shortage and city restrictions on most commercial/industrial sectors. Table 8.8summarizes the sector-specific indicators of economic impact identified by study participants as potential appropriate measures of how strongly the water consumption restrictions affect their industries.

Perceived Short-Term Economic Impact

The focus groups and survey results discussed below describe economic effects of drought restrictions. This project was not designed to measure empirically the short-term impacts of the water shortage and restrictions on the indicators listed in Tables 8.8 and 8.9. Survey and focus group results regarding changes in revenue, employment, and other indicators allow generalizations regarding how firms make water use decisions in response to economic incentives. These observations cannot be used to calculate average or overall economic impact.

Revenue and employment have been hurt in industries affected most directly by the mandatory water restrictions of drought condition 2. Focus group participants from the landscaping industry indicated that monthly sales were down about 50 percent in July. One firm has cut its employee work weeks to four days rather than 5, a 20 percent drop in employment measured in hours worked. Firms that work on a contract basis have seen less impact on revenue and employment in the short term. While some landscaping firms might recover some losses with increased revenue from landscape replacement activity in the spring, other types of commercial customers may not recover loses. For example, power washing businesses with monthly contracts may see revenue return to previous levels after the water shortage, but they will not recover any revenue for work lost.

Many participants have experienced small increases in fixed costs to comply with condition 2 outdoor watering restrictions and with the city request for voluntary water savings. Focus groups and surveys asked participants to estimate the short-term fixed and variable costs of the water shortage in drought condition 1 and part of drought condition 2, from April through August 1996. Table 8.10 illustrates the effects of conditions 1 and 2 on fixed costs. According to survey results, the water shortage has raised fixed costs in 49 percent of participating commercial/industrial organizations. Examples of fixed costs incurred by participating organizations include opening of groundwater wells by wholesale customers; purchase of new irrigation equipment by smaller commercial enterprises; capital expenditures for water saving equipment by larger industries; and commissioning of an engineering study on effluent reuse by a military installation

More detailed examples of fixed costs associated with the water shortage can be found in the case studies in section 8.3.

Many participants have experienced small increases in variable costs to comply with condition 2 outdoor watering restrictions and with the city request for voluntary water savings. Sixty percent of participating organizations report increased variable costs. Some firms located in Corpus Christi during the 1984-1985 water shortage invested in water saving equipment that they are reusing in 1996. This may partially explain the lower percentage of firms incurring fixed costs relative to variable costs. In addition, some variable cost increases can be associated with low water quality. Low water quality caused by low reservoir levels can raise operating expenditures. Table 8.11 illustrates the effects of conditions 1 and 2 on variable costs.

Survey and focus group results also describe some anticipated economic impacts of proposed allocations of water to business and industry. Interpretation of these observations is complicated by frequent changes in the city's proposed allocation and surcharge plans. For example, participants were asked to estimate the anticipated revenue and employment effects of condition 3 restrictions according to city ordinances in July. At that point, condition 3 was expected to yield a 25 percent reduction in commercial and industrial water use compared to the same month in the prior year. Current policies may involve both a different percentage reduction and a different baseline for calculating the reduction. Estimates of the economic impact of water restrictions are descriptive, but they cannot be used to calculate the aggregate impact of drought condition 3 on revenue and employment.

Many participants are unable to estimate the revenue and employment impact of condition 3 water allocation. Table 8.12 describes responses to commercial/industrial survey questions 28 and 29, which identify expected changes in sales revenue and employment if the city allocates water according to the July 1996 requirements of drought condition 3. The percent of participants responding to these questions is perhaps equally as useful as the average anticipated change in revenue and employment that they report. Only 53 percent of all participants were able to estimate an economic impact of condition 3 water allocation in terms of revenue. Only 27 percent were able to estimate an impact of allocation in terms of employment.

Anticipated impacts of condition 3 water rationing on revenue and employment are unclear. Study participants from the landscape/nursery sector expect allocation to depress revenue and employment to a greater extent than participants from any other sector. For example, more firms were able to estimate changes in revenue than changes in employment. This may suggest revenue effects will be stronger than employment effects. Alternatively, employment effects may simply be more difficult to estimate. These observations are consistent with focus group discussions. Many refineries and other industrial facilities do not have the flexibility to reduce employment in the short term even if they reduce production, because a full staff is required to keep all units operating even below capacity.

The revenue and employment effects of condition 3 water rationing will depend on the reduction required by the city and the baseline from which the reduction is calculated. How sensitive are production cost, revenue, and employment to water consumption restrictions? It is believed these effects will become increasingly large as the level of water rationing increases. For example, one industrial participant maintained that the cost of compliance with a 25 percent reduction requirement among Board of Trade members would increase a hundredfold over the cost of compliance with a 15 percent reduction requirement. That participant did not specify whether he was referring to opportunity costs of lost production, production costs, or some other cost measure. Table 8.13 lists Board of Trade estimates of the economic impact associated with reducing water use 15 percent and 25 percent.

The Board of Trade technical committee also estimated job losses resulting from reduced production levels under condition 3 water rationing. If Board of Trade members reduce water use 15 percent, they anticipate a direct employment loss of 80 jobs in the petrochemical manufacturing industry. Board of Trade members project this may result in a combined direct, indirect, and induced employment loss of 400 jobs in all area industries combined. More stringent levels of water rationing will increase employment losses. If condition 3 requires a reduction of 25 percent, Board of Trade members project a direct employment loss of 415 jobs. Board of Trade members further project that combined direct, indirect, and induced employment losses resulting from changes in petrochemical manufacturing output levels could be as many as 2,200 jobs.

Possible Long-Term Economic Impact

Commercial and industrial water customers are concerned about long-term economic impacts related to the risk of water shortage in Corpus Christi. From June through August 1996, the Greater Corpus Christi Business Alliance conducted business recruitment and retention surveys with 16 large commercial and industrial corporations. Half of those surveyed listed water supply among the top three needed improvements to the local business environment. More than one third listed water supply as the most needed improvement. In the Business Alliance survey, four of the area's largest water customers indicated that they anticipate long-term production and employment impacts if the water issue is not resolved.

A majority of commercial/industrial participants feel that the long-term risk of drought in Corpus Christi is high enough to justify the cost of investments to reduce water use. As Table 8.15 illustrates, 68 percent of participants felt that the long-term risk of drought justified investments to reduce water use. Only 20 percent disagreed with the statement. Focus group results and firm-level case studies also indicate that long-term investments to reduce water use are a priority for commercial/industrial participants.

The current water shortage has affected few participants' long-term expansion plans. Table 8.15 summarizes responses to a survey question that was designed to determine the extent to which the current water shortage had affected participants' expansion plans, an indicator of long-term economic impact. Only one fourth of survey respondents indicated that the current water shortage had affected company expansion decisions through July 1996. One explanation for this is that expansion and capital investment decisions usually have a long horizon. The effects of drought contingency measures that have been in place for only a few months are not likely to be significant for many firms. Decisions regarding current capital projects and investments at military installations, for example, are often made five years or more in advance. In addition, many firms will wait to know the details of city water restriction measures before they make changes to expansion and investment plans already under way. One school district is postponing use of a multimillion-dollar bond issue for athletic facility improvements until it knows how later stages of the drought contingency plan will affect potential investments. Industries that depend on discretionary water use by Corpus Christi residents, like the landscaping and power washing industries, have put all long-term expansion plans on hold in response to the water shortage.

Industrial participants expect the long-term risk of water shortage to affect their ability to compete for resources from parent firms. Focus group discussions and firm-level interviews both support this inference. The current water shortage contributed to the decision of one major corporation to refuse a proposed $100 million expansion at its Corpus Christi facility. In corporate-level decisions about capital investment, the water shortage presents an additional risk factor for Corpus Christi operations relative to other corporate facilities. According to one petrochemical firm, the cost per gallon of its recycled water is 5 to 10 times higher than the cost per gallon of city water. Another petrochemical industry participant maintained that capital expenditures for water-saving investments make water use so expensive that production in Corpus Christi may become uneconomical. Facilities that cannot attract investment from parent corporations often face a disadvantage because they are less efficient than competing facilities. This restricts their ability to attract long-term investments. Similarly, military installations, which may become more vulnerable to base closure decisions, are especially sensitive to the effects of long-term water shortage in Corpus Christi.

Commercial/industrial participants express concern that the long-term risk of water shortage will impact the local economy negatively. Table 8.16 lists responses to several survey questions that assessed participants' opinions about the impact of the long-term risk of water shortage on the Corpus Christi economy as a whole. Perceptions about how sensitive economic conditions are to the water shortage may affect organizations' long-term decisions about production and expansion in Corpus Christi.

Interview Results: Six Industrial Water Utility Customers

To supplement the economic impact information obtained through focus group and survey research, university staff conducted interviews with six members of the Corpus Christi Board of Trade, which represents the city's 16 major industries. Board of Trade members' combined water consumption is approximately 14.6 billion gallons per year, roughly 40 percent of all city water sales. Case studies A through F describe the impact of the water shortage and city restrictions on some of Corpus Christi's largest water customers at an individual level. The interviewer asked each the same series of nine questions, which covered the topics listed in Table 8.17.

None of the firms interviewed planned to wait for mandatory water restrictions to begin reducing water use. All had undertaken significant projects in response to the city's request for voluntary reduction in drought conditions 1 and 2. In addition, it should be noted that concern over the long-term water supply in Corpus Christi has driven the city's largest industries to conserve water on an ongoing basis. For example, the refinery industry in Corpus Christi is relatively water efficient. Corpus Christi refineries use an average of 30 to 35 gallons of water per barrel of crude oil throughput. Houston area refineries use an average of 90 gallons. All firms interviewed had made significant efforts to educate employees about ways to reduce water use and to improve leak inspection and the overall condition of water systems. Most had implemented non-production related measures to save water, including reduced landscape watering, dust control, and facility washing.

Interview questions provided a more comprehensive look at the production related water use behavior of individual firms. All firms interviewed have experienced an increase in costs associated with the decrease in city water quality, which requires the firms to invest more in chemical and mechanical treatment with no resultant savings in water costs. These costs are not included in the estimates reported for each firm.

Case Study A

Company A is a refinery that used an average of 150 million gallons of water per month from August 1995 through August 1996. Table 8.18 lists the efforts to reduce water use undertaken by company A in response to the current drought. Table 8.18 lists water saving measures implemented since the 1984-1985 water shortage.

Economic Approach to Reducing Water Use

Decisions about how to reduce water use are based on comparisons of cost per thousand gallons of water produced to cost per thousand gallons of city water. Measures implemented through August 1996 are those that produce recyclable water at a cost lower than that of city water.

Preparation for Potential Water Allocation

If current water saving efforts do not enable company A to meet future city water restrictions, it will consider implementing other capital projects to save water, even though those projects will produce water at a price much higher than that of city water. company A intends to do everything short of decreasing production to meet city restrictions and avoid incurring surcharges. Management is not comparing the costs of surcharges to the costs of compliance with potential city restrictions.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

The costs to company A of the long-term risk of water shortage function like a local tax. Costs cannot be passed on through its product, as pricing in the refinery industry is driven almost wholly by the Houston market. Management is not concerned with the water shortage's long-term impact on company A's ability to compete with other firms in the Corpus Christi refinery industry. If the water shortage continues indefinitely and city restrictions or water costs impede its ability to produce at capacity, company A might anticipate an effect on its ability to compete for resources and capital investment from its parent corporation.

Case Study B

Company B is a refinery that used an average of 210 million gallons of water per month from August 1995 through August 1996. Table 8.20 lists water saving measures implemented by company B in response to the current water shortage. Table 8.21 lists water saving measures implemented since 1994-1995.

Economic Approach to Reducing Water Use

Company B has been recognized for its efforts. The company has a three-stage drought contingency plan which anticipates restrictions associated with the city's four-stage plan and implements them proactively. Decisions about how to achieve water savings are based on comparisons of cost of recyclable water produced to cost of city water, but management will consider any project with long-term economic return. Less practical projects will be considered especially as an alternative to decreasing production.

Preparation for Potential Water Allocation

Water saving measures associated with the third stage of company B's drought contingency plan are expected to bring water use to the level anticipated to be required by city restrictions. If implemented projects do not conserve as much water as expected, company B may have to consider paying surcharges in the short term. Management would prefer to comply with city restrictions rather than make an economic decision to pay surcharges.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

The ability of company B to compete with other firms in the refining industry in Corpus Christi has not yet been affected by the water shortage. The company places heavy emphasis on reducing water use in its Corpus Christi operations, but it does not anticipate that long-term costs associated with water savings will negatively affect its ability to compete.

Case Study C

Company C is a refinery that used an average of 180 million gallons of water per month from August 1995 through August 1996. Table 8.22 lists water saving measures implemented by company C in response to the current water shortage. Table 8.23 lists water saving measures implemented since the 1984-1985 water shortage.

Economic Approach to Reducing Water Use

company C is implementing the most economically practical water-saving projects to meet anticipated city restrictions. Management does not plan to reduce production or employment due to the water shortage. However, water-saving projects do not result in increased earnings, resulting in a zero return on capital investment.

Preparation for Potential Water Allocation

Company C has established a target for water savings. Its goal is to reduce monthly water use by 15 percent of 1995 water use. It anticipates that this reduction will meet the short-term requirements of city water restrictions. If the water shortage continues and further reduction is necessary, the company might have to consider paying surcharges.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

One of the newer refineries in Corpus Christi, company C had to meet stricter environmental regulations than others in the industry when constructing its facility. For example, the company installed a wet gas scrubber for sulfur dioxide control. Some of the requirements of these regulations have increased water consumption and/or complicated water recycling for company C relative to other local firms. As a result, company C will incur higher costs than other firms to meet city restrictions. In the long-term, this will affect the company's ability to compete. In addition, the water shortage presents a risk factor to the corporation's Corpus Christi facility relative to other facilities in the same firm. Although this has not yet affected company C's ability to attract capital investment from the parent corporation, it might in the long-term.

Case Study D

Company D is a petrochemical manufacturer that used an average of 160 million gallons of water per month from August 1995 through August 1996. Table 8.24 lists water saving measures implemented by company D in response to the current water shortage. Table 8.25 lists water saving measures implemented since the 1984-1985 water shortage.

Economic Approach to Reducing Water Use

company D is implementing the most economically practical water saving projects possible to meet anticipated city restrictions. Two of the measures implemented, the recycling of treated wastewater to cooling towers and the installation of an RO unit for the demineralizer, may be economically practical to maintain after the water shortage eases.

Preparation for Potential Water Allocation

The company anticipates that projects under way will reduce water consumption enough to meet city restrictions. One additional capital project, a more permanent RO unit for the demineralizer, could be in place by early 1997 if necessary. Management is also researching the economic feasibility of additional options including recycling of municipal treatment plant effluent, refrigeration units for cooling, fan cooling, groundwater wells, and importation of fresh water by ship. company C will avoid reducing production if at all possible, but would consider transporting materials to another facility in order to process two of its products elsewhere and still comply with city restrictions and avoid surcharges.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

The ability of company D to compete with other local firms has not yet been affected by the long-term risk of water shortage. The company's ability to attract capital investment from the parent corporation is market driven and has not been affected by the long-term risk of water shortage. The parent corporation has recently invested in an expansion of one of its Corpus Christi facilities and is very concerned about the impact of water restrictions on its ability to begin using this expansion.

Case Study E

Company E is a refinery that used an average of 105 million gallons of water per month from August 1995 through August 1996. Table 8.26 lists water saving measures implemented by company E in response to the current water shortage. Table 8.27 lists water saving measures implemented since the 1984-1985 water shortage.

Economic Approach to Water Reducing Water Use

Company E reports implementing all economically feasible water saving measures.

Preparation for Potential Water Allocation

The efforts presently under way at company E may not reduce water use to the level required by potential city restrictions. The next most feasible water-saving measure at company E would involve a $2 million capital investment. The company would have to consider paying surcharges in the short and/or long-term if current saving measures do not bring the facility into compliance with city restrictions.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

Company E's ability to compete with other local firms has not yet been affected by the long-term risk of water shortage in Corpus Christi. If the current water shortage continues and the firm is unable to meet city restrictions, its ability to compete may be affected. If company E had to implement additional capital water-saving projects, the parent corporation would compare the feasibility of maintaining production in Corpus Christi to the cost of moving production to another facility.

Case Study F

Company F is a Board of Trade member that used an average of 93 million gallons of water per month from August 1995 through August 1996. Table 8.28 lists water saving measures implemented by company F in response to the current water shortage. Table 8.29 lists water-saving measures implemented since the 1984-1985 water shortage.

Economic Approach to Reducing Water Use

Company F has implemented water-saving projects that produce water cost savings high enough to cover project capital, chemical, and operational costs. As a result, the company will maintain these measures beyond the current water shortage unless a degradation of equipment is noted.

Preparation for Potential Water Allocation

Projects to reduce water use currently under way may not reduce water use at company F to the level required by potential city restrictions. If the city does allocate water, the company may further increase the cooling tower cycles on one of its units for additional water savings. It would then consider leasing an RO unit for the short term in order to comply with restrictions. company F would also consider the economic feasibility of obtaining its product from other company locations or from its competition if company F is unable to produce the product in Corpus Christi. The company might consider paying surcharges rather than reducing production if it could not meet city restrictions and still supply its customers' requirements. company F's monthly usage varies widely from year to year. The 1995 water usage was not typical of usage trends from previous years. company F will be affected severely if the city allocates water based on 1995 usage rather than historical usage from 1993 to 1995.

Potential Impacts of Long-Term Risk of Water Shortage in Corpus Christi

If the long-term risk of water shortage slows growth in local industries, this will directly affect company F's growth potential. In addition, competition in company F's industry has increased potential for long-term risk of company F's ability to compete due to water shortage. Water is a major production cost on several of company F's units. Higher water costs resulting from the acquisition of additional long-term water supplies would have a heavy impact. Of company F's facilities in Corpus Christi, several units use city water for cooling and would face a significant increase in operating costs. One facility, in particular, would be vulnerable to closure if a competitor constructed a less water intensive plant in the Corpus Christi market.

Focus Group and Survey Results: Residential Water Utility Customers

Focus group sessions and surveys of residential water customers in Corpus Christi described behavioral effects of the water shortage and city water restrictions. Nine residential customers participated in focus group meetings, and 26 responded to surveys. Residential participants described the impacts of current mandatory restrictions, reported current voluntary water saving measures, and identified those they might implement to comply with condition 3 water rationing. Information about behavioral responses is described in terms of patterns of water use and marginal water uses.

Mandatory Reductions in Water Use

Residential lawn watering was restricted during July and August to one day per week, based on customer street address, between the hours of 6:00 p.m. and 10:00 a.m., with authorized watering equipment. Condition 2 also prohibits run-off from lawns to streets and gutters and prohibits the washing of automobiles, trucks, boats, and any other type of mobile equipment without a bucket. The term *mandatory water savings* in this section refers to residential compliance with these aspects of condition 2 of the drought contingency plan. In mid-September the city implemented additional condition 2 restrictions, the effects of which are not included in the following description.

Residential customers report compliance with drought condition 2 outdoor watering restrictions. Residential focus group participants report that they are complying with condition 2 restrictions. Fifty-four percent of survey respondents feel that their efforts at the household level have made a meaningful contribution to the citywide effort to reduce water use. Residents believe that their water saving measures contribute to high compliance rates. In addition, 73 percent of survey respondents agree or strongly agree that their neighbors are complying with mandatory condition 2 restrictions.

Residents report that compliance with condition 2 watering restrictions is not costly. Survey responses to two questions that assessed the costs of compliance with condition 2 restrictions indicate that the fixed and variable costs of compliance are insignificant for most participating households. Only 11 of 26 survey respondents were able to describe or estimate a fixed cost of their efforts to reduce water use in conditions 1 and 2. By the end of July, only three households surveyed had spent more than $60 to reduce water use. Expenses reported were for soaker hoses and indoor retrofitting. Only the former can be considered a cost of complying with mandatory restrictions.

The effects of mandatory water restrictions on patterns of household water use may increase if the city enters drought condition 3 and rations water to residential customers. The drought contingency plan limits monthly residential water use based upon household size. Table 8.30 describes condition 3 residential water allocation. In contrast to the mandatory restrictions of condition 2, drought condition 3 will not require residential customers to implement specific water saving measures.

Households report that they will be able to comply with the short-term requirements of condition 3 allocation. Although most participating households agree that they will be able to manage with the water allowance prescribed for condition 3 (Table 8.31), household size and knowledge about water use may influence compliance with water rationing. Some participants anticipated that larger households would have a harder time complying with water rationing than smaller households.

Anticipated long-term foundation and landscaping costs may reduce residents' willingness to restrict outdoor watering under condition 3. As Table 8.32indicates, residential customers are divided about whether household costs will increase if the city limits residential water use under condition 3. Focus group results indicate that residents' main cost concerns are the long-term costs of structural foundation repair and landscape replacement, rather than the short-term costs of compliance with condition 3 water allocation. In condition 3, households will pay a surcharge for water use that exceeds their water allowance. Table 8.33 describes the city's cumulative residential surcharge plan for condition 3.

When focus group moderators explained condition 3 residential allocation and surcharge plans, one participant pointed out that residents could not have 1,000 gallons of effluent delivered for outdoor watering for a price as low as the penalty the city would charge for the first 1,000 gallons of water in excess of a customer's allocation. All seven participants at one residential meeting agreed that if no further penalty threatened, they would pay a surcharge for using more than their water ration rather than reduce their water use, especially to continue foundation watering.

Survey results were less conclusive, as Table 8.34 illustrates. When asked whether the city's residential surcharge policy provided an incentive to reduce water consumption, residential participants were divided as to the effectiveness of those restrictions.

Voluntary Water Savings

Any water saving measures implemented by residents during July and August beyond those required by drought condition 2 can be considered voluntary. Table 8.34 lists the voluntary efforts undertaken by residential survey respondents in response to the water shortage. All but one survey respondent reported implementing voluntary water saving efforts.

Residents report implementing voluntary outdoor water saving measures beyond those required by drought condition 2. Sixty-five percent of respondents have reduced outdoor watering to a level lower than that required by the mandatory restrictions of condition 2. This indicates that compliance with condition 2 restrictions is not an excessive burden on Corpus Christi households.

Residents report implementing voluntary indoor water saving measures in conditions 1 and 2. Survey respondents have also implemented measures to reduce indoor water use. Residential focus group participants report increased awareness of water use. For example, most participants wait to accumulate full loads before running washing machines and dishwashers. Many also report turning off bathroom faucets while brushing teeth and shaving. Residents have installed water saving plumbing devices and started household water reuse programs at a relatively low rate. Retrofitting and water reuse are the only two indoor measures listed in Table 8.35 that can be costly. This may explain the lower rate at which households have implemented these measures relative to other voluntary indoor water saving measures.

Households report maintaining or reimplementing many water-saving practices implemented in response to the 1984-1985 water shortage. Many households retrofitted bathroom and kitchen fixtures with water saving devices in response to the 1984-1985 water shortage. In addition, focus group participants report maintaining water saving behavior since 1984-1985, like running appliances with full loads and reusing dishwater for plant watering. No focus group participants report voluntarily maintaining outdoor watering restrictions since the water shortage of 1984-1985. Instead, they have reimplemented outdoor water saving measures in response to mandatory restrictions, often using equipment purchased during the last water shortage. Focus group participants do report having increased their use of drought-tolerant landscaping materials since the last water shortage.

Households report implementing many of the water saving measures they consider to be most effective. One residential survey question asked respondents to identify the three household water saving measures they considered to be most effective. Sixty-six percent of respondents have implemented at least two of the three measures that they consider to be most effective. This does not imply that households are implementing the most effective water saving measures. It does, however, imply that they are making a conscious effort to save as much water as possible. All focus group participants expressed a desire to know which measures were most effective. Amount of water saved appears to be an important factor affecting household decisions about what water saving measures to adopt, even though most households lack the information necessary to compare water savings between measures.

Total Water Use

Survey and focus group questions gauged residents' perceptions of the impact of their water saving efforts on their water consumption.

Residential water customers report that water saving efforts have reduced their household water use. Table 8.36 lists responses to a survey question that asked residential water customers whether their household water use had been reduced through water saving efforts.

Residents report that compliance with mandatory water restrictions does not necessarily reduce outdoor water use. Although residents report using less water as a result of their water saving efforts, many report increased outdoor water use in response to condition 2 watering restrictions. For example, customers that might have watered once every 10 days watered once every week when the city restricted household watering to assigned days. Changes in watering frequency might be due to lack of rain or a reaction to the assignment of days to water. Two focus group participants maintained, and others agreed, that they felt compelled to water on their assigned day, regardless of need.

Another example illustrates a similar point. A wholesale water customer participating in the study routinely notifies its own customers, towns, and rural areas about system maintenance 24 hours in advance. Each of these customers is required to maintain a 24-hour above-ground storage supply. When notification is given to residents and businesses that water service may be suspended for maintenance, a town's 24-hour water supply often disappears in 12 hours.

Focus group participants admit they may use more water than necessary in anticipation of restricted water use. In condition 3, water will be rationed and residents will make decisions about watering landscaping in relation to trade-offs with alternative uses. This may be a more effective way to reduce outdoor water use. Focus group participants indicate that when faced with a trade-off between indoor and outdoor, they will be more willing to decrease outdoor watering than indoor water use.

Obstacles to Water Savings

Cost, convenience, and lack of information are the three most commonly reported obstacles to reducing household water use. Anticipation of the long-term costs of reducing water use, including foundation repair and landscape replacement, appears to be an important obstacle to increased voluntary efforts. Focus group participants agreed that they would continue to water foundations, even under the threat of surcharge for using more than their allocation, unless the city implemented a mandatory restriction on watering foundations with city water. Residents agreed that effluent could be a substitute for city water on foundations, although many had not yet determined the costs of purchasing and applying effluent.

Convenience is an additional obstacle to increased household water saving efforts. Responses to survey question 27, listed in Table 8.37, indicate that inconvenience appears to be more of an issue than cost at the residential level. For example, when residents are restricted to watering on an assigned weekday, they are forced to choose between watering and other activities. The outdoor watering restrictions are considered inconvenient by many focus group participants because of this interference with normal use of time during nonworking hours.

Incomplete information is an obstacle to voluntary reduction of household water use in two different respects. First, households' level of knowledge about their own water use is low. Households will not be able to increase voluntary reduction of water use or to comply with water rationing unless they become more familiar with their own water use. While approximately one half of survey respondents were able to estimate their monthly water bill, only 42 percent reported any ability to estimate monthly household water use. While most respondents know the location of their water meter, only one half are able to read their meter. Residents' ability to monitor their own water use will influence the extent to which condition 3 restrictions reduce household water use in Corpus Christi.

In addition, residential customers lack information about methods of saving water. For example, participants at the first residential focus group meeting agreed unanimously that if they were asked to implement one more water-saving measure, they would like to reuse household gray water to water foundations. Only two participants knew what water they would reuse and how they would accomplish it. Most lacked the requisite knowledge about equipment purchase and plumbing modification to begin a reuse program.

Marginal Uses of Water

Focus group and survey questions assessed marginal uses of water in Corpus Christi households by asking residents to identify preferred methods of reducing water use. During the second residential focus group meeting, moderators asked participants to establish a hierarchy of preferences. Moderators described the city allocation and surcharge plan for condition 3 and asked residents to identify the measures they would implement to comply with water rationing. Given a list of eight categories of household water use, participants settled unanimously on the order in which they would implement water saving measures in these categories. Table 8.38 illustrates the results of this exercise in the order in which participants would begin to implement water saving measures if required to abide by city water rationing.

Outdoor water use is marginal relative to indoor water use among residential focus group participants. With the exception of foundation watering, which all residential participants are reluctant to cease because of the risk of long-term structural home damage, residents would prefer to limit all outdoor water consumption before limiting indoor water consumption.

Residents report greater willingness to reduce water use for a variety of purposes than to cease water use for selected purposes in the short term. The hierarchy of water-saving preferences in Table 8.34 does not imply that residents would first cease all car-washing, then cease all lawn watering, and so on in response to water rationing. Instead, residents would limit use in the first category, car washing, to the extent that it was convenient and cost-effective for them to do so before implementing water saving measures in lawn watering. Similarly, they would limit lawn-watering to household limits of cost, convenience, and other factors before limiting outdoor plant watering.

Water saving measures listed in Table 8.39 demonstrate marginality of household water uses in greater detail. Survey question 40 asked residents to identify measures they would implement in response to water rationing other than those already implemented. Responses therefore incorporate participants' current compliance with mandatory outdoor watering restrictions and their implementation of outdoor water saving measures beyond what is required by condition 2. This is reflected in the presence of a number of indoor water saving measures near the top of the list.

When residential customers were asked to choose between specific water saving measures, their preferences described a different hierarchy of water-saving preferences than those described in Table 8.38. Many factors might contribute to this difference. First, only 9 of 26 survey respondents participated in focus groups. When the surveys answered by focus group participants are analyzed separately, water saving preferences expressed in Question 40 resemble more closely the list in Table 8.38. In addition, question 40 asked respondents to identify the water saving measures that they would prefer to implement beyond what they are already doing. In the focus group water-saving preferences exercise, participants did not distinguish between measures that they have implemented and measures that they have not.

The results listed in Table 8.39 do, however, have an important feature in common with those listed in Table 8.38. Again, residents report a preference to reduce water use across a variety of household activities rather than ceasing water use in selected activities. In addition to the mandatory and voluntary measures to reduce water use they have already implemented, for example, households' first five preferred water-saving alternatives represent one outdoor measure, one indoor measure each in kitchens, bathrooms, and laundry rooms, and one indoor/outdoor measure. Residents' preference for incrementalism in water restrictions poses a challenge to the design of specific water restrictions like those of drought condition 2. City plans for condition 3 rationing, in contrast, are structured to take advantage of marginal uses of water in Corpus Christi households. Condition 3 restrictions will allow residents to make incremental water use decisions as long as the sum total of their water saving measures brings their water use to a point at or below their household allocation.

Focus Group and Survey Results: Attitudes toward the Water Shortage and Water Supply Policies

Focus group and survey research assessed residential and commercial/industrial customer attitudes toward water savings and city water policies. This section presents separate analysis of residential and commercial/industrial responses and addresses knowledge and perceptions of the water shortage, attitudes toward mandatory and voluntary water savings, opinions about how the city has handled the water shortage, and long-term water supply preferences.

Residential Customers

As discussed earlier, one obstacle to increased voluntary household water savings is lack of knowledge about water use and how to measure it. For example, many residential customers do not know how much water they use each month, and few can accurately estimate the price of water. This conclusion is based on one survey question that asked participants to estimate residential water rates. Eight respondents completed the question, and few chose the option closest to the actual price of any water increment. Residents' perceptions about their own water use may be influenced by incomplete understanding of how to monitor it. In addition, residents' perceptions about city water shortage issues may be based on incomplete information.

Knowledge and Perceptions of the Water Shortage

Focus group participants consistently rank the water shortage among the most important city concerns. Many focus group participants maintained that a solution to the water shortage should be the city's highest priority. Table 8.40 lists responses to survey question 24, which assessed customers' interest in the water shortage and related issues.

Residential customers report paying close attention to news of the current water shortage. Water quality problems associated with the drop in reservoir levels have focused increased residential concern on the water issue.

Residents demonstrate reasonable perceptions of the causes and severity of the water shortage. When asked to identify what they perceive to be the primary cause of the water shortage, a majority of residents chose "high evaporation combined with lack of rainfall to the city's reservoirs" (Table 8.41). Freshwater inflow requirements to bays and estuaries generate political interest and strong opinions in Corpus Christi. This may explain why many residents also identified freshwater releases as a primary cause of the shortage.

Survey questions also assessed residents' perceptions of the severity of the water shortage. Survey question 37 asked respondents to estimate when the city would begin condition 3 water rationing. Eighty-one percent estimated that water rationing would begin one to three months from the date of the survey. In July 1996, the city anticipated entering condition 3 around November 1, 1996, approximately four months from when surveys were completed. Residents are aware of the severity of the water shortage.

Residents accurately estimated the ability of the present level of water supplies to sustain water demand. Survey question 38 asked residents to estimate the period of time that water supplies remaining in the reservoirs would sustain residents and businesses under current rates of water use and reservoir recharge. One half of respondents recorded an estimate. All but two of these estimates ranged between six and 18 months, not far from the city's July 1996 estimate of 12 to 15 months.

Survey question 36 asked residents how long it had been since reservoirs were at 50 percent of total capacity. Seventy-seven percent of residential participants estimated that city reservoirs were at one half of total capacity sometime between July 1994 and July 1995. Total reservoir capacity reached 50 percent in August 1995. Residents underestimated the speed of past reservoir decline.

Attitudes Toward Mandatory and Voluntary Water Savings

Residents express positive attitudes toward mandatory and voluntary household water saving measures in conditions 1 and 2. Residents reported willingly implementing household water saving measures in conditions 1 and 2 as part of the citywide drought management effort. Both residential focus groups discussed potential negative impacts of Corpus Christi water quality and quantity problems on the economy and feared the water shortage might drive some industries and residents out of the city altogether. These concerns appeared to reinforce their willingness to implement water saving efforts under conditions 1 and 2. Residents expressed frustration with neighbors who might not be complying with condition 2 outdoor watering restrictions.

Most residents perceive current plans for household water rationing under condition 3 to be adequately restrictive, but not timely. Focus group moderators described city plans for residential water allocation under drought condition 3 and solicited participants' opinions.

Most residents reported that condition 3 water rationing appeared to be adequately restrictive and that most households would be able to comply if they ceased landscape watering and practiced basic indoor water conservation. Some expressed concern that larger households would have more difficulty complying with established limits than smaller households. As Table 8.42 demonstrates, 56 percent of survey respondents felt household water rationing under condition 3 should be implemented either as planned or in a more restrictive manner than planned.

Residential participants' chief objection to condition 3 allocation was that it might not be timely. Focus group participants felt that, at the time of the survey, condition 3 trigger levels (11 percent of combined reservoir capacity) and start dates were not pro-active enough. Table 69 lists responses to survey Question 35, which gauged residential participants' attitudes toward the original policy. Sixty-five percent of respondents felt the city should implement household allocation sooner than provided for by the drought contingency plan.

Most residents perceive condition 3 household water rationing to be fair, provided it is adequately enforced. As Table 8.44 indicates, 50 percent of residential participants feel that condition 3 household water allocation will result in a fair distribution of water among city residents. Only 35 percent disagreed with the statement. Focus group participants report condition 3 household water allocation might be unfair if the city does not enforce prescribed penalties, including surcharges and removal from the system.

Residential perceptions about the fairness of condition 3 rationing are influenced by perceptions of business and industry efforts to reduce water use. Residents perceive that Corpus Christi business and industry should be required to conserve in at least equal measure to households. Residential participants report willingness to contribute proportionally to citywide saving efforts. In addition, some residents who incorrectly believed the city would not ration water to business and industry under condition 3, perceived that households were being asked to shoulder too much of the burden of saving water. As illustrated in Table 8.45, 84 percent of residential participants would object to residential water rationing under condition 3 without comparable limits on commercial/industrial water use.

Residents see a larger role for voluntary reductions in water use as opposed to mandatory restrictions on water use in long-term city water conservation plans. Residential participants feel that households should practice conservative water use beyond the water shortage. Residents stop short, however, of identifying mandatory drought management practices that should be kept in place on a permanent basis. Focus group participants agreed that the severity of the current water shortage has focused attention on the semi-arid climate in Corpus Christi and that they would continue to use drought-tolerant landscaping where feasible beyond the water shortage. They also agreed that households should continue to avoid indoor and outdoor water waste. Otherwise, most residential participants look forward to returning to "normal" water use when the water shortage passes.

City Management of the Water Shortage

Many residents are unfamiliar with the city's four-stage drought contingency plan. Survey results listed in Table 8.46 indicate that while 58 percent of residential participants are familiar with the drought contingency plan, 42 percent are not. Moderators reviewed basic components of the plan's four drought conditions at all residential focus group meetings. Focus group results may therefore reflect a better understanding of the plan than do survey results, which captured participants' impressions prior to the first focus group sessions.

Residents are divided over the city's ability to plan a solution to the current water shortage. Table 8.47 lists responses to survey question 22, which gauged residents' confidence in the city's ability to plan a solution to the current water shortage. The results of this question are complicated by the fact that many residential participants are not well informed about the drought contingency plan and long-term city water conservation planning.

In focus group discussions, residents expressed less confidence in the city's ability to achieve long-term than short-term water savings. Most residential participants report that they initially assumed that the water shortage would end before mandatory restrictions or shortly thereafter, as occurred in the 1984-1985 shortage. As the water shortage intensified, residents expressed resentment that the city had not acquired a large enough long-term water supply to avert the current crisis. Residents seem generally unaware of city participation in the Trans-Texas Water Study and other long-term planning efforts.

Residents would like the city to provide information on long-term water conservation and water policy on an ongoing basis. Focus group discussions indicate that if household water conservation is to be part of a long-term strategy, the city should promote the benefits to residential customers on an ongoing basis. Participants expressed interest in receiving information about monitoring and reducing household water use, as well as information on reservoir levels, long-term water supply options and other city policies, relative water use of residential and commercial/industrial customers, and conservation efforts of major industries. They also suggested that information would be more accessible and useful if it were available through utility bill inserts and the public school system than if it were available only through local media.

Long-Term Water Supply Preferences

Residents report the need for more information to identify preferred long-term water supply alternatives. Table 8.48 lists survey respondents' long-term water supply preferences. Desalination of seawater is the most common preference expressed by residential participants. However, results are complicated by the fact that residents are not well informed about long-term supply options. Focus group participants expressed a desire for information about feasibility, cost, and timelines of long-term water supply options. For example, in most focus group discussions, participants knowledgeable about the costs and by-products of desalination convinced others that it was not the best option. This is not reflected in survey results.

Residents prefer a strictly proportional distribution of costs for long-term water supply solutions among water customers. Focus group discussions indicate that residents are willing to bear a share of costs for long-term water supply solutions. Although residential customers do not want higher water costs to drive business and industry out of Corpus Christi, they expect commercial/industrial customers to pay for long-term solutions in proportion to their total city water use. Participants were not given a set of cost allocation scenarios from which to choose and did not discuss proportionality based on use of water produced by potential projects, willingness to pay, or any other factor.

Residents appear less willing to share the costs of long-term water supply solutions when responding to a specific cost scenario. In order to better assess residents' willingness to share the costs of long-term water supply solutions, survey question 42 asked respondents to react to a series of hypothetical water rate increases to support the construction of one long-term supply alternative, the Lake Texana pipeline. As Table 8.49 demonstrates, residents may be substantially less willing to pay for a long-term water supply than focus group discussions indicate. The five options represent 0 percent, 25 percent, 50 percent, 100 percent, and 150 percent increases in residential water rates. Seventy-seven percent of respondents would support construction of the pipeline with no increase in water rates. Less than one half of respondents would support a 25 percent water rate increase. Only 12 percent of residential survey respondents would support a 50 percent water rate increase to contribute to the costs of the pipeline.

It is unclear whether attitudes measured in question 42 are transferable to other long-term water supply options, or whether they are specific to the pipeline. For example, some residents may object to the pipeline for reasons other than cost. Eight percent of respondents would not support the pipeline even if it could be constructed with no increase in water rates.

Commercial/Industrial Customers

Knowledge and Perceptions of the Water Shortage

Commercial/industrial participants demonstrated greater knowledge about the causes and severity of the water shortage than did residential participants. One possible reason is that some of these participants have incorporated the needs of water conservation and information about the reliability of water supplies into the corporate decision process.

Most commercial/industrial customers are well informed about the causes and severity of the water shortage. Table 8.50 lists responses to survey question 21, which asked respondents to identify what they perceived to be the primary cause of the water shortage. Most participants chose "high evaporation combined with lack of rainfall to the city's reservoirs." As among residential participants, respondents perceived freshwater releases to bays and estuaries to be another primary cause of the drought.

Commercial/industrial customers accurately estimated the ability of the present level of water supplies to sustain water demand. One survey question asked respondents to estimate the period of time that current reservoir supply would last at current rates of use and recharge. Seventy-one percent of participants answered the question. The average answer was 17 months, compared to the city estimate at the time of 12 to 15 months. Only seven respondents recorded answers that did not fall between 12 and 24 months.

Participants also accurately estimated the speed of past reservoir decline. When asked to estimate the period of time since reservoir levels were at 50 percent of total capacity, 93 percent of survey respondents answered the question. Of those, 84 percent recorded an estimate within six months of the approximate answer of one year.

Attitudes toward Mandatory and Voluntary Water Conservation

Commercial/industrial attitudes toward mandatory and voluntary water conservation are shaped by firm-level economic effects of conservation measures. Most focus group participants expressed support for citywide conservation and understood the need for commercial/industrial water conservation. However, individual attitudes about specific mandatory and voluntary restrictions to achieve short-term water savings can be attributed to the relative costs and benefits to commercial/industrial customers. Most commercial/industrial participants did not object to mandatory condition 2 water restrictions because these apply to non-production related water uses. Similarly, major industries did not raise objections to city requests for voluntary 10 to 15 percent water use reduction because these organizations were able to make individually cost-effective conservation decisions in response to the request.

Attitudes about water rationing under condition 3 are mixed. Organizations that foresee cost-effective compliance with water rationing report fewer objections. Some commercial and industrial sectors that anticipate a disproportionate condition 3 impact compared to other sectors have communicated their concerns through city committees.

Most commercial/industrial participants report that condition 3 and 4 mandatory water saving measures should be implemented as planned or in a manner less restrictive than planned. The city has changed its plans for water rationing in conditions 3 and 4 since the surveys were designed and completed, so rationing scenarios presented in some survey questions differ from current city plans. For example, the rationing scenario in survey question 27, described in Table 8.51, is somewhat different from current city plans. Nevertheless, it is useful to analyze answers to question 27 because these demonstrate a trend that appeared in focus group discussions. Commercial/industrial participants generally prefer that the city follow through with ordinances, public statements, and other prior communications. Many commercial and industrial organizations have already made decisions about production, employment, and capital investment based on early plans for conditions 3 and 4. Although most would not object to enactment of measures less restrictive than anticipated, commercial/industrial participants express a strong preference for consistency in city policy and communication.

Commercial/industrial customers see a role for voluntary conservation but not mandatory restrictions on how water is used in long-term city water conservation plans. While commercial/industrial participants generally support ongoing voluntary water conservation, they would not support maintenance of mandatory restrictions beyond the end of this water shortage. Some representatives of larger industries suggested that prices rather than ordinances provide a better incentive to save water. If conservation is to become a permanent part of city water policy, water prices could be a more effective tool than other forms of regulation. Commercial/industrial participants suggested that voluntary conservation can be encouraged in other ways, as well. For example, representatives of the landscaping industry suggested that the city start a certification program for water-wise landscaping. Other participants suggested that the city distribute retrofit kits along with recycling bins for new homeowners.

Attitudes toward City Management of the Water Shortage

Most commercial/industrial customers are familiar with the city's drought contingency plan. Table 8.52 lists responses to a survey question that gauged commercial/industrial familiarity with the drought contingency plan. Most focus group participants were knowledgeable about the four drought conditions and reported preparing in advance for anticipated mandatory water restrictions.

Commercial/industrial participants express confidence in the city's ability to plan a solution to the current water shortage. As Table 8.53 illustrates, 64 percent of commercial/industrial participants agree or strongly agree that the city is capable of planning a solution to the current water shortage.

Commercial/industrial participants identify consistent policy and enforcement as important elements of the city's drought management program. Focus group discussions indicate that commercial/industrial participants expect consistency in two aspects of city drought responses: policy and enforcement. Policies, especially mandatory water restrictions, should be consistent with city ordinances, findings of committees established to provide public input, and expectations expressed to commercial/industrial organizations by city staff. For example, many commercial/industrial participants, especially larger industries, have reported problems in implementing their plans to save water that seem to result from the fluctuation of city policies. Early clarification of condition 3 water rationing levels and the baseline from which individual rations will be calculated could have been beneficial in this regard.

In addition, many commercial/industrial participants perceive that any failure to enforce condition 2 lawn-watering restrictions might send a mixed message to commercial/industrial organizations anticipating restrictions in condition 3.

Participants report a need to improve the two-way flow of information between the city and commercial/industrial interests. Commercial/industrial participants are generally satisfied with the role of city committees as channels for the flow of information about the water shortage and city policies. Some participants maintain that their satisfaction with city management of the water shortage will be directly related to the city's incorporation of committee findings and suggestions into drought management policy, especially condition 3 restrictions. They will be satisfied with city management of condition 3, for example, if Council implements Water Conservation Advisory Committee suggestions about commercial/industrial water rationing. Regarding the flow of information from the city to commercial/industrial interests, participants expressed a desire for the city to speak with one voice, especially about mandatory restrictions.

Participants suggest that city water conservation policies should incorporate incentives to save water in advance of mandatory restrictions. Commercial/industrial participants report that condition 3 restrictions should reward organizations that have successfully implemented measures to reduce water use. For example, recent water savings from voluntary water saving efforts could count toward customer-level compliance with condition 3 water rationing. Firms could receive credit for reducing water use as much as months or years in advance of mandatory water restrictions. Commercial/industrial participants that report reducing water consumption on an ongoing basis express concern that drought management policy is not structured to reward this effort. Implementation of an allocation plan that does not reward this kind of proactive water conservation could provide a disincentive for water conservation in the future.

Long-Term Water Supply Preferences

Commercial/industrial participants report that preferences regarding long-term water supply options are based chiefly on the cost of water produced. Table 8.54 lists responses to survey question 22, which gauged the long-term water supply preferences of commercial/industrial participants. Many respondents marked more than one choice, and focus group discussions reinforced participants' reluctance to support one long-term option over all others. Most participants maintained that, given enough information on the costs of each option, they would choose the option that produced additional water supplies at the lowest cost per thousand gallons. Larger industries report a strong preference for the cost-effectiveness of the Lake Texana pipeline in focus group discussions. Most participants perceive that the city will need to investigate a number of the options listed in Table 8.54 in order to provide for current and future commercial/industrial water needs.

Most commercial/industrial participants would prefer that the cost of long-term water supply options be distributed in proportion to total water use. Focus group discussions indicate that commercial/industrial organizations prefer the costs of long-term water supplies to be distributed proportionally among all water users. Some participants suggested that new connections should be charged at higher rates than existing connections, perhaps in the form of higher connection fees. Commercial/industrial focus group participants did not choose from a given set of cost allocation scenarios and did not discuss proportionality based on use of water produced by potential projects, willingness to pay, or any other factor.

Table 8.1
Focus Group Composition and Meeting Dates

Focus Group	Meeting Dates	Number of Participants	Number of Organizations
Residential customers	July 17, August 14	5	4
Residential customers	July 18, August 14	4	2
Landscape/nursery	July 24, August 21	10	8
Tourism/hotel	July 25, August 22	5	5
Government/schools	July 31, August 28	10	7
Manufacturing/other commercial	August 1, August 29	13	9
Petrochemical/ship channel	August 7, September 4	17	12
Military	August 8, September 5	8	2
Local government	July 25	8	8
State government	August 12	7	5

Note: For residential groups, "organizations" are neighborhood associations.

Table 8.2
Main Issues Addressed by Residential and Commercial/industrial Focus Groups

Residential Focus Groups

- Effects of voluntary and involuntary drought responses on patterns of household water use
- Marginal uses of water and preferred drought management alternatives
- Perceptions of the drought and necessity of drought management
- Attitudes toward city drought management policies and policy options

Commercial/Industrial Focus Groups

- Effects of voluntary and involuntary drought responses on patterns of production and non-production water use
- Economic indicators of the impact of the water shortage and restrictions on businesses and industries
- Substitution and production effects of the water shortage
- Attitudes toward city drought management policies and policy options

Table 8.3
Commercial/Industrial Survey Responses: Question 1

Question: Below is a list of production related water conservation efforts. Please identify those efforts that your organization has implemented SINCE April 1996 or in response to warnings of water shortage by placing check marks in the appropriate spaces. (The city of Corpus Christi declared drought condition 1 on April 9.)

Drought Management Measure	Percent of Respondents
Increased systematic leak inspection	54
Altered process without capital investment	49
Started or expanded water re-capture and reuse	44
Established stricter time limits on water in production process	44
Established stricter volume limits on water in production process	39
Purchased/installed new water saving equipment	24
Increased use of labor	20
Decreased production	17
Other	17
Started or increased use of lower quality water	12
None of the above	0

Table 8.4
Commercial/Industrial Survey Responses: Question 2

Question: Please identify those non-production related water conservation efforts listed below that your organization has adopted to save water SINCE April 9, 1996 or in response to warnings of water shortage. Please check all that apply.

Drought Management Measure	Percent of Respondents
Ceased or reduced washing of buildings, sidewalks, and other structures	68
Ceased or reduced landscape watering to a level lower than city restrictions require	66
Formally encouraged employees to conserve water at all times	63
Reduced or ceased washing of company vehicles	51
Replaced existing faucets with water saving faucets in rest rooms/kitchens	17
Other	15
Reduced the level of water in existing toilets	12
Reduced janitorial water use	5
Replaced existing toilets with water saving toilets	5
None of the above	0

Table 8.5
Commercial/Industrial Survey Responses: Question 12

Question: How does your organization's water use this July compare to its water use last July?

Answer	Percent of Respondents
We are using less water this July than last July	61
We are using about the same amount of water this July as last July	20
We are using more water this July than last July	10
Don't know	7
Business was not located in Corpus Christi last July	2

Table 8.6
Commercial/Industrial Survey Responses: Question 31

Question: Suppose your business is located in the city of San Diego, California. The city of San Diego declares a drought emergency and requires all organizations to cut their water use by at least 25% to avoid paying a substantial fine. Assume that your organization cannot afford to pay the fine. What is the first measure you would recommend that your organization take to comply with the city's demand?

Answer	Percent of Respondents
Reduce production related water use	41
Reduce outdoor nonproduction related water use	17
Develop new water source	5
Reduce indoor non-production related water use	2
Increase water conservation education efforts	2
Did not respond	32

Note: Percentages may not add to 100 percent due to rounding.

Table 8.7
Most Common Obstacles to Commercial/Industrial Water Savings

Question: If you are not taking as many steps to save water as you would like in your business, what is preventing you from doing so?

- High cost of additional water saving measures
- Uncertainty about city water restriction percentage, baseline for reduction
- Lack of information about conservation methods
- Inability to influence customers' water use
- Health and/or safety risk
- Conflicts with federal, state, and local regulatory requirements
- Public objection/resistance
- Low water quality

Table 8.8
Focus Group and Survey Results, Sector-Specific Economic Impact Indicators

Focus Group Question: If you were going to try to put a dollar figure on the impact of the current water shortage and restrictions on your business, where would you look first? What indicators might first register the economic impact of this shortage on your business?

Survey Question #13: What would you consider to be the three best measures of the economic impact of restricted water use on your business?

Commercial/industrial sector	Suggested Indicators
Landscape/Nursery	Total Revenue
	Number of Employees (FTE)
Hotel/Tourism	Hotel Occupancy
	Average Room Rates ($)
Government/Schools	Total Revenue
Manufacturing/Other Commercial Users	Total Revenue
	Number of Employees (FTE)
	Long-term Maintenance Costs
	Capital Expenditures
Petrochemical/Ship Channel	Total Production
	Total Revenue
Military	Capital Expenditures
	Number of Employees (FTE)

Note: Measures of economic impact in the government/schools sector are difficult to identify. Some participating government/school organizations expect to see an impact on total revenue, but this should not be interpreted as a common measure of the water shortage's economic impact in this sector.

Table 8.9
Possible Local and Regional Economic Indicators

- Industrial tax revenue
- Sales tax revenue
- Platting acreage or fees
- Zoning acreage or fees
- New connections to utilities
- New home starts
- Assessed valuation

Table 8.10
Commercial/Industrial Survey Responses: Question 25

Question: Please describe and estimate the fixed cost of any one-time purchases or repairs your organization has made to comply with the current request for voluntary reduction in water use.

Answer	Percent of Respondents
Described and estimated fixed costs	22
Described but was unable to estimate fixed costs	5
Believes there are fixed costs but was unable to describe or estimate them	22
Believes there are no fixed costs	39
Other	2
Did not respond	10

Table 8.11
Commercial/Industrial Survey Responses: Question 26

Question: Please describe and estimate any regular (daily, weekly, monthly) costs, or variable costs, to your organization that can be directly attributed to the current request for voluntary reduction in water use. Do not include any fines for violation of city ordinances related to water use.

Answer	Percent of Respondents
Described and estimated variable costs	20
Described but was unable to estimate variable costs	20
Believes there are variable costs but was unable to describe or estimate them	20
Believes there are no variable costs	29
Other	0
Did not respond	12

Note: Percentages may not add to 100 percent due to rounding.

Table 8.12
Commercial/Industrial Survey Responses: Questions 28-29

Question 28: Assume that the city allocates water to your business as described in the drought contingency plan. Please describe any effects you may anticipate in terms of a change in sales revenue.

Question 29: Assume that the city allocates water to your business as described in the drought contingency plan. Please describe any effects you may anticipate in terms of a change in employment.

Commercial/Industrial Sector	Percent of Participants Responding	Average Anticipated Change in Sales Revenue	Percent of Participants Responding	Average Anticipated Change in Employment
Landscape/Nursery	56	-66	56	-57
Hotel/Tourism	100	-18	0	n/a
Government/Schools	0	n/a	0	n/a
Other Commercial/Manufacturing	60	-20	33	-25
Petrochemical/Ship Channel	45	-22	27	-13
Military	100	-15	50	-25

Table 8.13
Anticipated Economic Impact of Water Rationing, Board of Trade Members

Economic Indicator	Effect of 15% Reduction ($ million)	Effect of 24% Reduction ($ million)
Operating costs	1.85	8.46
Capital project costs	2.09	11.20
Throughput reduction costs (lost profit)	6.50	142.40

Note: Operating costs are yearly costs at 15 and 25 percent reductions in water use.

Source: Board of Trade Technical Committee, Presentation to Water Conservation Advisory Committee, Corpus Christi, Texas, August 21, 1996.

Table 8.14
Commercial/Industrial Survey Responses: Question 18

Question: Please indicate whether you agree or disagree with the following statement: Over the long-term, the risk of drought is not high enough to justify the cost of investments in equipment and/or practices to reduce water use in our organization.

Answer	Percent of Respondents
Disagree strongly	17
Disagree	51
Agree	20
Agree strongly	0
Don't know	5
Did not respond	7

Table 8.15
Commercial/Industrial Survey Responses: Question 16

Question: Has the risk of water shortage been a factor in your company's decisions to expand operations in areas supplied with water from Corpus Christi's reservoirs?

Answer	Percent of Respondents
Yes	24
No	59
Don't know	12
Did not respond	7

Table 8.16
Commercial/Industrial Survey Responses: Questions 33-37

Question: Please indicate whether you agree or disagree with the following statements.

33. The availability of water influences the decisions of new businesses to locate in Corpus Christi.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	0
Agree	39
Agree strongly	46
Don't know	0
Did not respond	15

34. The reliability of the Corpus Christi water supply could prevent the expansion of existing city businesses.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	0
Agree	41
Agree strongly	44
Don't know	0
Did not respond	15

35. Employment in Corpus Christi will be affected by the drought restrictions.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	2
Agree	41
Agree strongly	37
Don't know	5
Did not respond	15

36. The water shortage could contribute to a decrease in tourism this season.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	34
Agree	32
Agree strongly	17
Don't know	2
Did not respond	15

37. The value of land and homes in Corpus Christi could erode if more reliable water supplies cannot be acquired.

Answer	Percent of Respondents
Disagree strongly	2
Disagree	5
Agree	51
Agree strongly	27
Don't know	0
Did not respond	15

Table 8.17
Topics Addressed in Board of Trade Interviews

- Voluntary water saving measures implemented in response to current water shortage
- Total fixed and monthly costs of organization's response to current water shortage
- Water conservation investments made since last water shortage (1984-1985)
- Conservation measures planned in anticipation of drought condition 3 water restrictions
- Anticipated costs of compliance with potential water restrictions
- Role of potential noncompliance surcharges in economic water conservation decisions
- Effects of long-term risk of water shortage on ability to compete with other firms and other facilities within same firm

Table 8.18
Company A: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly Cost	Estimated Water Savings (gpm)
Implemented discretionary reduction	n/a	n/a	n/a
Recycled RO reject to cooling towers	$50,000	0	300
Recycled cooling tower blowdown to firewater	$65,000	0	150
Other	$35,000	0	n/a
Total	**$150,000**	**0**	**450**

Table 8.19
Company A: Water Saving Measures Implemented Since 1984-1985

Measure	Cost	Estimated Water Savings (gpm)
Installed RO for boiler feedwater treatment	$4,000,000	n/a
Total	**$4,000,000**	**n/a**

Table 8.20
Company B: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly cost	Estimated Water Savings (gpm)
Cycled up desalter water	n/a	n/a	n/a
Increased water recycling	n/a	n/a	n/a
Completed detailed water balance	n/a	n/a	n/a
Revamped condensate return	n/a	n/a	n/a
Total	**n/a**	**n/a**	**n/a**

Table 8.21
Company B: Water Saving Measures Implemented Since 1994-1995

Measure	Cost	Estimated Water Savings (gpm)
Increased cycles in cooling towers	n/a	n/a
Replaced water cooling with air cooling where possible	n/a	n/a
Added new RO and softener for boiler feedwater	n/a	n/a
Upgraded wastewater treatment plant	n/a	n/a
Total	**n/a**	**n/a**

Table 8.22
Company C: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly Cost	Estimated Water Savings (gpm)
Recycled cooling tower blowdown to firewater	$100,000	n/a	50
Leased EDR unit for cooling tower blowdown	$60,000	$27,000	150
Recycled scrubber water	$50,000	n/a	100
Installed RO unit for demineralizer return	$3,000,000	$75,000	325
Re-routed wash water within refinery	$75,000	n/a	75
Other	$50,000	n/a	50
Total	**$3,335,000**	**$102,000**	**750**

Table 8.23
Company C: Water Saving Measures Implemented Since 1984-1985

Measure	Cost	Estimated Water Savings (gpm)
Recycled stripped sour water	n/a	450
Maximized condensate recovery	n/a	n/a
Recycled blowdown to cooling tower makeup	n/a	100
Re-used oily condensate as desalter wash water	n/a	n/a
Optimized demineralizer trains	n/a	n/a
Installed air coolers where economically practical	n/a	n/a
Installed new scrubber	n/a	32
Total	**n/a**	**582**

Table 8.24
Company D: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly Cost	Estimated Water Savings (gpm)
Recycled treated wastewater to cooling towers	0	0	300
Installed RO unit for demineralizer	$800,000	$30,000	200
Installed RO unit for cooling tower blowdown	$300,000	$70,000	325
Accelerated schedule for plant turnaround	0	0	n/a
Total	**$1,100,000**	**$100,000**	**825**

Table 8.25
Company D: Water Saving Measures Implemented Since 1984-1985

Measure	Cost	Estimated Water Savings (gpm)
Reduced caustic soda usage for acid gas scrubbing	n/a	n/a
Reduced water use in decoke process	n/a	n/a
Implemented condensate recovery projects	n/a	n/a
Total	**n/a**	**n/a**

Table 8.26
Company E: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly Cost	Estimated Water Savings (gpm)
Cycled up five cooling towers	n/a	n/a	n/a
Recycled effluent to firewater	$252,600	0	n/a
Re-used tank testing waters	0	n/a	n/a
Check water, steam, condensate leaks weekly	0	0	n/a
Total	**$252,600**	**$102,000**	n/a

Table 8.27
Company E: Water Saving Measures Implemented Since 1984-1985

Measure	Cost	Estimated Water Savings (gpm)
Implemented condensate recovery projects	n/a	n/a
Total	**n/a**	**n/a**

Table 8.28
Company F: Water Saving Measures Started or Implemented April-August 1996

Measure	Fixed Cost	Monthly Cost	Estimated Water Savings (gpm)
Increased cycles on cooling towers	0	$400	71
Recycled cooling tower blowdown	0	0	n/a
Installed new controls on demineralizer	$70,000	0	1
Began lubricating pumps with seawater	$8,500	0	20
Total	**$78,500**	**$400**	192

Table 8.29
Company F: Water Saving Measures Implemented Since 1984-1985

Measure	Cost	Estimated Water Savings (gpm)
Installed equipment to recycle cooling tower blowdown	n/a	n/a
Added control valves to cooling tower blowdown	$20,000	n/a
Added two RO units on boiler makeup	$200,000	5
Total	**$220,000**	5

Table 8.30
Residential Water Allocation Plan, Drought Condition 3

Number of Residents in Household	Maximum Monthly Water Allowance (gallons)
1-2	6,000
3-4	7,000
5-6	8,000
7-8	9,000
9-10	10,000
11 or more	12,000

Table 8.31
Residential Survey Responses: Question 31

Question: Please indicate whether you agree or disagree with the following statement: My household can easily manage with the water allowance prescribed for drought condition 3 under the drought management plan.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	31
Agree	50
Agree strongly	4
Don't know	12
Did not respond	4

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.32
Residential Survey Responses: Question 32

Question: Please indicate whether you agree or disagree with the following statement: I anticipate that monthly expenses in my household will increase if the city decides to limit household water use as planned under drought condition 3.

Answer	Percent of Respondents
Disagree strongly	8
Disagree	35
Agree	42
Agree strongly	4
Don't know	12
Did not respond	4

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.33
Residential Surcharge Plan, Drought Condition 3

Gallons over monthly water allocation	Surcharge
First 1,000	$3.00
Second 1,000	$5.00
Third 1,000	$10.00
Each additional 1,000	$25.00

Table 8.34
Residential Survey Responses: Question 39

Question: Please indicate whether you agree or disagree with the following statement: The surcharge described above provides little or no incentive for most people to reduce water consumption by changing patterns of water use or replacing existing equipment with water saving equipment.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	42
Agree	31
Agree strongly	15
Don't know	8
Did not respond	4

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.35
Residential Survey Responses: Question 1

Question: Please identify those water conservation efforts listed below that your household has adopted to save water SINCE April 9, 1996 or in response to warnings of water shortage. (The city of Corpus Christi declared drought condition 1 on April 9 and instituted mandatory water conservation efforts on May 6, 1996.) Please check all that apply.

Drought Management Measure	Percent of Respondents
Ceased or reduced lawn watering to a level lower than city restrictions require	65
Repaired leaky faucets	62
Reduced/ceased use of dishwasher	62
Avoid flushing toilet as much as possible	54
Reduced use of washing machine	50
Reduced/ceased use of garbage disposal	50
Replaced existing shower head with water saving shower head	42
Adopted strict limits on showering time	38
Reduced the level of water in existing toilets	31
Began a household water reuse program	31
Replaced existing faucets with water saving faucets in kitchen/bathroom sinks	19
Ceased indoor and outdoor plant watering (other than lawns)	15
Other	15
Replaced existing toilet with water saving toilet	8
None of the above	4

Table 8.36
Residential Survey Responses: Question 16

Question: How does your water use this July compare to your water use last July?

Answer	Percent of Respondents
We are using less water this July than last July	62
We are using about the same amount of water this July as last July	15
We are using more water this July than last July	8
Don't know	4
Did not respond	12

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.37
Residential Survey Responses: Question 27

Question: Which is closest to your view? Current restrictions on water use under drought condition 2:

Answer	Percent of Respondents
Are both an inconvenience and a cost	19
Are more of an inconvenience than a cost	35
Are more of a cost than an inconvenience	4
Are neither an inconvenience nor a cost	35
Did not respond	8

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.38
Hierarchy of Residential Water Saving Preferences

1. Car washing
2. Lawn watering
3. Outdoor plant watering
4. Tree watering
5. Laundry water use
6. Bathroom water use
7. Kitchen water use
8. Foundation watering

Table 8.39
Residential Survey Responses: Question 40

Question: Pretend for a moment that you live in San Diego, California, and that the city of San Diego has rationed water use in each household and adopted a mandatory $1,000 fine for the first violation and for each violation thereafter. In column B, indicate which four of the practices listed below you would implement first to live within your water ration. Mark exactly four. None of the items below are required by the drought management plan. Do not mark in column B any of the measures that your household has already implemented.

Drought Management Measure	Percent of Respondents
Cease lawn watering	46
Reduce/cease use of dishwasher	38
Adopt strict limits on showering time	35
Begin a household water reuse program	35
Reduce use of washing machine	27
Repair leaky faucets	27
Reduce/cease use of garbage disposal	23
Replace existing toilet with water saving toilet	19
Avoid flushing toilet as much as possible	19
Cease indoor and outdoor plant watering (other than lawns)	19
Reduce the level of water in existing toilets	15
Replace existing faucets with water saving faucets in kitchen/bathroom sinks	12
Replace existing shower head with water saving shower head	8
None of the above	0
No response	15
Marked less than four options	8

Table 8.40
Residential Survey Responses: Question 24

Question: Please indicate whether you agree or disagree with the following statement: I read all the information I can find about current events surrounding the city's water management program and the current water shortage.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	27
Agree	62
Agree strongly	12
Don't know	0
Did not respond	0

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.41
Residential Survey Responses: Question 25

Question: The present water shortage is PRIMARILY a result of (please choose **one**):

Answer	Percent of Respondents
High evaporation combined with lack of rainfall to the city's reservoirs	57
Overuse of city water by residential customers	3
Overuse of city water by industrial customers	6
Inadequate management of the city's reservoirs	9
Freshwater inflow requirements to bays and estuaries	17
Other	9
Don't know	0
Did not respond	0

Note: Percentages may not add to 100 percent due to rounding. Percent of responses is listed rather than percent of respondents because six respondents marked more than one answer.

Table 8.42
Residential Survey Responses: Question 30

Question: Water rationing will begin when the city of Corpus Christi moves from drought condition 2 to drought condition 3. The plan allows each household to use a limited amount of water each month. In the first stages of drought condition 3, households will pay a surcharge for water use that exceeds their water allowance. What is closest to your view of how the city should act? (A table of monthly household limits was provided in the survey.)

Answer	Percent of Respondents
The city should not implement a water rationing program under drought condition 3	11
The city should implement a water rationing program less restrictive than the current plan under drought condition 3	30
The city should implement the water rationing program as planned under drought condition 3	52
The city should implement a water rationing program more restrictive than the current plan under drought condition 3	4
Did not respond	4

Note: Percentages may not add up to 100 percent due to rounding. One respondent included in "did not respond" marked more than one choice.

Table 8.43
Residential Survey Responses: Question 35

Question: The current drought management plan requires the city to limit household water use as described in Question 30 when the combined volume of the reservoirs is 11 percent of total capacity. Please indicate which of the following policies most closely represents your view of how the city should act.

Answer	Percent of Respondents
Limit household use as soon as possible	38
Limit household water use when reservoirs are 20 percent of total capacity	27
Limit household water use when reservoirs are 11 percent of total capacity	31
Wait even longer to limit household water use	4
Did not respond	0

Table 8.44
Residential Survey Responses: Question 33

Question: Please indicate whether you agree or disagree with the following statement: The system that will be used to ration water among residential customers in drought condition 3 (described in Question 30) results in a fair distribution of water among city residents.

Answer	Percent of Respondents
Disagree strongly	0
Disagree	35
Agree	46
Agree strongly	4
Don't know	15
Did not respond	0

Table 8.45
Residential Survey Responses: Question 34

Question: Please indicate whether you agree or disagree with the following statement: The city should limit water use among residential customers first before limiting water use among businesses and commercial interests.

Answer	Percent of Respondents
Disagree strongly	42
Disagree	42
Agree	12
Agree strongly	4
Don't know	0
Did not respond	0

Table 8.46
Residential Survey Responses: Question 20

Question: Are you familiar with drought conditions 1-4 of the city's drought management plan?

Answer	Percent of Respondents
Yes	58
No	42
Did not respond	0

Table 8.47
Residential Survey Responses: Question 22

Question: Please indicate whether you agree or disagree with the following statement: The city is capable of planning a solution to the current water shortage.

Answer	Percent of Respondents
Disagree strongly	4
Disagree	38
Agree	38
Agree strongly	19
Don't know	0
Did not respond	0

Note: Percentages may not add up to 100 percent due to rounding.

Table 8.48
Residential Survey Responses: Question 26

Question: Which alternative do you consider to be the BEST method of producing increased water supplies to the city of Corpus Christi? (Please choose **one**.)

Answer	Percent of Respondents
Increased water conservation by city residents	0
Increased water conservation by industry and businesses	0
Construction of pipeline to city from Lake Texana	19
Desalination of seawater	38
Exploration of local groundwater options	0
Modified operation of city reservoirs	0
Other	12
Don't know	8
Marked a combination of choices	23
Did not respond	0

Table 8.49
Residential Survey Responses: Question 42

Question: Studies show that the present water shortage could have been avoided if the proposed pipeline from Lake Texana had been completed. It is likely that the proposed pipeline could be approved and built in 18 months. Based on what you know now, please answer each of the following questions.

Would you support construction of the pipeline with no increase in water rates?

Answer	Percent of Respondents
Yes	77
No	8
Don't know	0
Did not respond	15

Would you support a price increase of 44 cents per 1,000 gallons to pay for the pipeline?

Answer	Percent of Respondents
Yes	46
No	23
Don't know	15
Did not respond	15

Would you support a price increase of 87 cents per 1,000 gallons to pay for the pipeline?

Answer	Percent of Respondents
Yes	12
No	46
Don't know	27
Did not respond	15

Would you support a price increase of $1.74 per 1,000 gallons to pay for the pipeline?

Answer	Percent of Respondents
Yes	4
No	65
Don't know	15
Did not respond	15

Would you support a price increase of $2.61 per 1,000 gallons to pay for the pipeline?

Answer	Percent of Respondents
Yes	4
No	77
Don't know	4
Did not respond	15

Table 8.50
Commercial/Industrial Survey Responses: Question 21

Question: The present water shortage is PRIMARILY a result of (please choose **one**):

Answer	Percent of Respondents
High evaporation combined with lack of rainfall to the city's reservoirs	54
Overuse of city water by residential customers	2
Overuse of city water by industrial customers	3
Inadequate management of the city's reservoirs	10
Freshwater inflow requirements to bays and estuaries	24
Other	5
Don't know	0
Did not respond	2

Note: Percent of responses is listed rather than percent of respondents because 11 respondents marked more than one answer.

Table 8.51
Commercial/Industrial Survey Responses: Question 27

Question: If the city reaches drought condition 4, each commercial and industrial customer's water use may be limited to a maximum monthly allowance. Each customer's monthly water allocation could be 75 percent of average monthly water use over the previous 12 months. If the city allocates water, businesses will pay a surcharge for water use that exceeds that allowance. What is closest to your view?

Answer	Percent of Respondents
The city should not implement a water rationing program	2
The city should delay implementation of a water rationing program or implement a program less restrictive than the current plan	32
The city should implement the water rationing program as planned	49
The city should implement a water rationing program as soon as possible or implement a water rationing program more restrictive than the current plan	17
Did not respond	0

Table 8.52
Commercial/Industrial Survey Responses: Question 10

Question: Are you familiar with drought conditions 1-4 of the city's drought management plan?

Answer	Percent of Respondents
Yes	83
No	17
Did not respond	0

Table 8.53
Commercial/Industrial Survey Responses: Question 20

Question: Please indicate whether you agree or disagree with the following statement: The city is capable of planning a solution to the current water shortage.

Answer	Percent of Respondents
Disagree strongly	12
Disagree	15
Agree	54
Agree strongly	10
Don't know	7
Did not respond	2

Table 8.54
Commercial/Industrial Survey Responses: Question 22

Answer	Percent of Respondents
Increased water conservation by city residents	0
Increased water conservation by industry and businesses	2
Construction of pipeline to city from Lake Texana	37
Desalination of seawater	24
Exploration of local groundwater options	7
Modified operation of city reservoirs	2
Other	7
Don't know	0
Marked a combination of choices	20
Did not respond	0

Note: Percentages may not add up to 100 percent due to rounding.

Chapter 9. Topics for Further Study

The conclusions and recommendations presented in this report could be enhanced through further study. For example, the water demand forecasting method presented here could be adapted to better address issues related to policy alternatives. Incorporation of population, housing, and economic variables into the forecasting equation could improve the utility and interpretive power of the analysis. For example, the analysis could incorporate local area economic data such as taxable sales or gross revenue from the Texas State Comptroller of Public Accounts or employment data from the Texas Workforce Commission. Population and housing variables from the U.S. Census might also serve as new explanatory variables.

At a minimum, this water savings analysis should be continued for the duration this water shortage. This analysis evaluates water savings between May and November 1996 only. Aggregate billing data with which to extend the analysis are not yet available. Water savings may show up only gradually as water restrictions go in force and customers adopt new habits or implement new processes. Modifications to the drought management program or analysis of water savings later in the program may show additional water savings. A reformulation of the water demand forecast and the water savings analysis to reflect policy goals other than drought management may also show nonvolumetric drought management effects.

Verification of output effects associated with water rationing could improve the reliability and usefulness of economic impact estimates. This report estimates the income and employment effects of reduced production in Corpus Christi's petrochemical manufacturing industry. It remains to be seen, however, whether condition 3 water rationing will result in reduced production in the petrochemical industry, as forecast, or whether other industries in Corpus Christi experience output effects as a direct result of some form of water rationing. To document the output effects of water rationing, the city could establish a method to collect and aggregate information on firm-level or industry-level production. Verification of output effects could allow more reliable application of an input-output model with which to estimate employment or income effects.

Further study could also assist in assessing the economic cost of water restrictions over the long term. For example, if the city implements condition 3 water rationing, customers may become increasingly aware of the risks of water shortage in Corpus Christi. This may influence expansion decisions and other capital investments. The city could attempt to monitor the effects of condition 3 water rationing on commercial and industrial expansion. Data from Corpus Christi's planning department could assist in this effort. For example, information on the number and kinds of zoning decisions, and the number of applications to rezone for higher intensity use may be useful in this regard. To track changes in industrial expansion plans, the city could work in cooperation with the Greater

Corpus Christi Business Alliance to analyze business recruitment and retention survey results or to expand the scope of that program. The business recruitment and retention survey assesses some effects of water scarcity on some business investment decisions. Estimates of economic cost will be incomplete if these ignore the opportunity cost of foregone commercial and industrial investment. Coupled with reliable estimates of output effects, long-run cost information could provide the city with a better picture of how to efficiently manage drought risks, drought responses, and water supply decisions.

Water savings appeared slowly in 1996. Some study of differences between drought management program implementation during condition 2 in 1996 and during condition 2 in 1984 is warranted. Corpus Christi's drought management program appears to have produced much different results in 1984 than in 1996. What causes lie behind these differences? Further study could identify differences in water restrictions and enforcement or differences in industrial, commercial, or residential water use behavior. For example, Shaw and Maidment (1988) report that condition 2 restrictions in 1984 allowed outdoor watering only once every 10 days. Under condition 2 in 1996, water customers were allowed to water outdoors once every week. Did this contribute to lower measurable water savings in 1996 than in 1984? One focus group participant suggested that water utility customers would not cooperate in 1996 as in 1984 because the city had responded to its success in the earlier period by raising water utility rates too high.

Differences in water savings between 1996 and 1984 might also be attributed to differences in the response of water customers to condition 2 restrictions and requests for voluntary water savings in 1996. For example, if many industrial efforts to reduce water use implemented in 1984-1985 have remained in place, industrial customers may have less slack to achieve water savings in 1996. The fact that many industrial customers report it is more cost-effective to lease capital equipment to achieve mandatory reductions in water use in response to condition 3 water rationing in 1996 may support this concept. Also of interest are the possible effects of increased environmental regulation that may require higher commercial and industrial water use. Examples include landscape ordinances and federal, state, and local air pollution regulations. New industrial facilities that install wet scrubbers for emissions control, for example, may require increased water use and experience more complications in water reuse.

Further study could also assess the persistence of water savings beyond the water rationing period. Some water savings associated with drought management may persist once rationing is no longer required. The city could consider measuring the persistence and volume of water savings, whether the persistence or volume of water savings differs among water user sectors, and the kinds of water saving measures customers report using beyond the drought management period. The city could use this information to formulate its response to water shortage in the future.

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Lyndon B. Johnson School of Public Affairs
Special Project Report

The Consequences of Water Consumption Restrictions During the Corpus Christi Drought of 1996

Volume 2: Appendixes

by

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2000

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Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the nine-month policy research project, in the course of which two or more faculty members from different disciplines direct the research of 10 to 30 graduate students of diverse backgrounds on a policy issue of concern to a government or nonprofit agency. This "client orientation" brings the students face to face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special talents. It also illuminates the occasional difficulties of relating research findings to the world of political realities.

The Consequences of Water Consumption Restrictions During the Corpus Christi Drought of 1996 is the product of a year-long analysis of the city of Corpus Christi's drought management program, which was implemented in 1996 in response to a three-year drought that had dramatically altered in-stream flows and reservoir levels. The report presents a method for estimating the water savings and economic costs resulting from implementation of the drought management program. The approach combines an analysis of water savings and an economic impact assessment with focus group sessions, written surveys, and interviews with Corpus Christi water utility customers.

The curriculum of the LBJ School is intended not only to develop effective public servants but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope that the report itself will contribute to the second.
Finally, it should be noted that neither the LBJ School nor The University of Texas at Austin necessarily endorses the views or findings of this report.

Acknowledgments

The Lyndon B. Johnson School of Public Affairs wishes to thank the many individuals who assisted in various ways with a number of aspects of this project. The Texas Water Development Board and the city of Corpus Christi provided the funding to support this project. The project team wishes to thank James Dodson, Susan Cable, Ed Garana, and Hubert Hall of the city of Corpus Christi for their varied and helpful assistance. Susan Cable worked closely with the project team to implement focus group sessions and identify those issues which were most important to the city's design and implementation of its water management program. Ed Garana and Hubert Hall discussed the water supply system and provided the water supply records needed for forecasting and water savings analysis. The project team also wishes to thank Joe Rios and Omar Mendoza of Corpus Christi's Municipal Information Systems Department for their cooperation and assistance in developing the municipal utility database. Kay Hoover of the city of Corpus Christi assisted by contacting potential focus group participants. John Sutton and Bill Hoffman of the Texas Water Development Board provided useful guidance and assistance at several points during this project. Chandler Stolp of the LBJ School advised on development of the forecasting models.

Several individuals assisted with the economic impact assessment. Don Hoyt of the State of Texas Office of the Comptroller of Public Accounts discussed applications of input-output analysis to economic impact assessment. Sandra Martinez of the State of Texas Office of the Comptroller of Public Accounts assisted with collection of background information to characterize the Corpus Christi Metropolitan Statistical Area. Herb Grubb of HDR Engineering, Inc., and Mickey Wright of the State of Texas Office of the Comptroller of Public Accounts provided useful feedback on the application of input-output analysis. The Corpus Christi Board of Trade Technical Committee discussed economic impacts of water rationing in the ship channel industries.

The many individuals that participated in focus group and discussions of water savings analysis and economic impact assessment also deserve recognition. Several individuals assisted in this project through participation in a group discussion held in Austin that considered the approach and methods used in this study. Participants included John Sutton and Bill Hoffman of the Texas Water Development Board, Bruce Moulton of the Texas Natural Resource Conservation Commission, Mark Hughes of the Texas Workforce Commission, and Susan Cable of the city of Corpus Christi. The project team also wishes to thank the water utility customers that volunteered as focus group participants in the city of Corpus Christi for their active participation in this project. Their names are not listed to preserve the confidentiality of their responses.

The authors are solely responsible for any errors, interpretations, or omissions.

Appendix A. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series, 1982-1996

Forecasting data including rainfall, temperature, and aggregate monthly water demand are listed in Table A.1. These data originate from monthly billing reports produced by the accounting division and corrected or updated by the Corpus Christi Water Division. Water demand is listed at an aggregate level in terms of total water use and treated water use as well as at the levels of residential, commercial, and industrial water-user sectors. Total water demand is defined as all treated and raw water sales by Corpus Christi's water division during the billing month to which those sales are assigned. For example, meters read at the beginning of one month may reflect some water use in the preceding month, but this water is charged to the month in which the meter was read. Treated water demand is defined as all treated water sales to both retail and wholesale water customers such as the Alice, Beeville, and San Patricio Municipal Water District. Residential water demand is all retail treated water sales to residential water customers. Commercial water demand is all retail treated water sales to commercial water customers. Industrial water demand is all retail treated and raw water sales to industrial water customers.

Population of the Corpus Christi Metropolitan Statistical Area and the number of retail water customers are listed alongside water demand. Population is used to control for the effects of increasing population on water demand. For example, total water demand in January 1982 was 2.154 million gallons and the population of Corpus Christi Metropolitan Statistical Area was 343,800 people. Per capita total water demand is total water demand divided by the population, or 6.267 thousand gallons per capita. This figure can be compared with water demand during months when population levels differ. For example, per capita water demand in January 1996 was 7.178 thousand gallons per capita. No population data are available for the retail service area. Therefore, the number of accounts is used to standardize water demand across years rather than population. For example, residential water demand in January 1996 was 404,032 thousand gallons and there were 58,043 accounts active during the billing month. Per account water use in the residential sector was 6.96 thousand gallons per capita.

Listed on the far right of Table A.1 is aggregate rainfall (inches) and mean maximum temperature (Fahrenheit). These data are from the Office of the State Climatologist at Texas A&M University.

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series, 1982-1996

Year	Month	Trend of Month	Total	Water Billed (thousand gallons) Treated	Residential	Commercial	Industrial	Number of Accounts (n) Residential	Comm.	Indust.	Population (thousand)	Mean Max Temp.	Aggregate Precip. (inches)
82	1	25	2154869	1472026	404032	275391	874008	58043	6862	85	343.8	69	0.07
82	2	26	2055535	1400095	365791	295830	795834	58068	6871	85	343.8	66	8.11
82	3	27	2214255	1490681	451333	322827	804614	58426	6933	85	343.8	75	0.46
82	4	28	2109827	1446861	436219	322011	777811	58238	6890	85	343.8	79	1.01
82	5	29	2503369	1799855	534674	350125	969701	58617	6940	85	343.8	84	4.17
82	6	30	3135338	2290207	796842	419661	1115423	58859	6950	85	343.8	92	0.72
82	7	31	3547197	2534562	931135	447464	1150856	58951	6974	85	343.8	94	0.01
82	8	32	3253206	2289938	755131	412746	1116666	58951	6980	85	343.8	95	0.64
82	9	33	2901160	2010327	629044	373359	1026837	59050	6983	85	343.8	93	0.55
82	10	34	2530711	1730716	502957	333973	918604	59101	6986	85	343.8	83	1.70
82	11	35	2338433	1614446	476202	337523	857026	59336	6987	85	343.8	73	4.33
82	12	36	2284306	1562842	453921	329820	839869	59327	6997	84	343.8	68	0.70
83	1	37	2205820	1475963	390851	295491	843400	59379	7003	84	351.4	66	0.75
83	2	38	2096255	1415667	427279	313000	760971	59592	7026	82	351.4	69	3.27
83	3	39	2250598	1576774	485594	302241	834002	59821	7071	82	351.4	74	3.03
83	4	40	2781693	1946534	647707	372000	987797	60192	7115	82	351.4	80	0.00
83	5	41	2853092	1945471	602027	404465	1020583	60334	7128	89	351.4	83	2.77
83	6	42	2944294	2056847	673755	426976	1034465	60612	7147	91	351.4	91	2.50
83	7	43	3003670	2151681	598264	418534	1222673	60588	7147	90	351.4	91	8.78
83	8	44	2960990	2277606	666774	441011	1234632	60710	7188	90	351.4	94	2.67
83	9	45	2720498	1987862	515591	394509	1143250	60767	7200	89	351.4	87	7.04
83	10	46	2572012	1828695	431069	353141	1128469	60790	7195	89	351.4	83	3.99
83	11	47	2589292	1910760	474938	390454	1114796	61008	7192	89	351.4	78	1.53
83	12	48	2718179	2002130	551587	414109	1101330	61160	7209	89	351.4	59	0.58
84	1	49	2571013	1813756	435233	372604	1084443	61105	7202	89	352.9	59	5.91
84	2	50	2508032	1772973	438684	345601	1074502	61197	7217	89	352.9	70	0.39
84	3	51	2941023	2032100	589325	386208	1134089	61456	7242	89	352.9	77	0.19
84	4	52	3194208	2278933	723688	429786	1153934	61671	7274	88	352.9	85	0.00
84	5	53	3336664	2405687	708735	461777	1293786	61904	7290	88	352.9	86	2.22
84	6	54	3225172	2173128	691652	410194	1110108	62067	7328	88	352.9	91	0.23

(continued)

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series

Year	Month	Trend	Water Billed (thousand gallons) Total	Treated	Residential	Commercial	Industrial	Number of Accounts (n) Residential	Comm.	Indust.	Population (thousand)	Mean Max Temp.	Aggregate Precip.
84	7	55	2648755	1847083	433187	348650	1036077	62005	7297	88	352.9	93	0.25
84	8	56	2511522	1707651	382692	333657	979913	61973	7442	88	352.9	94	0.90
84	9	57	1826619	1262304	208005	243206	824835	61832	7467	89	352.9	86	3.03
84	10	58	1740024	1244234	258268	265789	741908	61815	7483	91	352.9	84	6.49
84	11	59	1803674	1320672	321122	263303	766382	61618	7484	91	352.9	75	1.71
84	12	60	2004943	1374486	370676	284424	749458	61641	7508	93	352.9	75	0.92
85	1	61	1908309	1441386	332908	264762	883662	61715	7478	93	353.6	59	2.68
85	2	62	1960743	1435217	327902	261599	910662	61729	7496	93	353.6	62	2.86
85	3	63	2027850	1485221	404514	293742	853295	61838	7510	93	353.6	75	1.82
85	4	64	2092587	1630229	437004	323854	920043	61913	7501	93	353.6	80	3.54
85	5	65	2245382	1770834	479620	345776	987059	61971	7514	93	353.6	86	2.87
85	6	66	2298607	1733731	527869	379801	871636	62223	7520	92	353.6	88	3.99
85	7	67	2865292	2108132	667764	403634	1086272	62160	7529	91	353.6	91	1.04
85	8	68	3313271	2286871	687430	438227	1141015	62249	7540	91	353.6	94	2.88
85	9	69	2554404	1821524	473305	384360	975485	62337	7549	91	353.6	89	8.39
85	10	70	2109413	1572147	395929	333919	900115	62312	7536	93	353.6	84	3.40
85	11	71	2309222	1665991	421746	357123	919322	62384	7539	93	353.6	77	1.62
85	12	72	2002131	1482842	402880	324344	837798	62235	7543	94	353.6	65	1.61
86	1	73	1926404	1426747	364168	294570	828794	62289	7513	94	356.6	68	1.70
86	2	74	1979793	1496494	435731	328106	806662	62432	7534	94	356.6	74	1.07
86	3	75	2617072	1805421	556175	369342	940726	62576	7549	93	356.6	78	0.14
86	4	76	2561906	1817063	520131	374620	957687	62653	7542	92	356.6	83	0.66
86	5	77	2627600	1878423	496991	398113	1031491	62862	7539	93	356.6	85	5.13
86	6	78	2536839	2007320	594370	411623	1053503	62948	7538	93	356.6	90	3.10
86	7	79	3237605	2397674	780259	492300	1115283	62992	7550	93	356.6	94	0.25
86	8	80	3108534	2164551	597721	442244	1129590	62907	7500	93	356.6	93	4.94
86	9	81	2458190	1808991	480697	388322	991435	62692	7488	92	356.6	92	1.86
86	10	82	2440155	1815361	394096	350357	1129347	62561	7467	93	356.6	82	5.02
86	11	83	1968165	1524012	392473	317396	850376	62624	7457	92	356.6	73	3.74
86	12	84	2126069	1703198	426440	340430	949402	62441	7440	91	356.6	63	4.54

(continued)

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series

Year	Month	Trend	Total	Water Billed (thousand gallons) Treated	Residential	Commercial	Industrial	Number of Accounts (n) Residential	Comm.	Indust.	Population (thousand)	Mean Max Temp.	Aggregate Precip. (inches)
87	1	85	1946321	1560765	385750	307537	796413	62427	7397	89	352.1	65	2.22
87	2	86	1900417	1495158	360303	294684	876961	62306	7386	89	352.1	69	6.01
87	3	87	2222972	1670543	428045	325222	937678	62402	7394	89	352.1	73	0.42
87	4	88	2616240	1925047	531321	369895	1020314	62552	7375	89	352.1	81	1.13
87	5	89	2692835	1969166	538770	391551	1044538	62693	7388	87	352.1	86	4.15
87	6	90	2472701	1959531	540557	399731	1014020	62793	7370	87	352.1	89	4.92
87	7	91	2757265	2200796	649126	441287	1055843	62784	7364	87	352.1	92	3.17
87	8	92	2913634	2283285	677076	444048	1121402	62677	7378	88	352.1	93	3.49
87	9	93	2584439	2003861	554430	410533	1011638	62658	7346	89	352.1	91	0.99
87	10	94	2513848	1815798	487276	385390	933819	62647	7365	89	352.1	84	1.44
87	11	95	2288215	1707969	443340	369149	941251	62637	7330	89	352.1	74	1.79
87	12	96	2270610	1693776	422540	346251	973706.5	62594	7311	89	352.1	70	0.93
88	1	97	2172420	1599000	387426	319990	935480	62548	7291	88	350.3	63	0.85
88	2	98	2107568	1610720	446955	345566	879266	62640	7299	88	350.3	68	1.13
88	3	99	2625711	1870181	499441	366627	1021732	62798	7313	88	350.3	74	0.91
88	4	100	2850584	2002186	544199	385632	1031729	62887	7299	87	350.3	83	0.52
88	5	101	2899043	2111523	580099	436889	1099827	63028	7298	87	350.3	86	0.94
88	6	102	3034663	2280217	727839	478818	991776	63234	7288	87	350.3	91	1.64
88	7	103	3026569	2360841	712342	474635	1097470	63222	7273	87	350.3	95	1.79
88	8	104	3336579	2421481	671876	507642	1136929	63318	7289	87	350.3	95	1.52
88	9	105	2612763	2027296	544427	431357	1039045	63202	7285	87	350.3	90	6.27
88	10	106	2471336	1821509	460522	373079	1005880	63054	7250	87	350.3	86	2.60
88	11	107	2693925	1859864	478543	388247	970761	63133	7238	87	350.3	80	0.13
88	12	108	2534433	1841539	483448	391992	999838	63090	7227	87	350.3	71	0.98
89	1	109	2283760	1666476	430681	346280	930713	63176	7213	87	349.1	71	1.96
89	2	110	2404830	1728815	446914	356399	968130	63171	7213	87	349.1	66	0.95
89	3	111	2705465	2030507	608323	392016	1025145	63390	7212	87	349.1	77	0.21
89	4	112	2950877	2073287	575109	405840	1071277	63425	7231	87	349.1	82	3.59
89	5	113	3336842	2519541	786653	487592	1180133	63518	7229	86	349.1	90	0.10
89	6	114	3598028	2524532	746923	504223	1166652	63581	7226	86	349.1	92	3.17

(continued)

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series

Year	Month	Trend	Total	Water Billed (thousand gallons) Treated	Residential	Commercial	Industrial	Number of Accounts (n) Residential	Comm.	Indust.	Population (thousand)	Mean Max Temp.	Aggregate Precip. (inches)
89	7	115	3318131	2423459	710668	471643	1210435	63638	7232	87	349.1	94	1.02
89	8	116	3539179	2506312	749686	508615	1130083	63670	7234	87	349.1	94	2.36
89	9	117	3461940	2502254	696637	487992	1225828	63614	7239	87	349.1	91	2.05
89	10	118	3212077	2364990	666535	473843	1137984	63654	7252	87	349.1	86	0.11
89	11	119	2804673	2017323	535077	432969	1029860	63661	7242	87	349.1	77	1.83
89	12	120	2590472	2014986	529123	443384	1035226	63616	7231	87	349.1	59	1.50
90	1	121	2555406	1758194	457676	367547	920353	63692	7205	92	350.7	72	0.41
90	2	122	2226446	1682582	410585	355404	929427	63783	7195	92	350.7	75	3.96
90	3	123	2453532	1807872	468326	346781	1000263	63846	7193	95	350.7	75	2.97
90	4	124	2398732	1861414	475316	384505	1015516	63934	7186	95	350.7	80	3.40
90	5	125	2881596	2069723	627998	446527	990600	64085	7193	94	350.7	86	1.26
90	6	126	3446560	2465966	773623	525301	1078995	64281	7196	93	350.7	94	0.89
90	7	127	3344796	2443618	665823	497252	1179288	64351	7209	93	350.7	93	1.74
90	8	128	3189646	2479847	790333	540882	1044507	64456	7195	92	350.7	96	0.69
90	9	129	3025192	2160489	582936	465820	1110630	64329	7169	93	350.7	91	2.66
90	10	130	2915921	2097365	544574	447165	1091463	64266	7145	93	350.7	85	1.35
90	11	131	2803409	2000929	500919	416792	1077027	64345	7155	92	350.7	79	1.34
90	12	132	2735607	1916766	527769	404665	999487	64310	7124	93	350.7	69	0.43
91	1	133	2505013	1758557	391371	350715	1005060	64299	7129	92	356.2	63	1.69
91	2	134	2262867	1699088	434333	354004	910249	64433	7126	94	356.2	71	2.06
91	3	135	2690515	1936009	491719	391858	1073982	64496	7133	94	356.2	81	1.59
91	4	136	2551202	1898958	471357	396592	1022290	64560	7122	94	356.2	83	4.00
91	5	137	2776110	1983424	533355	437683	1010895	64844	7136	94	356.2	86	6.25
91	6	138	3091471	2236162	544040	463040	1195492	64943	7154	93	356.2	91	6.97
91	7	139	3047228	2345239	639998	472567	1179975	64946	7160	91	356.2	93	0.55
91	8	140	3360083	2410847	593466	482013	1268947	65002	7151	92	356.2	94	4.63
91	9	141	2707224	1895418	418898	399653	1089405	64949	7164	91	356.2	87	8.60
91	10	142	2872274	2011242	452034	401573	1173916	64887	7157	91	356.2	85	1.57
91	11	143	2618197	1911428	423756	387261	1095000	64976	7164	91	356.2	71	0.36
91	12	144	2377663	1791028	428170	369212	1024573	64898	7160	91	356.2	69	9.80

(continued)

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series

Year	Month	Trend	Total	Water Billed (thousand gallons) Treated	Residential	Commercial	Industrial	Number of Accounts (n) Residential	Comm.	Indust.	Population (thousand)	Mean Max Temp.	Aggregate Precip. (inches)
92	1	145	2129356	1640834	380263	338710	966131	64913	7132	91	361.4	62	5.11
92	2	146	2141877	1651983	390154	356457	931291	65069	7144	91	361.4	72	4.48
92	3	147	2337355	1809950	414230	365446	1040828	65128	7148	91	361.4	77	4.09
92	4	148	2360067	1820689	413907	375965	1042888	65253	7166	91	361.4	80	3.73
92	5	149	2467540	1885955	452870	399274	1080756	65381	7177	91	361.4	83	7.41
92	6	150	3028335	2402854	649175	506916	1232337	65612	7200	92	361.4	90	1.53
92	7	151	3304455	2392008	693442	482213	1129941	65640	7215	92	361.4	92	0.92
92	8	152	3645050	2710532	704705	498080	1382001	65659	7208	93	361.4	93	3.44
92	9	153	3173291	2239230	552923	455924	1215994	65702	7196	92	361.4	90	4.26
92	10	154	2910838	1952774	414822	370253	1184369	65587	7182	92	361.4	86	0.70
92	11	155	2666228	1915543	429098	389976	1112966	65730	7165	92	361.4	73	4.77
92	12	156	2765229	2009743	441134	478262	1193137	65809	7171	93	361.4	71	0.98
93	1	157	2540062	1785231	395575	352140	1158168	65811	7161	93	375.7	66	0.44
93	2	158	2433944	1713284	410690	371946	1021557	66028	7141	94	375.7	70	1.69
93	3	159	2787829	2043192	436097	378015	1326242	66132	7151	97	375.7	75	2.83
93	4	160	3003454	2075738	422406	370115	1360657	66144	7150	97	375.7	79	3.30
93	5	161	2616783	1947270	443759	399279	1103730	66167	7133	97	375.7	84	8.07
93	6	162	2772832	2161771	480436	437588	1302076	66193	7153	97	375.7	88	12.02
93	7	163	3515984	2712293	732826	521587	1408258	66455	7189	97	375.7	91	0.00
93	8	164	4171797	2972466	836576	565943	1475367	66624	7211	97	375.7	94	0.68
93	9	165	3447647	2485697	613741	495026	1352641	66715	7199	98	375.7	92	1.12
93	10	166	3047474	2081719	459264	405720	1235717	66685	7217	97	375.7	84	1.90
93	11	167	2841358	1980518	453589	405385	1169519	66790	7218	97	375.7	72	0.81
93	12	168	2718538	1889629	442873	385607	1127935	66868	7242	97	375.7	70	4.82
94	1	169	2663870	1772958	406411	363109	1153733	66927	7222	97	378.0	69	0.99
94	2	170	2483735	1831268	404449	371599	1074673	67011	7242	97	378.0	69	1.03
94	3	171	2879402	1993541	459473	387624	1251711	67117	7251	96	378.0	75	3.49
94	4	172	2759072	1927538	454214	391207	1172063	67168	7225	99	378.0	80	4.15
94	5	173	3071591	2120874	506604	414491	1287242	67348	7250	99	378.0	86	2.01
94	6	174	3293784	2329632	616840	500343	1291859	67528	7250	98	378.0	91	3.42

(continued)

Table A.1. Rainfall, Temperature, and Aggregate Monthly Water Demand Time Series

Year	Month	Trend	Water Billed (thousand gallons)					Number of Accounts (n)			Population	Mean Max.	Aggregate Precip.
			Total	Treated	Residential	Commercial	Industrial	Residential	Comm.	Indust.	(thousand)	Temp.	(inches)
94	7	175	3853633	2680761	798425	511628	1368049	67586	7270	98	378.0381	93	0.48
94	8	176	4091364	2789570	744160	526496	1577016	67643	7281	98	378.0381	93	1.09
94	9	177	3030621	2168309	534218	454471	1268431	67527	7309	98	378.0381	89	6.73
94	10	178	2875837	1970055	451074	402809	1203433	67547	7307	98	378.0381	84	7.31
94	11	179	2762659	1964643	481280	418955	1191274	67708	7294	99	378.0381	80	0.24
94	12	180	2630333	1855662	438383	388094	1183688	67785	7296	98	378.0381	71	8.02
95	1	181	2440729	1724267	395775	341355	1105788	67708	7269	98	380.3763	67.6	0.81
95	2	182	2403056	1695958	403552	366204	1046780	67798	7276	98	380.3763	72.3	2.12
95	3	183	2711499	1909332	440984	376831	1230038	67872	7289	100	380.3763	72.1	4.89
95	4	184	2867028	1954188	496049	392909	1179106	67961	7285	99	380.3763	81.3	0.35
95	5	185	3382322	2344346	624988	415132	1337421	68009	7267	100	380.3763	87.2	2.7
95	6	186	3380899	2371455	665960	499283	1219720	68084	7311	100	380.3763	89.4	2.99
95	7	187	3592096	2476985	734717	436522	1374234	68149	7293	100	380.3763	95.1	0.21
95	8	188	3456803	2381840	598416	503607	1343262	68097	7297	102	380.3763	92.5	5.11
95	9	189	3150291	2137690	506288	441787	1309592	68231	7326	98	380.3763	92.1	4.00
95	10	190	2895387	1974392	468169	417951	1214450	68269	7328	97	380.3763	84.5	9.61
95	11	191	2631795	1784358	433882	484812	1008268	68269	7314	97	380.3763	74.4	3.53
95	12	192	2490168	1838445	452787	273947	1199448	68333	7324	97	380.3763	67.6	0.61
96	1	193	2747052	1881869	434289	373686	1155269	68474	7335	97	382.714	70.3	0.01
96	2	194	2834156	1931953	501496	402336	1093518	68557	7340	97	382.714	72.3	0.02
96	3	195	2870977	1958645	554954	429025	1047356	68557	7340	97	382.714	72.8	0.05
96	4	196	2995877	1950360	550273	429355	1057093	68557	7340	97	382.714	81.3	1.56
96	5	197	3306472	2252142	654296	458408	1178800	68946	7341	94	382.714	87.6	1.14
96	6	198	3205016	2194720	625905	440184	1026630	69146	7358	93	382.714	93	2.14
96	7	199	3484039	2458118	724146	480473	1150234	69083	7347	93	382.714	95.8	0.35
96	8	200	3303082	2262681	544231	454888	1323736	69135	7356	95	382.714	94.21	6.26
96	9	201	2514927	1750891	395084	390872	1086276	69116	7335	94	382.714	90.7	2.26
96	10	202	2693480	1783778	399398	366722	1153838	69020	7345	96	382.714	86.2	0.86
96	11	203	2614680	1677849	458250	379043	1041714	69129	7346	95	382.714	78.3	0.99

Appendix B. Residential and Commercial Water Prices, 1978-1996

Table B.1 lists the marginal cost of water to retail customers of the Corpus Christi municipal water utility that are classified as residential water users inside the city limits. Month and year refer to the first month and year that the prices in each row became effective. For example, the most recent change in water prices occurred on August 1, 1995. Each customer is charged a fixed rate each month for account maintenance. Included in this charge is the first 2,000 gallons of water delivered to each account. Therefore, the marginal price of the first two thousand gallons to a residential water customer is $0.00, and the table indicates there is no charge for the first two thousand gallons each month. If a customer uses between 2,000 and 3,000 gallons of water, the charge is $1.74 for the third thousand gallons. The total water bill is the fixed monthly rate plus $1.74. If a customer uses between 5,000 and 6,000 gallons of water during a billing period, the marginal cost of the last thousand gallon increment, the increment from 5,000 to 6,000 gallons, is $1.74. The total water cost is the fixed rate plus three times $1.74. If a customer uses 11,000 gallons, the marginal water cost is $1.87. The total water cost is the fixed cost plus four times $1.74 plus five times $1.87. Water costs are rounded to 1,000 gallons each month. The city of Corpus Christi maintains an increasing block rate for residential water customers. Table B.2 lists the marginal cost of water to residential customers outside the city limits. That rate schedule is a flat rate.

Residential water customers are residents in single-family residences or duplexes. Water sales to Corpus Christi apartment complexes and other multifamily residences are considered nonresidential water sales for billing purposes. Nonresidential rates and rate structures differ from residential rates and rate structures. For example, nonresidential customers tend to pay higher fixed rates depending upon meter size; their rate structure is a decreasing block rate. All nonresidential water customers and multifamily residences other than duplexes pay nonresidential water rates. Table B.3 lists the commercial water rates inside the city limits. Table B.4 lists the nonresidential water rates outside the city limits.

Table B.1. Residential Water Rates Inside the City Limits
(Nominal dollars per 1,000 gallons)

		Upper Limit of Water Increment (gallons)							
Month	**Year**	**2,000**	**3,000**	**6,000**	**15,000**	**20,000**	**30,000**	**50,000**	**∞**
8	**95**	0.00	1.74	1.74	1.87	2.35	2.35	2.81	3.36
8	**94**	0.00	1.64	1.64	1.76	2.22	2.22	2.66	3.17
1	**94**	0.00	1.55	1.55	1.66	2.09	2.09	2.51	2.99
9	**92**	0.00	1.46	1.46	1.57	1.97	1.97	2.36	2.82
3	**91**	0.00	1.38	1.38	1.48	1.86	1.86	2.23	2.66
11	**90**	0.00	1.41	1.41	1.51	1.90	1.90	2.28	2.71
8	**88**	0.00	1.37	1.37	1.47	1.84	1.84	2.21	2.63
12	**84**	0.00	1.30	1.30	1.40	1.75	1.75	2.10	2.50
8	**83**	0.00	1.12	1.12	1.12	1.12	0.08	0.08	0.08
10	**81**	0.00	0.00	0.87	0.87	0.87	0.65	0.65	0.65
3	**78**	0.00	0.00	0.75	0.75	0.75	0.56	0.56	0.56

Table B.2. Residential Water Rates Outside the City Limits
(Nominal dollars per 1,000 gallons)

		Upper Limit of Water Increment (gallons)							
Month	**Year**	**2,000**	**3,000**	**6,000**	**15,000**	**20,000**	**30,000**	**50,000**	**∞**
8	**95**	3.358	3.358	3.358	3.358	3.358	3.358	3.358	3.358
8	**94**	3.168	3.168	3.168	3.168	3.168	3.168	3.168	3.168
1	**94**	2.989	2.989	2.989	2.989	2.989	2.989	2.989	2.989
9	**92**	2.820	2.820	2.820	2.820	2.820	2.820	2.820	2.820
3	**91**	2.660	2.660	2.660	2.660	2.660	2.660	2.660	2.660
11	**90**	2.710	2.710	2.710	2.710	2.710	2.710	2.710	2.710
8	**88**	2.630	2.630	2.630	2.630	2.630	2.630	2.630	2.630
12	**84**	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
8	**83**	0.000	2.250	2.250	2.250	2.250	1.730	1.730	1.730
10	**81**	0.000	0.000	1.750	1.750	1.750	1.300	1.300	1.300
3	**78**	0.000	0.000	1.500	1.500	1.500	1.120	1.120	1.120

Table B.3. Nonresidential Water Rates Inside the City Limits
(Nominal dollars per 1,000 gallons)

		Upper Limit of Water Increment (gallons)							
Month	**Year**	**2,000**	**3,000**	**15,000**	**20,000**	**100,000**	**1,000,000**	**10,000,000**	**10,000,000**
8	**95**	0.000	1.741	1.741	1.577	1.577	1.261	1.046	0.781
8	**94**	0.000	1.643	1.643	1.488	1.488	1.190	0.987	0.737
1	**94**	0.000	1.550	1.550	1.404	1.404	1.123	0.932	0.696
9	**92**	0.000	1.463	1.463	1.325	1.325	1.060	0.880	0.657
3	**91**	0.000	1.380	1.380	1.250	1.250	1.000	0.830	0.620
11	**90**	0.000	1.410	1.410	1.280	1.280	1.020	0.840	0.630
8	**88**	0.000	1.370	1.370	1.240	1.240	0.990	0.820	0.610
12	**84**	0.000	1.300	1.300	1.180	1.180	0.940	0.780	0.580
8	**83**	0.000	1.120	1.120	1.120	0.840	0.710	0.590	0.430
10	**81**	0.000	0.000	0.870	0.870	0.650	0.550	0.450	0.330
3	**78**	0.000	0.000	0.750	0.750	0.560	0.470	0.380	0.280

Table B.4. Nonresidential Water Rates Outside the City Limits
(Nominal dollars per 1,000 gallons)

		Upper Limit of Water Increment (gallons)							
Month	**Year**	**2,000**	**3,000**	**15,000**	**20,000**	**100,000**	**1,000,000**	**10,000,000**	**10,000,000**
8	**95**	0.000	3.484	3.484	3.155	3.155	2.511	1.489	1.021
8	**94**	0.000	3.287	3.287	2.977	2.977	2.369	1.405	0.964
1	**94**	0.000	3.101	3.101	2.809	2.809	2.235	1.326	0.910
9	**92**	0.000	2.926	2.926	2.650	2.650	2.109	1.251	0.859
3	**91**	0.000	2.760	2.760	2.500	2.500	1.990	1.180	0.810
11	**90**	0.000	2.810	2.810	2.550	2.550	2.030	1.210	0.820
8	**88**	0.000	2.730	2.730	2.480	2.480	1.970	1.170	0.800
12	**84**	0.000	2.600	2.600	2.360	2.360	1.880	1.110	0.760
8	**83**	0.000	2.250	2.250	2.250	1.730	1.410	0.840	0.560
10	**81**	0.000	0.000	1.750	1.750	1.300	1.100	0.640	0.410
3	**78**	0.000	0.000	1.500	1.500	1.120	0.940	0.550	0.350

Appendix C. Commercial/Industrial Survey Results

Appendix C reports results of commercial/industrial surveys. Surveys were completed at the start of the first meeting of each commercial/industrial focus group, before discussion began. Forty-one organizations from the study's six target commercial/industrial sectors completed surveys. The first column in Table C.1 describes participating organizations. Table C.1 lists responses to eight descriptive questions.

In survey questions 3 through 9 and question 11, respondents described their organizations' primary product, estimated average monthly sales, number of employees, average monthly water bill, and average monthly water use. In addition, they identified their high and low seasons, if any. Respondents also reported whether their organizations were considered inside city limits (ICL) or outside city limits (OCL) for the purposes of utility billing.

Tables C.2 through C.33 each list responses to individual survey questions in the order they were asked. Each table reports results first by sector and then in aggregate, on the far right side. For example, reading the first row in Table C.2, two hotels, six government/school participants, six manufacturers, five petrochemical firms, and one military installation have altered production processes without capital investment in an effort to conserve water during the current shortage. A total of 20 respondents from all sectors combined have implemented this conservation measure, representing 14 percent of all conservation measures implemented by commercial/industrial survey respondents.

Tables C.2 through C.33 can each be read in a similar manner. Results of survey question 15 and part of question 31 were too few and too varied to summarize in this appendix.

Table C.1. Results of Commercial/Industrial Survey Questions 3-9, 11 Descriptive Information

Survey No.	Type of Organization or Primary Product	Estimated Average Monthly Sales	Seasonal Change Water in Use?	Estimated No. of Employees	Respondents Potential Impact on Water Use	Estimated Average Monthly Water Use	Estimated Average Monthly Water Bill	ICL/ OCL
1	Nursery/sod	$25,000	Yes	NR	High	DK	$150	ICL
2	Landscape design	$20,000	Yes	5	Medium	DK	$0	ICL
3	Landscape equipment	DK	Yes	2	None	2,000	DK	ICL
4	Landscape pest control	$10,000	Yes	2	Medium	DK	DK	ICL
5	Landscape retail	DK	Yes	40	NR	DK	DK	ICL
6	Irrigation installation	$40,000	Yes	10	High	1,000	DK	ICL
7	Interior landscaping	$2,000	No	1	Medium	15,000	$75	ICL
8	Landscape maintenance	$50,000	Yes	30	High	DK	DK	ICL
9	Fertilizer/pest control	$25,000	Yes	4	Medium	100,000	$150	ICL
10	Hotel	$200,000	Yes	30	Low	DK	DK	ICL
11	Hotel	$90,000	Yes	25	NR	DK	DK	ICL
12	Hotel	NR	Yes	33	Low	DK	$1,000	ICL
13	Hotel	$300,000	Yes	85	High	NR	$3,200	ICL
14	Water plant	DK	Yes	8	High	150,000,000	$20,000	OCL
15	Water plant	DK	Yes	8	NR	80,000,000	DK	ICL
16	city department	NR	Yes	130	Medium	150,000	NR	ICL
17	city department	NR	Yes	3,500	Medium	DK	DK	ICL
18	city department	NR	No	150	None	118,000	DK	ICL
19	School district	NR	No	500	Medium	DK	DK	ICL
20	School district	NR	Yes	500	Medium	DK	DK	ICL
21	School district	NR	No	5,000	High	9,000,000	DK	ICL

(Continued)

Table C.1. Results of Commercial/Industrial Survey Questions 3-9, 11
Descriptive Information

22	City department	DK	No	DK	High	DK	DK	DK
23	Pharmaceutical	DK	No	1,200	Medium	142,500,000	$40,000	OCL
24	Concrete mfctr.	$300,000	No	45	Low	300,000	DK	OCL
25	Pigment mfctr.	$1,400,000	Yes	50	High	1,300,000	$1,500	ICL
26	Chemical	DK	No	250	Medium	100,000,000	$110,000	OCL
27	Paint mfctr.	$400,000	Yes	27	High	20,000	DK	ICL
28	Military contractor	DK	No	41	Medium	DK	DK	ICL
29	Petrochemical	$1,000,000.000	No	5,000	Medium	150,000,000	$125,000	OCL
30	Refining	DK	Yes	375	Medium	3,640,000	$102,000	OCL
31	Electric utility	$35,000,000	Yes	140	High	90,000,000	$80,000	Both
32	Refining	DK	No	1,800	High	126,000,000	DK	OCL
33	Hazardous recycling	$1,200,000	No	115	High	5,500,000	$9,000	OCL
34	Petrochemical	DK	No	1,300	High	200,000,000	DK	OCL
35	Refining	$330,000,000	Yes	500	Medium	180,000,000	$190,000	OCL
36	Chemical	$7,000,000	Yes	260	High	27,000,000	$27,000	OCL
37	Metals	$20,000,000	No	800	High	NR	NR	OCL
38	Chemical	DK	No	300	Medium	180,000,000	$185,000	OCL
39	Refining	DK	No	290	Low	43,000,000	DK	OCL
40	Military installation	DK	No	3,000	High	DK	$20,000	ICL
41	Military installation	NR	No	3,000	High	35,000,000	$30,000	ICL

DK = Don't know

NR = No response

Table C.2. Results of Commercial/Industrial Survey Question 1
Production-Related Water Conservation Efforts

Question: Below is a list of production-related water conservation efforts. Please identify those efforts that your organization has implemented since April 1996 or in response to warnings of water shortage by placing check marks in the appropriate spaces. (The city of Corpus Christi declared drought condition 1 on April 9.)

Conservation Measure	Number of Responses						All Sectors	
	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship channel	Military	Number	Percent
Altered process without capital investment.	0	2	6	6	5	1	20	14
Increased use of labor to reduce water consumption.	1	0	2	2	3	0	8	6
Purchased and installed new water-saving equipment (please describe).	0	1	0	3	5	1	10	7
Started water re-capture and re-use program.	0	0	1	3	5	1	10	7
Expanded water re-capture and re-use program.	0	0	0	1	7	0	8	6
Began using lower-quality water (groundwater, seawater) to replace/supplement treated water.	1	0	2	1	1	0	5	4
Increased use of lower-quality water to replace/supplement treated water.	0	1	2	0	4	0	7	5
Established stricter volume limits on water use at specific stages of production.	5	0	3	3	4	1	16	12
Established stricter time limits on water use at specific stages of production.	4	2	6	3	2	1	18	13
Increased systematic inspection for water leaks in production process.	2	0	6	5	7	2	22	16
Decreased production.	1	2	2	1	1	0	7	5
Other (please describe).	1	1	0	0	5	0	7	5
None of the above.	0	0	0	0	0	0	0	0
Did not respond to question.	0	0	0	0	0	0	0	0
Total	**15**	**9**	**30**	**28**	**49**	**7**	**138**	**100%**
Total number of organizations surveyed	**9**	**4**	**9**	**6**	**11**	**2**	**41**	

Table C.3. Results of Commercial/Industrial Survey Question 2
Non-Production-Related Conservation Efforts

Question: Please identify those non-production related water conservation efforts listed below that your organization has adopted to save water SINCE April 9, 1996 or in response to warnings of water shortage. Please check all that apply.

Conservation Measure	Number of Responses						All Sectors	
	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship channel	Military	Number	Percent
Reduced washing of buildings, sidewalks, and other structures (please estimate percent reduction).	3	2	2	4	6	1	18	13
Ceased washing of buildings, sidewalks, and other structures.	3	3	2	3	5	1	17	13
Reduced janitorial water use (please estimate percent reduction).	0	2	0	0	0	0	2	1
Replaced existing faucets with water-saving (low-flow) faucets in restroom and kitchen sinks.	0	0	1	1	3	2	7	5
Reduced the level of water in existing toilets.	1	0	0	2	1	1	5	4
Replaced existing toilets with new water-saving toilets.	0	0	0	0	0	2	2	1
Formally encouraged employees to conserve water at all times.	4	2	5	6	7	2	26	19
Reduced landscape watering to a level lower than present city restrictions require.	3	2	5	5	7	0	22	16
Ceased landscape watering.	2	1	1	1	4	0	9	7
Other (please describe).	0	0	2	1	2	1	6	4
None of the above.	0	0	0	0	0	0	0	0
Did not respond to question.	0	0	0	0	0	0	0	0
Total	**20**	**13**	**23**	**29**	**41**	**10**	**136**	**100%**
Total number of organizations surveyed	**9**	**4**	**9**	**6**	**11**	**2**	**41**	

Table C.4. Results of Commercial/Industrial Survey Question 10
Familiarity with Drought Contingency Plan

Question: Are you familiar with conditions 1-4 of the city's drought management plan?

Answer	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ ShipChannel	Military	All Sectors: Number	Percent
Yes	6	2	8	6	10	2	34	83
No	3	2	1	0	1	0	7	17
No response	0	0	0	0	0	0	0	0
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.5. Results of Commercial/Industrial Survey Question 12
Perceived Impact of Water Conservation on Total Water Consumption

Question: How does your organization's water use this July compare to its water use last July?

Conservation Measure	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship channel	Military	All Sectors: Number	Percen
We are using less water this July than last July.	5	2	5	5	6	2	25	61
We are using about the same amount of water this July as last July.	1	2	1	1	3	0	8	20
We are using more water this July than last July.	0	0	2	0	2	0	4	10
Don't know	2	0	1	0	0	0	3	7
No response	1	0	0	0	0	0	1	2
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.6. Results of Commercial/Industrial Survey Question 13
Indicators of Economic Impact

Question: What would you consider to be the three (3) best measures of the economic impact of restricted water use on your business? Please list the best measure first.

Answer	Number of Responses						All Sectors	
	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Indicator 1								
Total sales/revenue	7	0	2	0	0	0	9	22
Employment	0	0	0	1	0	1	2	5
Operating expenses	0	0	1	1	1	0	3	7
Production	0	0	0	3	6	0	9	22
Capital expenses	0	0	0	0	1	1	2	5
Other	0	1	0	0	2	0	3	7
No response	2	3	6	1	1	0	13	32
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**
Indicator 2								
Total sales/revenue	0	0	0	1	2	0	3	7
Employment	3	0	1	1	1	0	6	15
Operating expenses	0	0	0	2	3	0	5	12
Capital expenses	0	0	1	1	1	0	3	7
Other	0	1	0	0	1	0	2	5
No response	6	3	7	1	3	2	22	54
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**
Indicator 3								
Total sales/revenue	0	0	0	1	0	0	1	2
Employment	0	0	0	1	1	0	2	5
Operating expenses	0	0	0	0	4	0	4	10
Production	0	0	0	1	2	0	3	7
Capital expenses	0	0	0	0	1	0	1	2
Other	2	0	0	1	0	0	3	7
No response	7	4	9	2	3	2	27	66
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.7. Results of Commercial/Industrial Survey Question 14
Appropriateness of Economic Impact Measure

Question: Are these common measures of economic condition in your industry?

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
Yes	3	1	0	4	9	2	19	46
No	2	0	1	1	1	0	5	12
No response	4	3	8	1	1	0	17	41
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.8. Results of Commercial/Industrial Survey Question 16
Impact of Risk of Water Shortage on Commercial/Industrial Expansion Plans

Question: Has the risk of water shortage been a factor in your company's decisions to expand operations in areas supplied with water from Corpus Christi's reservoirs?

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
Yes	4	0	2	1	3	0	10	24
No	4	4	4	4	6	2	24	59
Don't know	0	0	2	1	2	0	5	12
No response	1	0	1	0	0	0	2	5
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.9. Results of Commercial/Industrial Survey Question 17
Perception of Efficacy of Water Conservation

Question: My organization's water use accounts for such a small amount of the total water demand in Corpus Christi that our individual efforts to date HAVE NOT made meaningful contribution to reducing overall water use.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	1	0	1	0	1	1	4	10
Disagree	4	2	6	2	8	1	23	56
Agree	4	1	1	2	1	0	9	22
Agree strongly	0	1	0	2	0	0	3	7
Don't know	0	0	1	0	1	0	2	5
No response	0	0	0	0	0	0	0	0
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.10. Results of Commercial/Industrial Survey Question 18
Long-Term Cost/Benefit of Investments in Water Conservation

Question: Over the long term, the risk of drought is not high enough to justify the cost of investments in equipment and/or practices to reduce water use in our organization.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	0	0	3	0	3	1	7	17
Disagree	4	0	4	5	7	1	21	51
Agree	3	3	1	1	0	0	8	20
Agree strongly	0	0	0	0	0	0	0	0
Don't know	1	0	0	0	1	0	2	5
No response	1	1	1	0	0	0	3	7
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.11. Results of Commercial/Industrial Survey Question 19
Perceptions of Cooperation with Request for Voluntary Conservation

Question: Other businesses in our industry in Corpus Christi are implementing water conservation measures.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	0	0	0	0	0	0	0	0
Disagree	1	1	1	0	0	0	3	7
Agree	7	0	4	3	6	0	20	49
Agree strongly	0	0	1	1	4	0	6	15
Don't know	1	3	2	2	1	2	11	27
No response	0	0	1	0	0	0	1	2
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.12. Results of Commercial/Industrial Survey Question 20
Confidence in City Ability to Manage the Water Shortage

Question: The city is capable of planning a solution to the current water shortage.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	1	0	2	1	1	0	5	12
Disagree	0	0	1	2	2	1	6	15
Agree	5	4	4	3	5	1	22	54
Agree strongly	0	0	2	0	2	0	4	10
Don't know	2	0	0	0	1	0	3	7
No response	1	0	0	0	0	0	1	2
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.13. Results of Commercial/Industrial Survey Question 21
Perceptions of Primary Cause of the Water Shortage

Question: The present water shortage is PRIMARILY a result of (please choose one):

Answer	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Perce
High evaporation combined with lack of rainfall to city reservoirs	7	3	6	5	9	2	32	54
Overuse of city water by residential consumers	0	0	0	0	1	0	1	2
Overuse of city water by industrial and commercial consumers	2	0	0	0	0	0	2	3
Inadequate management of the city's reservoirs	3	0	2	0	1	0	6	10
Freshwater inflow requirements to bays and estuaries	4	0	6	1	3	0	14	24
Other (please describe)	0	1	0	1	1	0	3	5
Did not respond	0	0	0	0	1	0	1	2
Total	**16**	**4**	**14**	**7**	**16**	**2**	**59**	**100%**

Table C.14. Results of Commercial/Industrial Survey Question 22
Perceptions of Cost-Effective Long-Term Water Supply Alternatives

Question: Which alternative do you consider to be the BEST method of producing increased water supplies to Corpus Christi?

Answer	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Percent
Increased water conservation by city residents	1	0	0	0	1	0	2	4
Increased water conservation by industry and businesses	2	0	0	0	1	0	3	5
Construction of pipeline to city from Lake Texana	4	3	3	2	10	1	23	41
Desalination of seawater	5	1	6	2	1	0	15	27
Exploration of local groundwater options	1	2	1	1	0	0	5	9
Modified operation of city reservoirs	1	0	1	1	1	1	5	9
Other (please describe)	0	0	0	1	2	0	3	5
Did not respond	0	0	0	0	0	0	0	0
Total	**14**	**6**	**11**	**7**	**16**	**2**	**56**	**100%**

Table C.15. Results of Commercial/Industrial Survey Question 23
Perceptions of Drought Severity

Question: What is your best estimate of how long it has been since the city reservoirs were at 50 percent (one-half) of total capacity?

Estimates (months)	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Percent
1-6 months	3	1	4	1	0	0	9	22
7-12 months	4	1	4	3	6	2	20	49
13-18 months	0	0	0	1	3	0	4	10
19-24 months	1	1	1	1	1	0	5	12
Over 24 months	0	0	0	0	0	0	0	0
Don't know	1	1	0	0	1	0	3	7
No response	0	0	0	0	0	0	0	0
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.16. Results of Commercial/Industrial Survey Question 24

Question: Please estimate the period of time you think that water supplies remaining in the reservoirs will sustain residents and businesses dependent upon these supplies under current rates of water use and current rates of reservoir recharge (provide your closest estimate in weeks, months, or years).

Estimates (months)	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Percent
1-6 months	1	0	0	1	0	0	2	5
7-12 months	4	1	4	0	3	1	13	32
13-18 months	0	1	1	2	3	1	8	20
19-24 months	0	0	0	1	3	0	4	10
More than 24 months	1	0	1	0	0	0	2	5
Don't know	3	2	3	2	2	0	12	29
No response	0	0	0	0	0	0	0	0
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.17. Results of Commercial/Industrial Survey Question 25

Question: Please describe and estimate the fixed cost of any one-time purchases or repairs your organization has made to comply with the CURRENT request for voluntary reduction in water use.

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
The estimated cost is $_____. Please describe these costs in the space provided below.	0	0	1	2	5	1	9	22
There are fixed costs but I am unable to estimate them. Please describe these costs below.	0	0	1	0	1	0	2	5
I believe there are fixed costs to my organization but I can neither describe nor estimate them.	1	1	2	2	2	1	9	22
There are no fixed costs to my organization.	7	3	4	1	1	0	16	39
Other (please explain briefly in the space below).	1	0	0	0	0	0	1	2
No response.	0	0	1	1	2	0	4	10
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Note: Fixed cost descriptions and estimates were too varied to report.

Table C.18. Results of Commercial/Industrial Survey Question 26

Question: Please describe and estimate any regular (daily, weekly, monthly) costs (variable costs) to your organization that can be directly attributed to the CURRENT request for voluntary reduction in water use. Do not include any fines for violation of city ordinances related to water use.

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
The estimated cost is $_____. Please describe these costs in the space provided below.	2	0	1	0	5	0	8	20
There are variable costs but I am unable to estimate them. Please describe these costs below.	2	1	3	2	0	0	8	20
I believe there are variable costs to my organization but I can neither describe nor estimate them.	1	0	0	2	4	1	8	20
There are no variable costs to my organization.	3	3	3	1	1	1	12	29
Other (please explain briefly in the space below).	0	0	0	0	0	0	0	0
No response.	1	0	2	1	1	0	5	12
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Note: Variable cost descriptions and estimates were too varied to report.

Table C.19. Results of Commercial/Industrial Survey Question 27
Perceptions of Risk of Running Out of Water

Question: Under the current plan, the city will enter drought condition 4 when the combined total capacity of the reservoirs reaches 7 percent If the city reaches drought condition 4, each commercial and industrial customer's water use may be limited to a maximum monthly allowance. Each customer's monthly water allocation could be 75 percent of average monthly water use over the previous 12 months. If the city allocates water, businesses will pay a surcharge for water use that exceeds that allowance. What is closest to your view?

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
The city should not implement a water rationing program.	0	0	0	0	1	0	1	2
The city should delay implementation of a water rationing program or implement a water rationing program less restrictive than the current plan.	4	3	2	0	3	1	13	32
The city should implement the water rationing program as planned.	4	1	4	4	7	0	20	49
The city should implement a water rationing program as soon as possible or implement a water rationing program more restrictive than the current plan.	1	0	3	2	0	1	7	17
No response	0	0	0	0	0	0	0	0
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.20. Results of Commercial/Industrial Question 28
Anticipated Effects of Condition 3 Water Rationing on Sales Revenue

Question: Assume that the city allocates water to your businesses as described in question 27. Please describe any effects you may anticipate in terms of a change in sales revenue. If you anticipate an increase or decrease in sales revenue, please estimate the percent change.

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
Anticipated increase in sales revenue.	0	0	0	0	0	0	0	0
No change anticipated.	2	0	3	1	1	0	7	17
Anticipated 5-15% decrease in sales revenue.	0	2	0	1	3	1	7	17
Anticipated 16-25% decrease in sales revenue.	1	2	0	2	1	1	7	17
Anticipated 26-35% decrease in sales revenue.	0	0	0	0	0	0	0	0
Anticipated 36-50% decrease in sales revenue.	1	0	0	0	1	0	2	5
Anticipated greater than 50% decrease in sales revenue.	3	0	0	0	0	0	3	7
Anticipated but could not estimate decrease in sales revenue.	1	0	1	0	3	0	5	12
Don't know	1	0	2	2	2	0	7	17
No response	0	0	3	0	0	0	3	7
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.21. Results of Commercial/Industrial Survey Question 29
Anticipated Effects of Condition 3 Water Rationing on Employment

Question: Please describe any effects you may anticipate in terms of a change in employment if the city allocates water as described in question 27. If you anticipate an increase or decrease in employment, please estimate the percent change.

Answer	Number of Responses Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors Number	Percent
Anticipated increase in employment.	0	0	0	0	0	0	0	0
No change anticipated.	3	2	5	2	3	1	16	39
Anticipated 5-15% decrease in employment.	0	0	0	0	2	0	2	5
Anticipated 16-25% decrease in employment.	2	0	0	2	1	1	6	15
Anticipated 26-35% decrease in employment.	0	0	0	0	0	0	0	0
Anticipated 36-50% decrease in employment.	1	0	0	0	0	0	1	2
Anticipated greater than 50% decrease in employment.	2	0	0	0	0	0	2	5
Anticipated but could not estimate decrease in employment.	1	0	0	0	1	0	2	5
Don't know	0	1	3	2	4	0	10	24
No response	0	1	1	0	0	0	2	5
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.22. Results of Commercial/Industrial Survey Question 30

Question: Under present conditions, what is your closest estimate of when the city of Corpus Christi will enter drought condition 4?

Estimates (months)	Number of Responses Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors Number	Percent
1-6 months	4	3	8	4	3	1	23	56
7-12 months	4	0	0	2	5	1	12	29
13-18 months	0	0	0	0	2	0	2	5
19-24 months	0	0	1	0	0	0	1	2
More than 24 months	0	0	0	0	0	0	0	0
Don't know	0	0	0	0	0	0	0	0
No response	1	1	0	0	1	0	3	7
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.23. Results of Commercial/Industrial Survey Question 31

Question: Suppose your business is located in the city of San Diego, California. The city of San Diego declares a drought emergency and requires all organizations to cut their water use by at least 25 percent to avoid paying a substantial fine. Assume that your organization cannot afford to pay the fine.

What is the first measure you would recommend that your organization take to comply with the city's demand?

Answer Number	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military
1	reduce stock watering	replace toilets	sell less water	recycle	NR	NR
2	NR	NR	sell less water	cease non-production water use	recycle	recycle wastewater
3	NR	educate guests	stop outdoor watering	drill well	transfer production	
4	reduce stock watering	NR	stop use of water for pool	reduce production 35%	install RO unit	
5	NR		NR	NR	cut production	
6	NR		stop outdoor watering	NR	recycle	
7	reduce stock watering		stop outdoor watering		recycle wastewater	
8	reduce stock watering		stop outdoor watering		reduce production	
9	NR		reduce water in toilets		recycle wastewater	
10					reduce production	
11					shut low priority units	

About how much water would that measure save?

Answer Number	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military
1	10	20	25	25	NR	25
2	NR	NR	NR	35	8	25
3	NR	10	75	25	25	
4	NR	NR	NR	25	8	
5	NR		NR	NR	25	
6	NR		30	NR	15	
7	25		10		15	
8	25		NR		NR	
9	NR		NR		25	
10					25	
11					10	

Note: Question 31 asked three more brief questions, but responses to these questions were too few and too varied to report..

Table C.24. Results of Commercial/Industrial Survey Question 32

Question: Please indicate whether you agree or disagree with the following statement.

The city should limit water use among residential customers before limiting water use among businesses and commercial interests.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	2	0	1	1	0	0	4	10
Disagree	4	0	5	1	3	0	13	32
Agree	2	3	1	4	4	1	15	37
Agree strongly	0	1	1	0	1	0	3	7
Don't know	0	0	0	0	0	0	0	0
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.25. Results of Commercial/Industrial Survey Question 33

Question: Please indicate whether you agree or disagree with the following statement.

The availability of water influences the decisions of new businesses to locate in Corpus Christi.

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
Disagree strongly	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0
Agree	2	2	5	2	4	1	16	39
Agree strongly	6	2	3	4	4	0	19	46
Don't know	0	0	0	0	0	0	0	0
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.26. Results of Commercial/Industrial Survey Question 34

Question: Please indicate whether you agree or disagree with the following statement.

The reliability of the Corpus Christi water supply could prevent the expansion of existing city businesses.

	Number of Responses						All Sectors	
Answer	**Landscape/ Nursery**	**Hotel/ Tourism**	**Government/ Schools**	**Other Comm./ Manufacturing**	**Petrochem./ Ship Channel**	**Military**	**Number**	**Percent**
Disagree strongly	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0
Agree	3	2	5	2	4	1	17	41
Agree strongly	5	2	3	4	4	0	18	44
Don't know	0	0	0	0	0	0	0	0
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.27. Results of Commercial/Industrial Survey Question 35

Question: Please indicate whether you agree or disagree with the following statement.
Employment in Corpus Christi will be affected by the drought restrictions.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	1	1	2
Agree	3	2	4	5	3	0	17	41
Agree strongly	5	1	3	1	5	0	15	37
Don't know	0	1	1	0	0	0	2	5
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.28. Results of Commercial/Industrial Survey Question 36

Question: Please indicate whether you agree or disagree with the following statement.
The water shortage could contribute to a decrease in tourism this season.

	Number of Responses						All Sectors	
Answer	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Disagree strongly	0	0	0	0	0	0	0	0
Disagree	3	1	4	2	3	1	14	34
Agree	3	0	2	4	4	0	13	32
Agree strongly	1	3	2	0	1	0	7	17
Don't know	1	0	0	0	0	0	1	2
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.29. Results of Commercial/Industrial Survey Question 37

Question: Please indicate whether you agree or disagree with the following statement.

The value of land and homes in Corpus Christi could erode if more reliable water supplies cannot be acquired.

Answer	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Percent
Disagree strongly	0	0	1	0	0	0	1	2
Disagree	0	0	1	0	1	0	2	5
Agree	6	3	4	5	2	1	21	51
Agree strongly	2	1	2	1	5	0	11	27
Don't know	0	0	0	0	0	0	0	0
No response	1	0	1	0	3	1	6	15
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.30. Results of Commercial/Industrial Survey Question 38

Question: Was your business located in Corpus Christi during the water shortage of 1984-1985?

Answer	Number of Responses: Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	All Sectors: Number	Percent
Yes	5	2	6	4	7	1	25	61
No	3	2	1	2	1	0	9	22
No response	1	0	2	0	3	1	7	17
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.31. Results of Commercial/Industrial Survey Question 39

Question: Please estimate the impact of the water shortage of 1984-1985 on employment in your organization.

Answer	Number of Responses						All Sectors	
	Landscape /Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Estimated increase in employment.	0	0	0	0	0	0	0	0
No impact on employment.	0	0	3	1	4	1	9	22
Estimated 5-15% decrease in employment.	0	0	0	0	0	0	0	0
Estimated 16-25% decrease in employment.	2	0	0	1	0	0	3	7
Estimated 26-35% decrease in employment.	0	0	0	0	0	0	0	0
Estimated 36-50% decrease in employment.	2	0	0	0	0	0	2	5
Estimated greater than 50% decrease in employment.	1	0	0	0	0	0	1	2
Don't know	0	1	2	2	2	0	7	17
No response	4	3	4	2	5	1	19	46
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.32. Results of Commercial/Industrial Question 40

Question: Please estimate the impact of the water shortage of 1984-1985 on revenue in your organization.

Answer	Number of Responses						All Sectors	
	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military	Number	Percent
Estimated increase in revenue.	0	0	0	0	0	0	0	0
No impact on revenue.	0	0	1	1	3	1	6	15
Estimated 5-15% decrease in revenue.	0	0	1	0	1	0	2	5
Estimated 16-25% decrease in revenue.	2	0	0	1	0	0	3	7
Estimated 26-35% decrease in revenue.	0	0	0	0	0	0	0	0
Estimated 36-50% decrease in revenue.	1	0	0	0	0	0	1	2
Estimated greater than 50% decrease in revenue.	2	0	0	0	0	0	2	5
Reported decrease without estimating amount.	0	0	1	0	0	0	1	2
Don't know	0	1	2	2	2	0	7	17
No response	4	3	4	2	5	1	19	46
Total	**9**	**4**	**9**	**6**	**11**	**2**	**41**	**100%**

Table C.33. Results of Commercial/Industrial Survey Question 41

Question: If the water shortage of 1984-1985 affected aspects of your business other than employment and revenue, Please describe these effects below.

Answer Number	Landscape/ Nursery	Hotel/ Tourism	Government/ Schools	Other Comm./ Manufacturing	Petrochem./ Ship Channel	Military
1	Stock loss, expansion delay	No response	No response	Expansion delay, job security loss	No response	None
2	No response	No response	No response	Equipment damage	No response	No response
3	No response	No response	No response	Customer loss	Considered moving production elsewhere	
4	No response	No response	No response	No response	No response	
5	No response	No response	No response	No response	No response	
6	No response	No response	Safety hazard	No response	No response	
7	No response	No response	No response		No response	
8	No response	No response	No response		No response	
9	No response	No response	No response		Fined for dust emission	
10	No response	No response	No response		No response	
11	No response	No response	No response		No response	

Appendix D: Residential Survey Results

Appendix D reports results of residential customer surveys. Surveys were completed by all eight residential focus group participants at the start of the first meeting of each group, before discussion began. In addition, 18 residential customers completed surveys distributed through apartment complexes and neighborhood associations.

Tables D.1 through D.5 list responses to 14 descriptive questions. In survey questions 4 through 6, respondents identified their annual household income, the number of persons in their residence, and their type of residence. Questions 7, 7a, and 7b asked apartment dwellers whether water costs were included in monthly rent, whether their apartment had an individual water meter, and whether their apartment management had started a water conservation program. Questions 8 through 15 asked whether respondents were responsible for paying their household water bills, whether they were the member of their household with the most knowledge about water use, and whether they had the greatest impact on water use. Respondents were also asked to list their gender, age, educational background, typical monthly water bill, and typical monthly water use.

Tables D.6 through D.41 list responses to individual survey questions in the order they were asked. Each table first reports results of focus group participants, then of mailed survey respondents, and then in aggregate on the far right side. For example, the first row in Table D.6 shows that focus group participants and 10 mailed survey respondents indicated in response to question 1 that they had reduced use of household washing machines due to the water shortage. A total of 13 respondents reported implementing this household conservation measure, representing 9 percent of the total number of measures implemented by participating households. Tables D.7 through D.41 can be read in a similar manner.

Survey questions are reported above tabular results. Results of survey question 28 were not sufficient to report in this appendix.

Table D.1. Results of Residential Survey Questions 4-6 Descriptive Information

Respondent Number	Annual Household Income	Number in Residence	Residence Description
1	$25-35,000	2	Single family home
2	>$75,000	2	Single family home
3	>$75,000	3	Single family home
4	$45-55,000	2	Single family home
5	$35-45,000	7	Single family home
6	$65-75,000	3	Single family home
7	$45-55,000	3	Single family home
8	$55-65,000	3	Single family home
9	NR	2	Single family home
10	$55-65,000	3	Single family home
11	$65-75,000	4	Single family home
12	$15-25,000	2	Single family home
13	$45-55,000	4	Single family home
14	NR	2	Single family home
15	$65-75,000	4	Single family home
16	$15-25,000	2	Apt./Condominium
17	$35-45,000	5	Single family home
18	$35-45,000	2	Apt./Condominium
19	$15-25,000	1	Apt./Condominium
20	NR	1	Apt./Condominium
21	$35-45,000	2	Apt./Condominium
22	$35-45,000	4	Apt./Condominium
23	$25-35,000	3	Apt./Condominium
24	$25-35,000	1	Apt./Condominium
25	NR	NR	Apt./Condominium
26	$15-25,000	1	Apt./Condominium

Table D.2. Results of Residential Survey Question 7

Question: Do you live in an apartment or other building where water costs are included in monthly rent?

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Yes	0	10	10	38
No	0	0	0	0
Don't know	0	0	0	0
No response	8	8	16	62
Total	**8**	**18**	**26**	**100%**

Table D.3. Results of Residential Survey Question 7a

Question: Does your apartment/condominium have an individual water meter?

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Yes	0	0	0	0
No	0	6	6	23
Don't know	0	4	4	15
No response	8	8	16	62
Total	**8**	**18**	**26**	**100%**

Table D.4. Results of Residential Customer Survey Question 7b

Question: Has the management at your apartment/condominium complex started a water conservation program?

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Yes	0	9	9	35
No	0	0	0	0
Don't know	0	1	1	4
No response	8	8	16	62
Total	**8**	**18**	**26**	**100%**

Table D.5. Results of Residential Survey Questions 8-15 Descriptive Information

Respondent Number	Does Respondent Pay Water Bill?	Does Respondent Know Most About Water Use?	Does Respondent Have Greatest Impact on Water Use?	Gender	Age	Education	Typical Monthly Water Bill	Typical Monthly Water Use
1	Yes	NR	NR	Male	>65	high school	$30-35	$7,000
2	Yes	Yes	Yes	Male	40-49	grad school	$45	$8,000
3	No	Yes	Yes	Female	40-49	grad school	DK	DK
4	Yes	Yes	No	Female	50-65	grad school	$43	$10,000
5	Yes	Yes	Yes	Female	40-49	college grad	$45	NR
6	Yes	Yes	Yes	Female	40-49	grad school	$7	$3,000
7	Yes	Yes	No	Female	40-49	college	DK	DK
8	Yes	Yes	Yes	Female	40-49	college	$45	$11,000
9	Yes	Yes	No	Male	>65	grad school	$40	$19,000
10	NR	Yes	No	Female	21-29	college	$48	NR
11	Yes	Yes	Yes	Male	>65	grad school	$18	$6,000
12	Yes	Yes	Yes	Female	>65	college	$31	$3,000
13	Yes	Yes	Yes	Male	30-39	college	$45	$10,000
14	Yes	No	No	Female	40-49	college	$40	$5,000
15	Yes	Yes	Yes	Male	40-49	college grad	$35	$7,000
16	NR	Yes	Yes	Male	>65	college	DK	DK
17	Yes	Yes	Yes	Female	40-49	voc/tech	$45	DK
18	No	Yes	Yes	Female	<21	college	DK	DK
19	NR	Yes	Yes	Female	>65	grad school	DK	DK
20	NR	Yes	Yes	Female	50-65	college grad	NR	DK
21	NR	Yes	Yes	Female	40-49	college	NR	NR
22	NR	NR	NR	Female	30-39	college	DK	DK
23	NR	Yes	Yes	Male	30-39	voc/tech	DK	DK
24	NR	Yes	Yes	Male	21-29	grad school	DK	DK
25	No	Yes	No	Female	40-49	college	DK	DK
26	No	Yes	Yes	Male	>65	grad school	DK	DK

Table D.6. Results of Residential Survey Question 1

Question: Please identify those water conservation efforts listed below that your household has adopted to save water SINCE April 9, 1996 or in response to warnings of water shortage. (The city of Corpus Christi declared drought condition 1 on April 9 and instituted mandatory water conservation efforts on May 6, 1996.) Please check all that apply.

Voluntary Conservation Measure	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Reduced use of washing machine (please estimate percent of decrease).	3	10	13	9
Reduced use of garbage disposal (please estimate percent of decrease).	4	7	11	8
Ceased use of garbage disposal.	0	2	2	1
Reduced use of dishwasher (please estimate percent of decrease).	4	8	12	8
Ceased use of dishwasher in favor of hand washing.	1	4	5	3
Adopted strict limits on showering time (indicate time limit if any).	1	9	10	7
Replaced existing shower head with water-saving (low-flow) shower head.	2	9	11	8
Replaced existing faucets with water-saving (low-flow) faucets in kitchen and bathroom sinks.	2	3	5	3
Repaired leaky faucets.	4	12	16	11
Reduced the level of water in existing toilets.	2	6	8	6
Replaced existing toilet with new water-saving toilet.	2	0	2	1
Avoid flushing as much as possible.	4	10	14	10
Began a household water re-use program.	2	6	8	6
Ceased indoor and outdoor plant watering (other than lawns).	1	3	4	3
Reduced lawn-watering to a level lower than present city lawn-watering restrictions require.	4	9	13	
Ceased lawn-watering.	0	6	6	4
None of the above.	1	0	1	1
Other (please describe).	2	2	4	3
No response.	0	0	0	0
Total	**39**	**106**	**145**	**100%**

Table D.7. Results of Residential Survey Question 2

Question: Which three (3) of the water conservation practices listed in question 1 do you think are most effective? Please look again at the list of choices in question 1 and place an asterisk (*) next to the three practices that you think save the most water. You do not have to limit your answers to those you checked in response to question 1.

	Number of Responses		All Respondents	
Voluntary Conservation Measure	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Reduced use of washing machine (please estimate percent of decrease).	5	3	8	11
Reduced use of garbage disposal (please estimate percent of decrease).	0	1	1	1
Ceased use of garbage disposal.	0	1	1	1
Reduced use of dishwasher (please estimate percent of decrease).	2	3	5	7
Ceased use of dishwasher in favor of hand washing.	1	1	2	3
Adopted strict limits on showering time (indicate time limit if any).	2	4	6	8
Replaced existing shower head with water-saving (low-flow) shower head.	1	4	5	7
Replaced existing faucets with water-saving (low-flow) faucets in kitchen and bathroom sinks.	3	1	4	6
Repaired leaky faucets.	2	9	11	15
Reduced the level of water in existing toilets.	1	0	1	1
Replaced existing toilet with new water-saving toilet.	2	1	3	4
Avoid flushing as much as possible.	1	4	5	7
Began a household water re-use program.	0	2	2	3
Ceased indoor and outdoor plant watering (other than lawns).	0	1	1	1
Reduced lawn-watering to a level lower than present city lawn-watering restrictions require.	1	5	6	8
Ceased lawn-watering.	1	6	7	10
None of the above.	0	0	0	0
Other (please describe).	0	0	0	0
No response.	1	2	3	4
Total	**23**	**48**	**71**	**100%**

Note: One mailed survey respondent marked only two choices.

Table D.8. Results of Residential Survey Question 3

Question: Water prices for a household in the city of Corpus Christi increase as the amount of water used by the household increases. Please circle the price that you believe is closest to the actual price of each water increment.

Responses, by Water Increment	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
First 2,000 gallons				
Chose estimate closest to actual price.	0	1	1	4
Underestimated actual price by $1.00 or less.	0	0	0	0
Underestimated actual price by $1.01 to $3.00.	0	0	0	0
Underestimated actual price by more than $3.00.	0	0	0	0
Overestimated actual price by $1.00 or less.	0	1	1	4
Overestimated actual price by $1.01 to $3.00.	4	2	6	23
Overestimated actual price by more than $3.00.	0	4	4	15
Did not respond.	4	10	14	54
Total	**8**	**18**	**26**	**100%**
Next 4,000 gallons				
Chose estimate closest to actual price.	2	1	3	12
Underestimated actual price by $1.00 or less.	1	1	2	8
Underestimated actual price by $1.01 to $3.00.	0	1	1	4
Underestimated actual price by more than $3.00.	0	0	0	0
Overestimated actual price by $1.00 or less.	2	1	3	12
Overestimated actual price by $1.01 to $3.00.	0	3	3	12
Overestimated actual price by more than $3.00.	0	0	0	0
Did not respond.	3	11	14	54
Total	**8**	**18**	**26**	**100%**
Next 9,000 gallons				
Chose estimate closest to actual price.	0	1	1	4
Underestimated actual price by $1.00 or less.	1	1	2	8
Underestimated actual price by $1.01 to $3.00.	0	0	0	0
Underestimated actual price by more than $3.00.	0	0	0	0
Overestimated actual price by $1.00 or less.	1	1	2	8
Overestimated actual price by $1.01 to $3.00.	2	4	6	23
Overestimated actual price by more than $3.00.	0	0	0	0
Did not respond.	4	11	15	58
Total	**8**	**18**	**26**	**100%**
Next 15,000 gallons				
Chose estimate closest to actual price.	0	1	1	4
Underestimated actual price by $1.00 or less.	1	0	1	4
Underestimated actual price by $1.00 to $3.00.	0	0	0	0
Underestimated actual price by more than $3.00.	0	0	0	0
Overestimated actual price by $1.00 or less.	1	1	2	8
Overestimated actual price by $1.00 to $3.00.	2	3	5	19
Overestimated actual price by more than $3.00.	0	1	1	4
Did not respond.	4	12	16	62
Total	**8**	**18**	**26**	**100%**
Next 20,000 gallons				
Chose estimate closest to actual price.	0	1	1	4
Underestimated actual price by $1.00 or less.	1	0	1	4
Underestimated actual price by $1.00 to $3.00.	0	0	0	0
Underestimated actual price by more than $3.00.	0	0	0	0
Overestimated actual price by $1.00 or less.	1	1	2	8
Overestimated actual price by $1.00 to $3.00.	1	3	4	15
Overestimated actual price by more than $3.00.	1	1	2	8
Did not respond.	4	12	16	62
Total	**8**	**18**	**26**	**100%**

Table D.9. Results of Residential Survey Question 16

Question: How does your water use this July compare to your water use last July?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
I am using less water this July than last July.	4	12	16	62
I am using about the same amount of water this July as last July.	2	2	4	15
I am using more water this July than last July.	1	1	2	8
Don't know.	1	0	1	4
No response.	0	3	3	12
Total	**8**	**18**	**26**	**100%**

Table D.10. Results of Residential Survey Question 17

Question: Do you know where your water meter is located?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Yes	8	11	19	73
No	0	6	6	23
No response	0	1	1	4
Total	**8**	**18**	**26**	**100%**

Table D.11. Results of Residential Survey Question 18

Question: Do you know how to read your water meter?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Yes	4	10	14	54
No	4	5	9	35
No response	0	3	3	12
Total	**8**	**18**	**26**	**100%**

Table D.12. Results of Residential Survey Question 19

Question: Were you a resident of Corpus Christi or of a community served by the Corpus Christi Water Department during 1984-1985?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Yes	7	10	17	65
No	1	5	6	23
No response	0	3	3	12
Total	**8**	**18**	**26**	**100%**

Table D.13. Results of Residential Customer Survey Question 20

Question: Are you familiar with drought conditions 1-4 of the city's drought management plan?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Yes	5	10	15	58
No	3	8	11	42
No response	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.18. Results of Residential Survey Question 25

Question: The present water shortage is PRIMARILY a result of (please choose one):

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
High evaporation combined with lack of rainfall to the city's reservoirs.	7	13	20	57
Overuse of city water by residential customers.	0	1	1	3
Overuse of city water by industrial customers.	0	2	2	6
Inadequate management of the city's reservoirs.	0	3	3	9
Freshwater inflow requirements to bays and estuaries.	1	5	6	17
Other (please describe).	0	3	3	9
Don't know.	0	0	0	0
No response.	0	0	0	0
Total	**8**	**27**	**35**	**100%**

Table D.19. Results of Residential Survey Question 26

Question: Which alternative do you consider to be the BEST method of producing increased water supplies to the city of Corpus Christi? (Please choose one.)

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Increased water conservation by city residents.	0	0	0	0
Increased water conservation by industry and business.	0	2	2	5
Construction of pipeline to city from Lake Texana.	3	5	8	22
Desalination of seawater.	4	12	16	43
Exploration of local groundwater options.	0	2	2	5
Modified operation of city reservoirs.	0	3	3	8
Other (please describe).	1	3	4	1
Don't know.	0	2	2	5
No response.	0	0	0	0
Total	**8**	**29**	**37**	**100%**

Table D.20. Results of Residential Survey Question 27

Question: Which is closest to your view? Current restrictions on water use under drought condition 2:

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Are both an inconvenience and a cost.	1	4	5	19
Are more of an inconvenience than a cost.	4	5	9	35
Are more of a cost than an inconvenience.	0	1	1	4
Are neither an inconvenience nor a cost.	3	6	9	35
No response.	0	2	2	8
Total	**8**	**18**	**26**	**100%**

Table D.21. Results of Residential Survey Question 29

Question: Please describe and estimate any regular (daily, weekly, monthly) costs to your household that can be directly attributed to the CURRENT regulations on water use. Do not include any fines for violation of city ordinances related to water use.

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
The estimated cost is $____. Please describe these costs in the space provided below.	0	2	2	8
There are costs but I am unable to estimate them. Please describe these costs below.	2	3	5	19
I believe there are costs to my household but I can neither describe nor estimate these costs.	1	3	4	15
There are no daily/weekly/monthly costs to my household.	5	9	14	54
Other (please explain briefly in the space below).	0	1	1	4
No response.	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.22. Results of Residential Survey Question 30

Question: Water rationing will begin when the city of Corpus Christi moves from drought condition 2 to drought condition 3. The plan allows each household to use a limited amount of water each month. (Table of monthly household allocations was included in survey.) In the first stages of drought condition 3, households will pay a surcharge for water use that exceeds their water allowance. What is closest to your view of how the city should act?

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
The city should not implement a water rationing program under drought condition 3.	0	3	3	11
The city should implement a water rationing program less restrictive than the current plan under drought condition 3.	2	6	8	30
The city should implement a water rationing program as planned under drought condition 3.	6	8	14	52
The city should implement a water rationing program more restrictive than the current plan under drought condition 3.	0	1	1	4
No response.	0	1	1	4
Total	**8**	**19**	**27**	**100%**

Table D.23. Results of Residential Survey Question 31

Question: Please indicate whether you agree or disagree with the following statement. *My household can easily manage with the water allowance prescribed for drought condition 3 under the drought management plan.*

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Disagree strongly	0	0	0	0
Disagree	3	5	8	31
Agree	4	9	13	50
Agree strongly	0	1	1	4
Don't know	1	2	3	12
Did not respond	0	1	1	4
Total	**8**	**18**	**26**	**100%**

Table D.24. Results of Residential Survey Question 32

Question: Please indicate whether you agree or disagree with the following statement. *I anticipate that monthly expenses in my household will increase if the city decides to limit household water use as planned under drought condition 3.*

	Number of Responses		All Respondents	
Answer	Focus Group Participants	Mailed Surveys	Number	Percent
Disagree strongly	0	2	2	8
Disagree	3	6	9	35
Agree	4	7	11	42
Agree strongly	1	0	1	4
Don't know	0	3	3	12
Did not respond	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.25. Results of Residential Survey Question 33

Question: Please indicate whether you agree or disagree with the following statement. *The system that will be used to ration water among residential customers in drought condition 3 (described in question 30) results in a fair distribution of water among city residents.*

	Number of Responses		All Respondents	
Answer	Focus Group Participants	Mailed Surveys	Number	Percent
Disagree strongly	0	0	0	0
Disagree	2	7	9	35
Agree	5	7	12	46
Agree strongly	0	1	1	4
Don't know	1	3	4	15
Did not respond	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.26. Results of Residential Survey Question 34

Question: Please indicate whether you agree or disagree with the following statement. *The city should limit water use among residential customers first before limiting water use among businesses and commercial interests.*

	Number of Responses		All Respondents	
Answer	Focus Group Participants	Mailed Surveys	Number	Percent
Disagree strongly	4	7	11	42
Disagree	2	9	11	42
Agree	2	1	3	12
Agree strongly	0	1	1	4
Don't know	0	0	0	0
Did not respond	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.27. Results of Residential Survey Question 35

Question: The current drought management plan requires the city to limit household water use as described in question 30 when the combined volume of the reservoirs is 11 percent of total capacity. Please indicate which of the following policies most closely represents your view of how the city should act.

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Limit household water use as soon as possible.	2	8	10	38
Limit household water use when reservoirs are 20 percent of total capacity.	4	3	7	27
Limit household water use when reservoirs are 11 percent of total capacity.	2	6	8	31
Wait even longer to limit household water use.	0	1	1	4
No response	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.28. Results of Residential Survey Question 36

Question: What is your best estimate of how long it has been since the city reservoirs were at 50 percent (one-half) of total capacity?

Estimates (months)	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
1-6 months	0	2	2	8
7-12 months	2	8	10	38
13-18 months	4	2	6	23
19-24 months	1	5	6	23
More than 24 months	0	0	0	0
Don't know	1	1	2	8
No response	0	0	0	0
Total	**8**	**18**	**26**	**100%**

Table D.29. Results of Residential Survey Question 37

Question: Under present conditions, what is your closest estimate of when the city of Corpus Christi will enter drought condition 3 and begin limiting water use as described in question 30?

Estimates (months)	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
1-6 months	7	17	24	92%
7-12 months	0	1	1	4%
13-18 months	0	0	0	0%
19-24 months	1	0	1	4%
More than 24 months	0	0	0	0%
Don't know	0	0	0	0%
No response	0	0	0	0%
Total	**8**	**18**	**26**	**100%**

Table D.30. Results of Residential Survey Question 38

Question: Please estimate the period of time you think that water supplies remaining in the reservoirs will sustain residents and businesses under current rates of water use and reservoir recharge (provide your closest estimate in weeks, months, or years).

	Number of Responses		All Respondents	
Estimates (months)	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
1-6 months	2	2	4	15
7-12 months	0	5	5	19
13-18 months	1	1	2	8
19-24 months	0	0	0	0
More than 24 months	1	1	2	8
Don't know	4	7	11	42
No response	0	2	2	8
Total	**8**	**18**	**26**	**100%**

Table D.31. Results of Residential Survey Question 39

Question: Please indicate whether you agree or disagree with the following statement. (Table of residential surcharges included in survey.)

The surcharge described above provides little or no incentive for most people to reduce water consumption by changing patterns of water use or replacing existing equipment with water-saving equipment.

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Disagree strongly	0	0	0	0%
Disagree	4	7	11	42%
Agree	3	5	8	31%
Agree strongly	1	3	4	15%
Don't know	0	2	2	8%
Did not respond	0	1	1	4%
Total	**8**	**18**	**26**	**100%**

Table D.32. Results of Residential Survey Question 40

Question: In column A below, please mark those water conservation efforts that your household has adopted to save water during the city's water shortage. Then, pretend for a moment that you live in San Diego, California, and that the city of San Diego has rationed water use in each household and adopted a mandatory $1,000 fine for the first violation and for each violation thereafter. In column B indicate which four (4) of the practices listed below you would implement first to live within your water ration. Mark exactly four. None of the items below are required under the drought management plan. Do no mark in column B any of the choices that you marked in column A.

	Number of Responses		All Responses	
Voluntary Conservation Measure	Focus Group Participants	Mailed Surveys	Number	Percent
Reduced use of washing machine (please estimate percent of decrease).	1	6	7	8
Reduced use of garbage disposal (please estimate percent of decrease).	0	3	3	3
Ceased use of garbage disposal.	1	2	3	3
Reduced use of dishwasher (please estimate percent of decrease).	0	3	3	3
Ceased use of dishwasher in favor of hand washing.	0	8	8	9
Adopted strict limits on showering time (indicate time limit if any).	5	4	9	10
Replaced existing shower head with water-saving (low-flow) shower head.	1	1	2	2
Replaced faucets with water-saving (low-flow) faucets in kitchen/bathroom sinks.	3	4	7	8
Repaired leaky faucets.	1	2	3	3
Reduced the level of water in existing toilets.	1	3	4	4
Replaced existing toilet with new water-saving toilet.	1	4	5	6
Avoid flushing as much as possible.	2	3	5	6
Began a household water re-use program.	4	5	9	10
Ceased indoor and outdoor plant watering (other than lawns).	2	3	5	6
Ceased lawn-watering.	2	10	12	13
None of the above.	0	0	0	0
Other (please describe).	0	0	0	0
No response.	2	2	4	4
Total	**26**	**63**	**89**	**100%**

Table D.33. Results of Residential Survey Question 41

Question: Suppose that as the drought continues, there is no end in sight. The city Manager has asked you to select five water-use restrictions to begin immediately. Please select the next five (5) restrictions on water use by placing a check in the space provided.

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
New customer connections to the city's water supply are prohibited.	0	4	4	3
Use of water to serve at restaurants unless requested by customer is prohibited.	6	12	18	14
Use of water to expand commercial nurseries is prohibited.	4	13	17	13
Use of water for scenic and recreational ponds and lakes is prohibited.	8	13	21	16
Use of water for private residential swimming pools, hot tubs, and wading pools is prohibited.	7	11	18	14
Use of water for pools in hotels, health clubs, and country clubs is prohibited.	7	8	15	11
Use of water in public swimming pools is prohibited.	5	8	13	10
Use of water to begin growing crops on new agricultural land is prohibited.	1	7	8	6
Use of water to begin new planting and landscaping is prohibited.	4	13	17	13
No response.	0	0	0	0
Total	**42**	**89**	**131**	**100%**

Table D.34. Results of Residential Survey Question 42

Question: Studies show that the present water shortage could have been avoided if the proposed pipeline from Lake Texana had been completed. It is likely that the proposed pipeline could be approved and built in 18 months. Based on what you know now, please answer each of the following questions.

A. Would you support construction of the pipeline with no increase in water rates?

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Yes	6	14	20	77
No	1	1	2	8
Don't know	0	0	0	0
No response	1	3	4	15
Total	**8**	**18**	**26**	**100%**

B. Would you support a price increase of 44 cents per 1,000 gallons to pay for the pipeline?

Yes	3	9	12	46
No	3	3	6	23
Don't know	1	3	4	1
No response	1	3	4	15
Total	**8**	**18**	**26**	**100%**

C. Would you support a price increase of 87 cents per 1,000 gallons to pay for the pipeline?

Yes	1	2	3	12
No	3	9	12	46
Don't know	3	4	7	2
No response	1	3	4	15
Total	**8**	**18**	**26**	**100%**

D. Would you support a price increase of $1.74 per 1,000 gallons to pay for the pipeline?

Yes	0	1	1	4
No	5	12	17	65
Don't know	2	2	4	15
No response	1	3	4	15
Total	**8**	**18**	**26**	**100%**

E. Would you support a price increase of $2.61 per 1,000 gallons to pay for the pipeline?

Yes	0	1	1	4
No	6	14	20	77
Don't know	1	0	1	4
No response	1	3	4	15
Total	**8**	**18**	**26**	**100%**

TableD.35. Results of Residential Survey Question 43

Question: Some people have suggested that the city of Corpus Christi could achieve the goals of water conservation by raising the price of water rather than limiting the amount of water people use. Please indicate whether you would prefer limits on your water use or the price increases listed below.

A. If water prices were two (2) times current rates, would you prefer:

	Number of Responses		All Respondents	
Answer	Focus Group Participants	Mailed Surveys	Number	Percent
Higher rates	1	6	7	27
Limits on water use	6	8	14	54
No response	1	4	5	19
Total	**8**	**18**	**26**	**100%**

B. If water prices were three (3) times current rates, would you prefer:

Higher rates	0	3	3	12
Limits on water use	7	11	18	69
No response	1	4	5	19
Total	**8**	**18**	**26**	**100%**

C. If water prices were four (4) times current rates, would you prefer:

Higher rates	0	2	2	8
Limits on water use	7	12	19	73
No response	1	4	5	19
Total	**8**	**18**	**26**	**100%**

D. If water prices were five (5) times current rates, would you prefer:

Higher rates	0	2	2	8
Limits on water use	7	12	19	73
No response	1	4	5	1
Total	**8**	**18**	**26**	**100%**

Table D.36. Results of Residential Survey Question 44

Question: How would you rank the cost of your water bill relative to other costs in your household? Please indicate whether the monthly household costs listed below are higher or lower than your monthly water cost by circling your choices in the table below.

Other Household Cost	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Monthly grocery bills				
are higher than monthly water bill.	6	13	19	73
are lower than monthly water bill.	0	0	0	0
no response	2	5	7	27
Total	**8**	**18**	**26**	**100%**
Monthly electric utility bill				
is higher than monthly water bill.	6	12	18	69
is lower than monthly water bill.	0	0	0	0
no response	2	6	8	31
Total	**8**	**18**	**26**	**100%**
Monthly cost of gasoline for one car				
is higher than monthly water bill.	4	8	12	46
is lower than monthly water bill.	2	4	6	23
no response	2	6	8	3
Total	**8**	**18**	**26**	**100%**
Monthly cable television bill				
is higher than monthly water bill.	1	3	4	15
is lower than monthly water bill.	5	9	14	54
no response	2	6	8	31
Total	**8**	**18**	**26**	**100%**
Monthly laundry or dry-cleaning costs				
are higher than monthly water bill.	1	5	6	23
are lower than monthly water bill.	4	6	10	38
no response	3	7	10	38
Total	**8**	**18**	**26**	**100%**
Monthly cost of garbage pickup				
is higher than monthly water bill.	3	8	11	42
is lower than monthly water bill.	3	4	7	27
no response	2	6	8	31
Total	**8**	**18**	**26**	**100%**

Table D.37. Results of Residential Survey Question 45

Question: Please indicate whether you agree or disagree with the following statement. *The availability of water influences the decisions of new businesses to locate in Corpus Christi.*

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Disagree strongly	0	0	0	0
Disagree	1	1	2	8
Agree	2	13	15	58
Agree strongly	3	4	7	27
Don't know	0	0	0	0
Did not respond	2	0	2	8
Total	**8**	**18**	**26**	**100%**

Table D.38. Results of Residential Survey Question 46

Question: Please indicate whether you agree or disagree with the following statement. *The reliability of the Corpus Christi water supply could prevent the expansion of existing city businesses.*

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Disagree strongly	0	0	0	0
Disagree	1	2	3	12
Agree	2	11	13	50
Agree strongly	3	4	7	27
Don't know	0	1	1	4
Did not respond	2	0	2	8
Total	**8**	**18**	**26**	**100%**

Table D.39. Results of Residential Survey Question 47

Question: Please indicate whether you agree or disagree with the following statement. *Employment in Corpus Christi will be affected by the drought restrictions.*

Answer	Number of Responses: Focus Group Participants	Number of Responses: Mailed Surveys	All Respondents: Number	All Respondents: Percent
Disagree strongly	0	0	0	0
Disagree	0	2	2	8
Agree	3	12	15	58
Agree strongly	2	3	5	19
Don't know	0	1	1	4
Did not respond	3	0	3	12
Total	**8**	**18**	**26**	**100%**

Table D.40. Results of Residential Survey Question 48

Question: Please indicate whether you agree or disagree with the following statement. *The water shortage could contribute to a decrease in tourism this season.*

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Disagree strongly	0	0	0	0
Disagree	2	5	7	27
Agree	1	10	11	42
Agree strongly	2	2	4	15
Don't know	0	0	0	0
Did not respond	3	1	4	15
Total	**8**	**18**	**26**	**100%**

Table D.41. Results of Residential Survey Question 49

Question: Please indicate whether you agree or disagree with the following statement. *The value of land and homes in Corpus Christi could erode if more reliable water supplies cannot be acquired.*

	Number of Responses		All Respondents	
Answer	**Focus Group Participants**	**Mailed Surveys**	**Number**	**Percent**
Disagree strongly	0	0	0	0
Disagree	0	1	1	4
Agree	2	12	14	54
Agree strongly	3	4	7	27
Don't know	0	1	1	4
Did not respond	3	0	3	12
Total	**8**	**18**	**26**	**100%**

Anonymous Participant Questionnaire
Residential Water Users

The following survey is designed to help the city of Corpus Christi obtain information about customers' preferences and interests. The time allotted for this survey is 30 minutes. We would rather you make a reasonable estimate than skip a question, but if you don't feel comfortable answering a question, please skip it. If you do not finish all of the questions, please draw a line across the page below your last response.

1. Please identify those water conservation efforts listed below that your household has adopted to save water SINCE April 9, 1996 or in response to warnings of water shortage. (The city of Corpus Christi declared drought condition 1 on April 9 and instituted mandatory water conservation efforts on May 6, 1996.) Please check all that apply.

____Reduced use of washing machine (please estimate percent of decrease ________%).
____Reduced use of garbage disposal (please estimate percent of decrease _________%).
____Ceased use of garbage disposal.
____Reduced use of dishwasher (please estimate percent of decrease _________%).
____Ceased use of dishwasher in favor of hand washing.
____Adopted strict limits on showering time (indicate time limit in minutes if any _______).
____Replaced existing shower head with water-saving (low-flow) shower head. List make and/or model if known: ____.
____Replaced existing faucets with water-saving (low-flow) faucets in kitchen and bathroom sinks.
____Repaired leaky faucets.
____Reduced the level of water in existing toilets.
____Replace existing toilet with new water-saving toilet.
____Avoid flushing toilet as much as possible.
____Began a household water reuse program.
____Ceased indoor and outdoor plant watering (other than lawns).
____Reduced lawn watering to a level lower than present city lawn-watering restrictions require.
____Ceased lawn watering.
____None of the above.

Please describe any other water conservation practices you have adopted in your household (use back of page for more space):

2. Which three of the water conservation practices listed in question 1 do you think are most effective? Please look again at the list of choices in question 1 and place an asterisk (*) next to the three practices that you think save the most water. You do not have to limit your answers to those you checked in response to question 1.

3. Water prices for a household in the city of Corpus Christi increase as the amount of water used by the household increases. Please circle the price that you believe is closest to the actual price of each water increment. Do not include any fixed monthly charges. Please mark one price for each water increment.

Water Increment			**Price per 1,000 gallons**								
first	2,000 gallons	$0.00	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50
next	4,000 "	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00
next	9,000 "	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50
next	15,000 "	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
next	20,000 "	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00	$6.50

We appreciate your patience. Now, we ask that you answer the following questions about your household to help us in our study.

4. Which of the following categories most closely describes your annual **household** income.

____less than $15,000 per year
____$15,001 - $25,000 per year
____$25,001 - 35,000 per year
____$35,001 - $45,000 per year
____$45,001 - $55,000 per year
____$55,001 - $65,000 per year
____$65,001 - $75,000 per year
____over $75,000 per year

5.How many people live in your household? ______________________

6. Which best describes the place where you live:

___Single-family home ___Apartment/condominium ___Duplex ___Other (describe)

If you answered "single-family home" to this question, please skip to question 8.

7. Do you live in an apartment or other building where water costs are included in monthly rent?

_____Yes _____No _____Don't know

If you answered no to question 7, please skip questions 7a and 7b. If you answered "yes" to question 7, please answer the following questions:

7a. Does your apartment/condominium have an individual water meter?

_____Yes ____No _____Don't know

7b. Has the management at your apartment/condominium complex started a water conservation program?

_____Yes ____No _____Don't know

8. If your household receives a water bill each month, are you the person responsible for paying it?

_____Yes _____No

9. Are you the person most knowledgeable about how water is used in your household? ____Yes ____No

10. Are you the person in your household with the greatest impact on water use strategies? ___Yes ___No

11. Gender: ____ Male ____Female

12. Age: _____under 21 _____21-29 _____30-39 _____40-49 _____50-65 _____over 65

13. Please check the category that best describes the level of your education:

____ Eigth grade or less
____ Some high school
____ High school completed
____ Vocational/technical or trade school
____ Some college
____ College graduate
____ Graduate work

14. Please provide your best estimate of the typical monthly water bill in your household:

$__________ _____Don't know

15. Please provide your best estimate of the typical volume of water used in your household each month:

__________ gallons ______Don't know

16. How does your water use this July compare to your water use last July?

____ I am using less water this July than last July.
____ I am using about the same amount of water this July as last July.
____ I am using more water this July than last July.

17. Do you know where your water meter is located? ____Yes____No

18. Do you know how to read your water meter? ____Yes____No

Thank you . . . Just a few more general questions.

19. Were you a resident of Corpus Christi or of a community served by the Corpus Christi Water Department during 1984-1985? ____Yes ____ No

20. Are you familiar with drought conditions 1-4 of the city's drought management plan? ___Yes ___No

Please indicate whether you agree or disagree with the following statements:

21. My household water use accounts for such a small amount of the total water demand in Corpus Christi that my individual efforts to date HAVE NOT made a meaningful contribution to reducing overall water use.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

22.The city is capable of planning a solution to the current water shortage.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

23. People in my neighborhood abide by the city's regulations for outdoor water use.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

24. I read all the information I can find about current events surrounding the city's water management program and the current water shortage.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

25. The present water shortage is PRIMARILY a result of (please choose **one**):

____high evaporation combined with lack of rainfall to the city's reservoirs.
____overuse of city water by residential consumers.
____overuse of city water by industrial consumers.
____inadequate management of the city's reservoirs.
____freshwater inflow requirements to bays and estuaries.
____other (please describe: ____).
____don't know

26. Which alternative do you consider to be the BEST method of producing increased water supplies to the city of Corpus Christi (please choose **one**)?

____increased water conservation by city residents
____increased water conservation by industry and businesses
____construction of pipeline to city from Lake Texana
____desalination of seawater
____exploration of local groundwater options
____modified operation of city reservoirs
____other (please describe: ____)
____don't know

27. Which is closest to your view? Current restrictions on water use under drought condition 2:

____are both an inconvenience and a cost.
____are more of an inconvenience than a cost.
____are more of a cost than an inconvenience.
____are neither an inconvenience nor a cost.

28. Please describe and estimate the cost of any one-time purchases or repairs you have made to comply with the CURRENT regulations on outdoor water use.

29. Please describe and estimate any regular (daily, weekly, monthly) costs to your household that can be directly attributed to the CURRENT regulations on water use. Do not include any fines for violation of city ordinances related to water use.

____ The estimated cost is $________ (please circle: daily/weekly/monthly). Please describe these costs in the space provided below.

____ There are costs but I am unable to estimate them. Please describe these costs below.

____ I believe there are costs to my household but I can neither describe nor estimate these costs.

____ There are no daily/weekly/monthly costs to my household.

____ other (please explain briefly in the space below:)

30. Water rationing will begin when the city of Corpus Christi moves from drought condition 2 to drought condition 3. The plan allows each household to use a limited amount of water each month. The monthly limits will be:

Number of residents in household	**Maximum monthly water allowance**
1-2 people	**6,000 gallons**
3-4 people	**7,000 gallons**
5-6 people	**8,000 gallons**
7-8 people	**9,000 gallons**
9-10 people	**10,000 gallons**
11 or more	**12,000 gallons**

In the first stages of drought condition 3, households will pay a surcharge for water use that exceeds their water allowance. What is closest to your view of how the city should act?

____The city should not implement a water rationing program under drought condition 3.

____The city should implement a water rationing program less restrictive than the current plan under Drought Condition 3.

____The city should implement the water rationing program as planned under drought condition 3.

____The city should implement a water rationing program more restrictive than the current plan under Drought Condition 3.

Please indicate whether you agree or disagree with the following statements about the rationing plan described in question 30:

31. My household can easily manage with the water allowance prescribed for drought condition 3 under the drought management plan:

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

32. I anticipate that monthly expenses in my household will increase if the city decides to limit household water use as planned under drought condition 3.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

33. The system that will be used to ration water among residential customers in drought condition 3 (described in question 30) results in a fair distribution of water among city residents.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

34. The city should limit water use among residential customers first before limiting water use among businesses and commercial interests.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

35. The current drought management plan requires the city to limit household water use as described in question 30 when the combined volume of the reservoirs is 11 percent of total capacity. Please indicate which of the following policies most closely represents your view of how the city should act.

____ Limit household water use as soon as possible.

____ Limit household water use when reservoirs are 20 percent of total capacity.

____ Limit household water use when reservoirs are 11 percent of total capacity.

____ Wait even longer to limit household water use.

36. What is your best estimate of how long it has been since the city reservoirs were at 50 percent (one half) of total capacity?

____1 month	____3 months	____9 months	____18 months
____2 months	____6 months	____1 year	____2 years

37. Under present conditions, what is your closest estimate of when the city of Corpus Christi will enter drought condition 3 and begin limiting water use as described in question 30?

____1 month	____3 months	____9 months	____18 months
____2 months	____6 months	____1 year	____2 years

38. Please estimate the period of time you think that water supplies remaining in the reservoirs will sustain residents and businesses under current rates of water use and current rates of reservoir recharge (provide your closest estimate in weeks, months, or years).

_______weeks   _________months   _______years   ______Don't know

39. In the next stage of the drought management plan, each household that uses more than its maximum monthly water allowance will pay a surcharge for water, in addition to regular water rates. The surcharge for water is as follows:

Number of gallons OVER allocation	Surcharge per 1,000 gallons
First 1,000 gallons over allocation	$3.00
Next 1,000 gallons over allocation	$5.00
Next 1,000 gallons over allocation	$10.00
Each additional 1,000 gallons over allocation	$25.00

Please indicate whether you agree or disagree with the following statement:

The surcharge described above provides little or no incentive for most people to reduce water consumption by changing patterns of water use or replacing existing equipment with water-saving equipment.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

40. In column A below, please mark those water conservation efforts that your household has adopted to save water during the city's water shortage.

Then, pretend for a moment that you live in San Diego, California, and that the city of San Diego has rationed water use in each household and adopted a mandatory $1,000 fine for the first violation and for each violation thereafter. In column B, indicate which four (4) of the practices listed below you would implement first to live within your water ration. **Mark exactly four.** None of the items below are required under the drought management plan. **Do not mark in column B any of the choices that you marked in column A.**

A	B	
___	___	Reduce use of washing machines (please estimate percent of decrease __________%).
___	___	Reduce use of garbage disposal (please estimate percent of decrease __________%).
___	___	Cease use of garbage disposal.
___	___	Reduce use of dishwasher (please estimate decreased use as a percentage __________%).
___	___	Cease use of dishwasher in favor of hand washing.
___	___	Limit showering time (please indicate time limit __________minutes).
___	___	Replace existing shower head with water-saving shower head.
___	___	Replace existing faucets with water-saving (low-flow) faucets in kitchen and bathroom sinks.
___	___	Repair leaky faucets.
___	___	Reduce water level in the existing toilet.
___	___	Replace existing toilet with water-saving toilet.
___	___	Avoid flushing toilet as much as possible.
___	___	Begin a household water reuse program.
___	___	Cease watering of indoor and outdoor plants (other than lawns).
___	___	Cease lawn watering.
___	___	None of the above.

If there are any water conservation practices NOT listed above that you would adopt in your household BEFORE undertaking the water conservation strategies listed above, please describe them below.

41. Suppose that as the drought continues, there is no end in sight. The city Manager has asked you to select five water-use restrictions to begin immediately. Please select the next **five (5)** restrictions on water use by placing a check in the space provided.

____New customer connections to the city's water supply are prohibited.

____Use of water to serve at restaurants unless requested by the customer is prohibited.

____Use of water to expand commercial nurseries is prohibited.

____Use of water for scenic and recreational ponds and lakes is prohibited.

____Use of water for private residential swimming pools, hot tubs, and wading pools is prohibited.

____Use of water for pools in hotels, health clubs, and country clubs is prohibited.

____Use of water in public swimming pools is prohibited.

____Use of water to begin growing crops on new agricultural land is prohibited.

____Use of water to begin new planting and landscaping is prohibited.

42.Studies show that the present water shortage could have been avoided if the proposed pipeline from Lake Texana had been completed. It is likely that the proposed pipeline could be approved and built in 18 months. Based on what you know now, please answer each of following questions.

Would you support construction of the pipeline with no increase in water rates?

____Yes ____No ____Don't know

Would you support a price increase of 44 cents per 1,000 gallons to pay for the pipeline?

____Yes ____No ____Don't know

Would you support a price increase of 87 cents per 1,000 gallons to pay for the pipeline?

____Yes____No ____Don't know

Would you support a price increase of $1.74 per 1,000 gallons to pay for the pipeline?

____Yes ____No ____Don't know

Would you support a price increase of $2.61 per 1,000 gallons to pay for the pipeline?

____Yes ____No ____Don't know

43. Some people have suggested that the city of Corpus Christi could achieve the goals of water conservation by raising the price of water rather than limiting the amount of water people use. Please indicate whether you would prefer limits on your water use or the price increases listed below:

If water prices were **two (2)** times current rates, would you prefer:____higher rates ____limits on water use

If water prices were **three (3)** times current rates, would you prefer:____higher rates ____limits on water use

If water prices were **four (4)** times current rates, would you prefer:____higher rates____limits on water use

If water prices were **five (5)** times current rates, would you prefer:____higher rates____limits on water use

44. How would you rank the cost of your water bill relative to other costs in your household? Please indicate whether the monthly household costs listed below are higher or lower than your monthly water cost by circling your choices in the table below.

Monthly water bill is:		
higher than	lower than	monthly grocery bills
higher than	lower than	monthly electric utility bill
higher than	lower than	monthly cost of gasoline for one car
higher than	lower than	monthly cable television bill
higher than	lower than	monthly laundry or dry-cleaning costs
higher than	lower than	monthly cost of garbage pickup

If the city enters drought condition 4, it may begin to allocate water to business and industry and to charge a penalty to businesses that use more than their monthly allocation. If this happens, will the water shortage begin to affect the Corpus Christi economy? **Please indicate whether you agree or disagree with the following statements.**

45. The availability of water influences the decisions of new businesses to locate in Corpus Christi.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

46. The reliability of the Corpus Christi water supply could prevent the expansion of existing city businesses.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

47. Employment in Corpus Christi will be affected by the drought restrictions.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

48.The water shortage could contribute to a decrease in tourism this season.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

49. The value of land and homes in Corpus Christi could erode if more reliable water supplies cannot be acquired.

Disagree strongly	Disagree	Agree	Agree strongly	Don't know

Thank you very much for your cooperation. In a few minutes we will collect the surveys and begin the focus group session.

Appendix E. A Manual for Converting the Municipal Utility Database to Analyzable Form

This appendix describes the process and programs the project team used to convert the municipal utility database to a format suitable for analysis with conventional database and statistical software. The city of Corpus Christi maintains its municipal utility database on an IBM mainframe machine in a system called VSAM constructed in COBOL. The system was designed in 1977 as an accounting system suitable for tracking and viewing information by customer account. All system programming is accomplished using the COBOL language. Because the municipal information system maintains a high workload and a significant programming effort is required to access and convert the database, the system is not accessible to water utility managers who want to carry out analyses of water demand or the water supply system at the level of customer account. One objective of this project has been to develop database screens and to incorporate these data into a water conservation analysis that would permit a level of data disaggregation not available from other sources.

The Municipal Information System (MIS) Department of the city of Corpus Christi provided the project team with copies of the backup municipal utility database files for fiscal years 1992 through 1996 and for the first month of fiscal year 1997. The fiscal year runs from August 1 through July 31. Backup files consist of three databases including the master file, the history file, and the support file. Only information contained in the master and history files were relevant to the goals of this project. Master files describe the details of accounts current in any one fiscal year. For example, the files contain information on customer name, service address, billing address, and payment history. Each master file record is indexed by a single account number and codes describing rate structures and utility services. History files are a record of each customers' water use, gas use, billing date, and meter read date during each month of the fiscal year. In addition, each history file contains a record of water use, gas use, billing date, and meter read date during the immediate past fiscal year for residential customer accounts and the immediate past two years for nonresidential customer accounts. History records for each fiscal year were referenced from the master file by account number for the fiscal year of the master file. Support files contain information for accounts with multiple meters associated with a single service address.

The MIS department created copies of master and history files, converted these copies from COBOL to EBCIDIC format, and stored these data on 6,250 reel tapes and 210-megabyte 3,480 cartridge tapes. Most data files obtained from the city of Corpus Christi required multiple tapes. University of Texas at Austin (UT/A) hardware requirements made routine use of 6,250 reel tapes impractical and the project team adopted 3,480 cartridge tapes as the standard early in the project. Data were transferred from the 3,480 cartridge tapes to UT/A's VAX machine and converted to ASCII format. Table E.1 describes each data tape received from the city, names the download file, identifies UT/A's conversion program, and describes information about the output file and its location. For example, the city of Corpus Christi provided the project team with the fiscal year 1993 utility master file on Tape ID Number 1009 and specified the record length as 1,065 characters and the block size as 31,950. The download file contained on the tape was MAS93, which was 131 megabytes. The project team used a FORTRAN program, MAS1065.FOR, to convert selected information in the database to a format suitable for dBASE IV and SAS. The FORTRAN program appends a unique "out" extension to the output file. Therefore, MAS93 was converted to MAS93.OUT, which is 37 megabytes.

The conversion process consists of transferring the original download files to a mainframe or personal computer and running the appropriate FORTRAN conversion programs to create subset ASCII files. Conversion programs are titled MAS80.FOR, MAS1065.FOR, and HIS250.FOR. All subset files for each fiscal year are combined into a single dBASE file for each fiscal year based upon a control file titled CTRLFILE, which is produced automatically by the FORTRAN conversion program. The format and structure of this intermediate dBASE file is provided in Table E.2 along with brief information about the source field in the original history and master files. The original field name in the municipal utility database is underlined beneath its corresponding field name. The abbreviations MF and AR that prefix field names stand for master and history files, respectively, and indicate the origin of the data field. A data dictionary describing the complete contents of master and history files and field subcodes is available from the Municipal Information Systems Department. Data may be aggregated or further processed while in dBASE format, as in the addition of aggregate rainfall and monthly mean maximum temperature (FILMAS.PRG) based on each customer's meter read date, or the calculation of marginal water prices (PTPRICE.PRG). Analysis of the database is accomplished using a single aggregate database created by combining subset databases from each fiscal year. Output datasets can be created using only the variables necessary for specific analyses. Separate dBASE files for each fiscal year are maintained because these files are smaller and can therefore be used to minimize the processing time and space requirements of some tasks.

The contents and structure of the multiyear dBASE file, HMSA3456.DBF, are provided in Table E.3. This project accessed only that information that appeared useful to accomplish project goals. Thirteen fields from the original master file and 24 fields from the original history files were combined to form the output databases. Database records are indexed by key fields including account number, rate code, and water code. The account number is a nine-digit number in which the first two digits represent the billing cycle and the last digit is a location-specific customer identification code. Account numbers are permanently assigned to individual meters and the last digit of the account number increments by one when a new customer takes over the account. Each customer account is classified by a six-digit rate code used to identify the rate structure which the account falls into for billing purposes for services being used. The first digit describes whether the account falls inside or outside the city limits. Subsequent digits indicate the types of available services purchased, including water, utility gas, sewer, and garbage pickup. The water code is used to identify water utility customer type; for example, whether this account is a residential, commercial, industrial, or city account. This project made routine use of the account number, rate code, and water codes to cross-reference records and aggregate information in the master and history files.

The final database, HMSA3456.DBF, includes 41 fields, including 3 fields that are either calculated or merged from other databases. Aggregate monthly rainfall (inches) and mean maximum monthly temperature (Farenheit) represent rainfall and temperature for each account during the water use period. These variables are calculated by aggregating daily rainfall and averaging daily temperature data over the water use period. Rainfall and temperature data were obtained from the Office of the Texas State Climatologist at Texas A&M University. The third calculated variable is PRICE. PRICE represents the marginal price paid by this customer for the last thousand-gallon increment.

Data Processing Procedure

The data conversion system developed for the Corpus Christi municipal utility database is an unintegrated system. A description of procedural steps is provided in Table E.5. While this maximizes the amount of flexibility a user has to adapt the project as needed, that user needs to know how the conversion process works to successfully complete the procedure. Knowledge of FORTRAN programming and dBASE IV are minimum requirements.

The objective of the procedure is to create an output dataset consisting of a set of variables that are appropriate for the selected analysis. A procedural flowchart (Figure E.1) describes the process. Steps in the figure are numbered, and these steps and numbers correspond to the numbers in Table E.5. The location of files created at each step during the conversion process is listed according to location on data tapes. UT/A staff provided data tapes used in the analysis to city of Corpus Christi staff upon completion of this report.

Table E.1. Table Listing File Types

Fiscal Year	Tape ID Number	Tape Type	Record Length	Block Size	Conversion Program	Original Download File: Filename	Original Download File: File Size (megabytes)	ASCII Subset: Filename	ASCII Subset: File Size (megabytes)	dBASE IV File: Filename	dBASE IV File: File Size (megabytes)
Utility Master Files											
1992	1010	3480	1065	31950	MAS1065.FOR	MASFY92	131				
1993	1009	3480	1065	31950	MAS1065.FOR	MASFY93	131	MAS93.OUT	37	MAS93.DBF	37
1994	1006	3480	1065	31950	MAS1065.FOR	MASFY941	134	MAS941.OUT	38	MAS94.DBF	74
1994	1008	3480	1065	31950	MAS1065.FOR	MASFY942	131	MAS942.OUT	37		
1995	1007	3480	1065	31950	MAS1065.FOR	MASFY95	132	MAS95.OUT	37	MAS95.DBF	37
1996	T02496	6250	1065	31950	MS80.FOR	MASFY96	132	MAS96.OUT	37	MAS96.DBF	37
Utility History Files											
1992	A01020	3480	250	32750	HIS250.FOR						
1992	A01021	3480	250	32750	HIS250.FOR						
1992	A01022	3480	250	32750	HIS250.FOR						
1992	A01023	3480	250	32750	HIS250.FOR						
1993	101	3480	250	32750	HIS250.FOR	HIS101	203	HIS101.OUT	30	HIS93.DBF	72
1993	102	3480	250	32750	HIS250.FOR	HIS102	205	HIS102.OUT	30		
1993	103	3480	250	32750	HIS250.FOR	HIS103	205	HIS103.OUT	31		
1993	104	3480	250	32750	HIS250.FOR	HIS104	103	HIS104.OUT	15		
1994	000145	3480	250	32750	HIS250.FOR	HIS145	217	HIS145.OUT	32	HIS94.DBF	53
1994	000193	3480	250	32750	HIS250.FOR	HIS193	32	HIS193.OUT	5		
1994	000278	3480	250	32750	HIS250.FOR	HIS278	217	HIS278.OUT	33		
1994	000338	3480	250	32750	HIS250.FOR	HIS338	69	HIS338.OUT	10		
1995	2650	3480	250	32750	HIS250.FOR	HIS2650	72	HIS2650.OUT	11	HIS95.DBF	74
1995	2655	3480	250	32750	HIS250.FOR	HIS2655	214	HIS2655.OUT	32		
1995	2761	3480	250	32750	HIS250.FOR	HIS2761	217	HIS2761.OUT	32		
1995	2773	3480	250	32750	HIS250.FOR	HIS2773	218	HIS2773.OUT	33		
1996	2575	3480	250	32750	HIS250.FOR	HIS2575	189	HIS2575.OUT	32	HIS96.DBF	66
1996	2609	3480	250	32750	HIS250.FOR	HIS2609	131	HIS2609.OUT	19		
1996	2614	3480	250	32750	HIS250.FOR	HIS2614	216	HIS2614.OUT	33		
1996	2623	3480	250	32750	HIS250.FOR	HIS2623	88	HIS2623.OUT	13		
1996.8	000968	3480	250	32750	HIS250.FOR	HIS968	215	HIS968.OUT	31	HIS0896.DBF	7
1996.8	000973	3480	250	32750	HIS250.FOR	HIS973	219	HIS973.OUT	33		
1996.8	001020	3480	250	32750	HIS250.FOR	HIS1020	13	HIS1020.OUT	2		
1996.8	001062	3480	250	32750	HIS250.FOR	HIS1062	217	HIS1062.OUT	33		

Table E.2. Format and Structure of the Intermediate dBASE IV file HISMAS9x.DBF

Variable Name	Content (Municipal Utility Reference Field Underlined)	Type	Width
ACCT_NUM	Account number MF-Account - customer account number for service address	Character	9
NAME	Customer name MF-Name - Name of customer at the service address standardized to last name, first name, middle initial, suffix	Character	25
STR_CODE	Street code MF-Service Address - Physical address of the water meter location	Character	4
S_A_BLOCK	Service address block MF-Sev-Addr-Block	Character	5
S_A_SUFF	Service address suffix MF-Serv-Addr-Suffix	Character	3
S_A_DIRE	Service address direction MF-Serv-Address Direction - (N,E,S,W,NE,NW,SE,SW)	Character	2
S_A_STRE	Service address street MF-Serv-Addr-Street - (NAME)	Character	20
S_A_SSUF	Service street suffix MF-Serv-Street-Suffix - (example: ST)	Character	2
S_A_ATYP	Service address apartment type MF-Serv-Address-Type	Character	2
S_A_ANO	Service address apartment number MF-Serv-Address-NO	Character	4
M_A_BLOCK	Mailing address block MF-Mail-Addr-Block	Character	5
M_A_SUFF	Mailing address suffix MF-Mail-Addr-Suffix	Character	3
M_A_DIRE	Mailing address direction MF-Mail-Address Direction - (N,E,S,W,NE,NW,SE,SW)	Character	2
M_A_STRE	Mailing address street MF-Mail-Addr-Street - (NAME)	Character	20
M_A_SSUF	Mailing street suffix MF-Mail-Street-Suffix - (example: ST)	Character	2
M_A_ATYP	Mailing address apartment type MF-Mail-Address-Type	Character	2
M_A_ANO	Mailing address apartment number MF-Mail-Address-NO	Character	4
M_A_CITY	Mailing address city name MF-Mail-Addr-city	Character	15
M_A_ZCOD	Mailing address zipcode MF-Mail-Addr-Zipcode	Character	11
BILLDATE	The date which the city of Corpus Christi bills the customer AR-PROCESS-DATE - DDMMYY	Character	6
READDATE	Meter read date. Date the water meter was read (DDMMYY)	Character	6

Table E.2. Format and Structure of the Intermediate dBASE IV file HISMAS9x.DBF

	substring from AR:KEY - MMDDYY		
RATES	Indicates inside of outside city limits and utility services used MF-Rates - Identifies the rate structure for billng purposes	Character	6
ACCT_STA	Account status[1] MF-Acct-Status - Indicates current status of the account	Character	2
WCI_DATE	Water meter cut in date MF-Water-Cut-In-Date - Date water service starts on this account/meter	Character	6
WCO_DATE	Water meter cut off date MF-Water-Cut-Off-Date - Date water service discontinued for non-payment, seasonal, etc..	Character	6
INS_DATE	Water meter install date MF-Water-Mtr-Instal-Date - Date meter was installed	Character	6
EST_FLAG	The label for estimated bill flag for records with AR-TRANS-CODE subcoded 'EE'	Character	1
S_A_ZCOD	Service address zip code MF-Serv-Addr-Zipcode	Character	2
PRECIP	Aggregated precipitation (inches) during month of meter reading	Numeric	6
MAXTEMP	Averaged daily maximum temperature (degrees Fahrenheit)	Numeric	5
PRICE	The marginal water price (calculated)	Numeric	6
TRAN_COD	Transaction code[1] AR-TRANS-CODE - Code that identifies the type of history file record	Character	2
W_U_DAY	The number of days water was used since last reading or estimate AR-WATER-USE.DAYS	Character	3
W_READ	Water meter reading AR-WATER-READING	Character	7
W_CONS	Water consumption (thousand gallons) AR-WATER-CONS	Character	7
W_AMT	Dollar amount billed for water AR-WATER-AMT	Character	9
G_U_DAY	Gas use days AR-GAS-USE.DAYS	Character	3
G_READ	Gas meter reading number AR-GAS-READING	Character	7
G_CONS	Gas consumption AR-GAS-CONSUMPTION	Character	7
G_AMT	Dollar amount billed for gas consumption AR-GAS-AMT	Character	9

Table E.3. Format and Structure of the dBASE IV file HMSA3456.DBF

Variable Name	Content	Type	Width
ACCT_NUM	Account number	Character	9
NAME	Customer name	Character	25
BILLDATE	The date which the city of Corpus Christi bills the customer	Character	6
READDATE	The date which the water meters were read	Character	6
RATES	Water code to identify the sectors and the area to the city	Character	6
ACCT_STA	Account status	Character	2
WCI_DATE	Water meter cut in date	Character	6
WCO_DATE	Water meter cut off date	Character	6
INS_DATE	Water meter install date	Character	6
EST_FLAG	The label for estimated bill	Character	1
S_A_ZCOD	Service address zip code	Character	2
PRECIP	Aggregated precipitation	Character	6
MAXTEMP	Averaged daily maximum temperature	Character	5
PRICE	The marginal water price	Character	6
TRAN_COD	Transaction code	Character	2
W_U_DAY	Water use days	Character	3
W_READ	Water meter reading number	Character	7
W_CONS	Water consumption	Character	7
W_AMT	Bill amount for water consumption	Character	9
G_U_DAY	Gas use days	Character	3
G_READ	Gas meter reading number	Character	7
G_CONS	Gas consumption	Character	7
G_AMT	Bill amount for gas consumption	Character	9

Table E.4. Aggregated dBASE Files Created and Archived for this Project

Fiscal Year	Data File	Data Size (megabytes)
1992	not processed	-
1993	hismas93.dbf	245
1994	hismas94.dbf	178
1995	hismas95.dbf	251
1996	hismas96.dbf	223
1993-96	hmsa3456.dbf	499

Table E.5. Description of Flowchart Steps for Conversion Procedure

Step 1. Request copies of original backup data

Backup files containing the municipal utility data can be obtained in EBCIDIC format from the Municipal Information System Department, city of Corpus Christi. The department can create copies of backup files on either 10-inch reels or 3480 cartridge tapes. Two backup files in EBCIDIC format are required for each fiscal year of the study period--the master file and the history file.

Steps 2 and 3. Transfer data from tapes

Backup files should be transferred to an IBM-compatible computer. Both master and history files require multiple tapes for each fiscal year of data. A separate file containing only a portion of the complete database is created when each tape is downloaded. These are referred to as the "subset data." At least 450 megabytes of free storage are required to complete conversion of utility data for one fiscal year. Because the city's backup files are saved in EBCIDIC format, they need to be converted to ASCII format before continuing the procedure.

Step 4. Run conversion programs to create ASCII files

Raw data contain all variables in the utility database. Substantial amounts of time and storage space can be saved by discarding in the process any data that will not be analyzed. FORTRAN programs for this conversion are coded to write the subset data with only the necessary variables. Since both 6250 reel tapes and 3480 cartridge tapes were used for this project and these storage systems differ, two routines were needed: MAS80.For and HIS80.FOR. These routines download data from reel tapes. The routines MAS1650.FOR and HIS250.FOR manage data downloaded from 3480 cartridge tapes. Users can alter the selection of variables by making changes in the FORTRAN program. A complete list of codes and subcodes is available from the municipal information system. Table E.5 presents a partial list of variables used for the water conservation analysis.

Step 5. Create subset data in dBASE format

Outputs of the FORTRAN conversion program include a subset data file and a control file. These indicate the selection of variables (the subset datafile) and the data structure for dBASE files (control file). One blank dBASE file named HIS.DBF has been provided with the collection of datasets archived on tape for this project (HIS.DBF). If the selection of variables changes, a user should create a new dBASE file with the appropriate structure to receive the subset data.

Step 6. Copy datafile structure to new dBASE file

Copy the subset datafile structure output from that provided in the archive (HIS.DBF) to a new file to which all subset data will be appended. For example, this file could be called HIS93.DBF if it were to include the utility data for fiscal year 1993. This same procedure is completed in a separate step 6b for the master files.

Step 7. Append subset data (HIS101.OUT) to HIS93.DBF

The dBASE command Append should be used to store the subset data HIS101.OUT or other subset data in the storage database for the appropriate fiscal year. HIS93.DBF is a temporary storage file that contains all subset history files. This file is later merged with data from the master files. This same procedure should be completed in step 7b for the master files.

Step 8. Create output dataset in dBASE format

This is the dBASE file contained the subset history data. A separate dBASE file containing the master file is obtained by completing steps 6b and 7b.

Step 9. Run the dBASE program FILMAS.PRG

After history and master files have been converted to a dBASE file, the next step is to combine them by using account number (ACCT_NUM). The dBASE program "FILMAS.PRG" serves this purpose. The program will prompt the user for input and output file names during the run. For example, if fiscal year 1993 history and master files are being merged, then the user would indicate the input file names are HIS93.DBF and MAS93.DBF. The output file name would be HISMAS93.DBF.

Step 10. Obtain climatological data

Daily precipitation and mean maximum temperature were obtained in digital format from the Office of State Climatologist at Texas A&M University.

Step 11. Create rainfall temperature input dataset

Daily rainfall and temperature data must be available in digital format corresponding to the entire period of the history and master files. These data, beginning January 1, 1992 and running through August 31, 1996, are provided in a file entitled RAINTEMP.DBF.

Step 12. Run the dBASE program PTPRICE.PRG

The dBASE program "PTPRICE.PRG" combines the weather data and calculates each users marginal water price with utility data to form a comprehensive database.

Step 13. Program output is the combined dBASE file

This file contains utility data, weather data, and water price data. For the fiscal year 1993 data the output dataset would be named HISMAS93.DBF. The procedure beginning with steps 1 through 13 should be completed for each relevant fiscal year of the municipal utility database before going on to step 14.

Step 14. Run the dBASE program copyfiel.prg

The purpose of this program is to combine the data for each fiscal year into one single file and eliminate unnecessary variables. The large size of output data files may make them difficult to use with some systems, so the set of variables is reduced according to the purpose of the analysis. COPYFIEL.PRG creates the output dataset with only those fields necessary for the intended analysis. In this case, the output file is "HMSA3456.DBF".

Step 15. The final output aggregated data

This is an output file including selected variables covering four fiscal years of the municipal utility database including 1993, 1994, 1995, and 1996.

Appendix F. A Collection of FORTRAN Programs for Converting the Municipal Database Files

Sections 1 through 4 of this appendix are printouts of the FORTRAN programs used to convert the database files as described in Appendix E.

- Section 1 is MAS1065.FOR, which reads data converted to ASCII files from backup master files on 3480 cartridge tapes.
- Section 2 is MAS80.FOR, which reads data converted to ASCII from backup master files on 6250 reel tapes.
- Section 3 is HIS250.FOR, which reads data converted to ASCII files from backup history files on 3480 cartridge tapes.
- Section 4 is HIS80.FOR, which reads data converted to ASCII files form backup history files on 6250 reel tapes.

1. MAS1065.FOR

```
******************************************************************************
* LOW = the number of elements of RECORD(1065) that has been written so far
* RECORD(1065) = an array holding each record
* REMAIN = the number of elements of LINE(80) for next RECORD(1065)
* CHK = chk if the length of 1065 has been reached
* BCHK = chk if fixline has been called so that LINE(161) and LINE(162) can be chked
* TLLINE = total number of lines read
* ERRCHK = the number of times FIXSUB is called
* ERRLINE = the number of lines that are thrown away due to record error
* NSLT = the number of fields selected
* OUTNSLT = the number of fields selected for outpatient
* NRCRD = the number of records read in the block
* CTRL(12) = ctrl the field selection
* outctrl(*) = field selection control for outpatient
* CNT(12) = chk the number of non-zero entries
* ERRCNT(3) = count err records for 3 file types
* OUCNT(12) = chk the number of non-zero entries for outpatient
* BFPT(12) = returns a field's beginning point
* EFPT(12) = returns a field's ending point
* EFPT(i)-BFPT(i)+1 = the width of field(i)
* SLCT(12) = collect all the fields that are selected
* fname(12)= fieldnames
* kept(12)=kept/drop: all=all, drop=drop
* errfile= file which contains the error record content checked out by program
* state=the comlumn number of TX
******************************************************************************
*$DEBUG
       integer begin_time, end_time, dif_time
       real tlline
       character*20 status
       character*12 infile,recfile
       character*12 masfile,err1file,err2file
       character*1 line, line1, line2, record
       dimension  record(1065)
       dimension  line(80),line1(80),line2(80)
       integer low,remain,length,chk,errchk,errline,nrcrd,trcrd,
     1         bchk,nslt,outnslt,errcnt,k,fcnt
       integer ctrl,outctrl,bfpt,efpt,slct,endlabel,
     1         outslct,exchange,backward,linenum,wrtchk
       real outcnt
       character*12 outfile
       character*11 kept(97)
       character*16 fname(97)
       dimension ctrl(97),bfpt(97),efpt(97),slct(97),cnt(97),
     1 outslct(97),exchange(9),backward(9),
     2 outctrl(97),outcnt(97)
       common /ctrlctrl/ ctrl0
******************************************************************************
*   ctrl(i)=0 -> field(i) is not selected, 1 -> field(i) is selected
*  Ctrl0=0, print GFILE only
*  Ctrl0=3, print both
******************************************************************************
       data ctrl0/3./
       DATA CTRL/0,0,0,0,0,0,0,0,0,0,0,
     1          0,0,0,0,0,0,0,0,0,0,0,
     2          0,0,0,0,0,0,0,0,0,0,0,
     3          0,0,0,0,0,0,0,0,0,0,0,
     4          0,0,0,0,0,0,0,0,0,0,0,
     5          0,0,0,0,0,0,0,0,0,0,0,
     6          0,0,0,0,0,0,0,0,0,0,0,
     7          0,0,0,0,0,0,0,0,0,0,0,
     8          0,0,0,0,0,0,0,0,0,0,0,
     9           0,0,0,0,0,0,0/
       DATA OUTCTRL/1,0,1,0,1,0,1,0,1,0,1,0,
     1             1,0,1,0,1,0,1,0,1,0,
     2             1,0,1,0,1,0,1,0,1,0,
     3             1,0,1,0,1,0,1,0,1,0,
     4             1,0,1,0,1,0,1,0,1,0,
     5             1,0,1,0,1,0,1,0,1,0,
     6             1,0,1,0,1,0,1,0,1,0,
     7             1,0,1,0,1,0,1,0,1,0,
     8             1,0,1,0,1,0,1,0,1,0,
     9             1,0,1,0,1,0,1/
       DATA exchange/580,583,593,621,624,634,673,681,689/
       DATA backward/6,1,8,6,1,8,10,6,6/
******************************************************************************
       DATA BFPT/1,  3,  4, 13, 14, 39, 50, 54, 55, 60,
     1         61, 64, 65, 67, 68, 88, 89, 91, 92, 94,
```

```
     2           95, 99,100,105,106,109,110,112,113,133,
     3          134,136,137,139,140,144,145,160,161,163,
     4          178,184,185,191,192,198,285,291,292,298,
     5          317,318,319,325,326,332,333,340,353,359,
     6          360,366,385,386,387,393,401,408,419,420,
     7          542,548,549,555,556,557,574,581,582,584,
     8          585,594,615,622,623,625,626,635,663,674,
     9          675,682,683,690,941,943,944/
*****************************************************************************
      DATA EFPT/2,  3, 12, 13, 38, 49, 53, 54, 59, 60,
     1           63, 64, 66, 67, 87, 88, 90, 91, 93, 94,
     2           98, 99,104,105,108,109,111,112,132,133,
     3          135,136,138,139,143,144,159,160,162,177,
     4          183,184,190,191,197,284,290,291,297,316,
     5          317,318,324,325,331,332,339,352,358,359,
     6          365,384,385,386,392,399,407,418,419,541,
     7          547,548,554,555,556,573,580,581,583,584,
     8          593,614,621,622,624,625,634,662,673,674,
     9          681,682,689,940,942,943,954/
*****************************************************************************
*  initilize fname(i) and kept(i)
*****************************************************************************
      DATA KEPT/
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     1 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     2 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     3 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     4 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     5 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     6 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     7 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     8 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     9 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)'/

      DATA fname/
     * 'Acct-Sta',    ' ', 'Account',    ' ',    'Name','skip',
     1 'str-code',    ' ','S-A-Bloc',    ' ','S-A-Suff',    ' ',
     1 'S-A-Dire',    ' ','A-S-Stre',    ' ','S-A-S-Su',    ' ',
     1 'S-A-Atyp',    ' ', 'S-A-Ano',    ' ','M-A-Bloc',    ' ',
     1 'M-A-Suff',    ' ','M-A-Dire',    ' ','M-A-Stre',    ' ',
     1 'M-A-Suff',    ' ','M-A-Atyp',    ' ', 'M-A-Ano',    ' ',
     1 'M-A-City',    ' ','M-A-Stat','skip',   'Rates',    ' ',
      2 'Old-Rate',    ' ','R-C-Date','skip','WCI-Date',    ' ',
     3 'WCO-Date','skip','W-T-Code',    ' ','W-T-Date',    ' ',
     4 'Ins-Date',    ' ','W-Q-Cons','skip','GCI-Date',    ' ',
     5 'GCO-Date','skip','G-T-Code',    ' ','G-T-Date','skip',
     6 'G-Q-Read','skip','G-R-Read','skip','P-R-Date',    ' ',
     7 'C-R-Date',    ' ','Est-Flag','skip','W-Consum',    ' ',
     8 'W-U-Days',    ' ',   'W-Amt','skip','G-Consum',    ' ',
     9 'G-U-Days',    ' ',   'G-Amt','skip', 'G-T-Amt',    ' ',
     * 'T-W-Cons',    ' ','T-G-Cons','skip','S-A-Zcod',    ' ',
     * 'M-A-Zcod'/
*****************************************************************************
* give output filenames and open output files
*****************************************************************************
      outfile='gfile'
      DATA masfile/'mas.out'/
      err1file='err1file'
      err2file='err2file'
      recfile='recfile'
*****************************************************************************
* open output files
*****************************************************************************
      open(unit=6,file=outfile,status='unknown')
      open(unit=7,file='ctrlfile',status='unknown')
      open(unit=9,file=masfile,status='unknown')
      open(unit=10,file=err1file,status='unknown')
      open(unit=11,file=err2file,status='unknown')
      open(unit=12,file=recfile,status='unknown')
*****************************************************************************
*  get the infile names
*****************************************************************************
      write(*,*) ' infile=? '
      read(*,'(A12)') infile
```

```
*       write(*,*) ' labelln=? '
*       read(*,'(I1)') endlabel
       begin_time = secnds()
       open(unit=5,file=infile,status='old')
*******************************************************************************
*  initilize the SLCT
*******************************************************************************
       NSLT=0
       INSLT=0
       OUTSLT=0
       DSLT=0
****************************************GENERAL
       Do 30 i=1,97
         cnt(i)=0.
         outcnt(i)=0.
         if (ctrl(i) .eq. 1) then
           NSLT=NSLT+1
           slct(NSLT)=i
         endif
****************************************OUTPATIENT
         if (outctrl(i) .eq. 1) then
           outNSLT=outNSLT+1
           outslct(outNSLT)=i
         endif
30     continue
       low=1
       do 40 i=1,nslt
         length=efpt(slct(i))-bfpt(slct(i))
         write(6,'(5hfield,i2,4i4)')
     +     slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length
         low=low+length+1
40     continue
*******************************************************************************
 *  initialize low, length, remain, etc.
*******************************************************************************
       errchk=0
       bchk=0
       low=0
       length=1065
       remain=0
       tlline=0
       linenum=0
       nrcrd=0
       wrtchk=0
***********************************************************************
* quick initialization
***********************************************************************
       trcrd=0
*       do i=1,3
*         read(5,'(80A1)',err=100) (line(j),j=1,80)
*       enddo
*******************************************************************************
*  data cutting loop (1) Read in 80 characters in a line
*                    (2) write them into a record (400 characters long) !!This is an OLD
say
*                    (2) write them into a record (1065 characters long)
*******************************************************************************
50     read(5,'(1065A1)',err=100) (record(i),i=1,1065)
*******************************************************************************
        remind=0
        tlline=tlline+1.
        linenum=linenum+1
*       write(status,'(20A1)') (record(i),i=1,20)
*******************************************************************************
*  chk to see if MOD(nrcrecord/23)=0 *chk to see if MOD(nrcrecord/30)=0
*******************************************************************************
       nrcrd=nrcrd+1
*       write(12,*) 'status=',status
*       write(*,*) 'nrcrd=',nrcrd
*       write(*,*) 'status=',status
*******************************************************************************
*   the following section chks to see if this record is correct
*******************************************************************************
150    if(record(546) .ne. '9' .or. record(553) .ne. '9'
     1   .or. record(161) .eq. ' ' .or. record(162) .eq. ' '
     1   .or. record(160) .ne. ' ' .or. record(163) .ne. ' ') then
       if(record(546) .ne. '8' .or. record(553) .ne. '8'
     1   .or. record(161) .eq. ' ' .or. record(162) .eq. ' '
     1   .or. record(160) .ne. ' ' .or. record(163) .ne. ' ') then
       if(record(161) .ne. 'T' .or. record(162) .ne. 'X'   .or.
     1   record(160) .ne. ' ' .or. record(163) .ne. ' ') then
```

```
      if(record(161) .ne. 'C' .or. record(162) .ne. 'A'   .or.
    1   record(160) .ne. ' ' .or. record(163) .ne. ' ') then
      if(record(161) .ne. 'F' .or. record(162) .ne. 'L'   .or.
    1   record(160) .ne. ' ' .or. record(163) .ne. ' ') then
        linenum=0
        write(10,'(1065A1)') (record(i),i=1,1065)
        errchk=errchk+1
*         bchk=1   ! bchk=1 to indicate fixsub is called
*         call fixsub(line,tlline,record,length,
*    1              low)
        goto 50
      endif
      endif
      endif
      endif
      endif
*************************************************************************
*  start with next record's processing
*************************************************************************
*       if(nrcrd .gt. 94300) then
       wrtchk=wrtchk+1
*180        write(9,'(1065A1)') (record(i),i=1,1065)
*************************************************************************
*  using subroutine wrtsub to write records to event files
*************************************************************************
       call wrtsub(slct,outslct,bfpt,efpt,record,nslt,
    1             outnslt,exchange,backward)
*      endif
*      endif
       goto 50
*************************************************************************
100    continue
       write(7,*) 'trcrd=', trcrd, 'errchk', errchk
*       write(7,*) 'errln=', errline, 'errchk=',errchk
       write(6,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
       write(*,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
************************************************FOR GENERAL FILE***********
         write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
    +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
         low=1
         do 200 i=1,nslt
           if (trcrd .ne. 0.) then
             cnt(i)=cnt(i)/float(trcrd)*100.
           endif
           length=efpt(slct(i))-bfpt(slct(i))
           write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
    +      slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length,
    +      length+1,cnt(i),kept(slct(i)),fname(slct(i))
           low=low+length+1
200      continue
************************************************FOR outpatientfile *******
       write(7,*) 'trcrd=',trcrd, 'errchk', errchk, 'wrtchk', wrtchk
       k=1
*       write(7,*) 'OutFile=', ' # of rcd=',fcnt
       write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
    +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
       low=1
       do 220 i=1,outnslt
         if (trcrd .ne. 0.) then
           outcnt(i)=outcnt(i)/float(trcrd)*100.
         endif
         length=efpt(outslct(i))-bfpt(outslct(i))
         write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
    +    outslct(i),bfpt(outslct(i)),efpt(outslct(i)),low,low+length,
    +    length+1,outcnt(i),kept(outslct(i)),fname(outslct(i))
         low=low+length+1
220    continue
       end_time=secnds()
       dif_time = end_time - begin_time
       write(*,'(1x,6hstart:,i10,2x,4hend:,i10,2x,6hlapse:,i5,1hs)')
    +  begin_time,end_time,dif_time
       close(5)
       close(9)
       close(10)
       close(11)
       close(12)
       stop
       end
*************************************************************************
*  This section was completed at 01:12:27AM;11-Jun-1994
*************************************************************************
```

```
      real FUNCTION  secnds()
       INTEGER*2 hour, minute, second, hundredth
      CALL GETTIM( hour, minute, second, hundredth )
      secnds = ((DBLE( hour ) * 3600.0) + (DBLE( minute) * 60.0) +
     +          DBLE( second) + (DBLE( hundredth ) / 100.0))
      END
*****************************************************************************

******************************************************************************
* subroutine wrtsub takes record(382),slct,bfpt,efpt,nslt from CUTCLAIM main
* program, and writes the selected fields (characters) to outstr(382) before
* it writes outstr to events files based on the values in the events identify-
* ing field.
******************************************************************************
* SLCT(i) returns the series # of the selected field(i)  1<=SLCT(i)<=72
* bfpt(k) returns the BEGGINNING point of field(k)
* EFPT(k) returns the ENDING point of field(k)  1=<BFPT(k),EFPT(k)<=382
******************************************************************************
      subroutine wrtsub(slct,outslct,bfpt,efpt,record,
     1 nslt,outnslt,exchange,backward)
     integer nslt,outnslt,kout,trcrd,errcnt
     integer bfpt,efpt,slct,outslct,chk,exchange,backward
     real outcnt,cnt
     character*1 record(1),outstr(1065)
*     character*3 cntycode
*     character*12 plantype
     dimension bfpt(1),efpt(1),slct(1),outslct(1),
     1 cnt(1),outcnt(1),exchange(9),backward(9)
     common /ctrlctrl/ ctrl0
*     write(cntycode,'(3A1)') (record(i),i=25,27)
*     write(plantype,'(12A1)') (record(i),i=90,101)
******************************************************************************
*   write them out to general file
******************************************************************************
************************GENERAL FILE****************
     do i=1,9
       if (record(exchange(i)) .eq. '{' .or.
     1       record(exchange(i)) .eq. '}') then
         record(exchange(i))='0'
       else
       if (record(exchange(i)) .eq. 'A') then
         record(exchange(i))='1'
       else
       if (record(exchange(i)) .eq. 'B') then
         record(exchange(i))='2'
       else
       if (record(exchange(i)) .eq. 'C') then
         record(exchange(i))='3'
       else
       if (record(exchange(i)) .eq. 'D') then
         record(exchange(i))='4'
       else
       if (record(exchange(i)) .eq. 'E') then
         record(exchange(i))='5'
       else
       if (record(exchange(i)) .eq. 'F') then
         record(exchange(i))='6'
       else
       if (record(exchange(i)) .eq. 'G') then
         record(exchange(i))='7'
       else
       if (record(exchange(i)) .eq. 'H') then
         record(exchange(i))='8'
       else
       if (record(exchange(i)) .eq. 'I') then
         record(exchange(i))='9'
        else
       if (record(exchange(i)) .eq. 'J') then
         record(exchange(i))='1'
         record(exchange(i)-backward(i))='-'
       else
       if (record(exchange(i)) .eq. 'K') then
         record(exchange(i))='2'
         record(exchange(i)-backward(i))='-'
       else
       if (record(exchange(i)) .eq. 'L') then
         record(exchange(i))='3'
         record(exchange(i)-backward(i))='-'
       else
       if (record(exchange(i)) .eq. 'M') then
```

```
            record(exchange(i))='4'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'N') then
            record(exchange(i))='5'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'O') then
            record(exchange(i))='6'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'P') then
            record(exchange(i))='7'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'Q') then
            record(exchange(i))='8'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'R') then
            record(exchange(i))='9'
            record(exchange(i)-backward(i))='-'
          else
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
        enddo
        IF (ctrl0 .eq. 0. .or. ctrl0 .eq. 3.) then      ! WIF1
        kout=0
        do 20 i=1,nslt
          chk=0
          do 15 k=bfpt(slct(i)),efpt(slct(i))
*             if (chk .eq. 0) then                         ! WIF1-1
*               if(record(k) .ne. ' ' .and. record(k) .ne. '0') then     ! WIF1-2
*                cnt(i)=cnt(i)+1.0
*                chk=1
*               endif                                                    ! WIF1-2
*             endif                                                      ! WIF1-1
          kout=kout+1
          outstr(kout)=record(k)
15        continue
20      continue
c        write(6,'(80A1)') (outstr(i),i=1,kout)
        write(6,'(1065A1)') (outstr(i),i=1,kout)
        ENDIF                                        ! WIF1
*        IF (ctrl0 .eq. 1. .or. ctrl0 .eq. 3.) THEN  ! WIF2
************************OUTPATIENT FILE****************
*         if (ctrl0 .eq. 3) goto 100                 ! added so that outpat is not
written
         kout=0
         do 50 i=1,outnslt
          chk=0
          do 45 k=bfpt(outslct(i)),efpt(outslct(i))
*             if (chk .eq. 0) then
*               if(record(k) .ne. ' ' .and. record(k) .ne. '0') then
*                outcnt(i)=outcnt(i)+1.0
*                chk=1
*               endif
*             endif
          kout=kout+1
          outstr(kout)=record(k)
45        continue
50       continue
*         if (record(34) .eq. ' ' .or. record(34) .eq. '3' .or.
*     1       record(34) .eq. '5' .or. record(34) .eq. '6' .or.
```

```
*     2       record(34) .eq. 'C' .or. record(34) .eq. 'E' .or.
*     3       record(34) .eq. 'R') then
          write(9,'(1065A1)') (outstr(i),i=1,kout)
*        endif
*       ENDIF                                    ! WIF2
100   continue
      return
      end
```

2. MAS80.FOR

```
******************************************************************************
* LOW = the number of elements of RECORD(1065) that has been written so far
* RECORD(1065) = an array holding each record
* REMAIN = the number of elements of LINE(80) for next RECORD(1065)
* CHK = chk if the length of 1065 has been reached
* BCHK = chk if fixline has been called so that LINE(161) and LINE(162) can be chked
* TLLINE = total number of lines read
* ERRCHK = the number of times FIXSUB is called
* ERRLINE = the number of lines that are thrown away due to record error
* NSLT = the number of fields selected
* OUTNSLT = the number of fields selected for outpatient
* NRCRD = the number of records read in the block
* CTRL(12) = ctrl the field selection
* outctrl(*) = field selection control for outpatient
* CNT(12) = chk the number of non-zero entries
* ERRCNT(3) = count err records for 3 file types
* OUCNT(12) = chk the number of non-zero entries for outpatient
* BFPT(12) = returns a field's beginning point
* EFPT(12) = returns a field's ending point
* EFPT(i)-BFPT(i)+1 = the width of field(i)
* SLCT(12) = collect all the fields that are selected
* fname(12)= fieldnames
* kept(12)=kept/drop: all=all, drop=drop
* errfile= file which contains the error record content checked out by program
* state=the comlumn number of TX
******************************************************************************
*$DEBUG
      integer begin_time, end_time, dif_time
      real tlline
      character*20 status
      character*12 infile,recfile
      character*12 masfile,errlfile,err2file
      character*1 line, line1, line2, record
      dimension  record(1065)
      dimension  line(80),line1(80),line2(80)
      integer low,remain,length,chk,errchk,errline,nrcrd,trcrd,
     1        bchk,nslt,outnslt,errcnt,k,fcnt
      integer ctrl,outctrl,bfpt,efpt,slct,endlabel,
     1        outslct,exchange,backward,linenum,wrtchk
      real outcnt
      character*12 outfile
      character*11 kept(63)
      character*16 fname(63)
      dimension ctrl(63),bfpt(63),efpt(63),slct(63),cnt(63),
     1 outslct(63),exchange(9),backward(9),
     2 outctrl(63),outcnt(63)
      common /ctrlctrl/ ctrl0
******************************************************************************
*   ctrl(i)=0 -> field(i) is not selected, 1 -> field(i) is selected
*  Ctrl0=0, print GFILE only, Ctrl0=1, print Inpatient, etc, files only
*  Ctrl0=3, print both
******************************************************************************
      data ctrl0/3./
      DATA CTRL/0,0,0,0,0,0,0,0,0,0,
     1          0,0,0,0,0,0,0,0,0,0,
     2          0,0,0,0,0,0,0,0,0,0,
     3                 0,0,0,0,0,0,0,0,0,0,
     4                 0,0,0,0,0,0,0,0,0,0,
     5                 0,0,0,0,0,0,0,0,0,0,
     6                 0,0,0/
      DATA OUTCTRL/1,0,1,0,1,0,1,0,1,0,
     1             1,0,1,0,1,0,1,0,1,0,
     2            1,0,1,0,1,0,1,0,1,0,
     3                   1,0,1,0,1,0,1,0,1,0,
     4                   1,0,1,0,1,0,1,0,1,0,
     5                   1,0,1,0,1,0,1,0,1,0,
     6                   1,0,1/
      DATA exchange/580,583,593,621,624,634,673,681,689/
```

```
      DATA backward/6,1,8,6,1,8,10,6,6/
*****************************************************************************
      DATA BFPT/1,  3,  4, 13, 14, 39, 55, 60,178,184,
     1         185,191,192,198,285,291,292,298,317,318,
     2         319,325,326,332,333,340,353,359,360,366,
     3         385,386,387,393,401,408,419,420,542,548,
     4         549,555,556,557,574,581,582,584,585,594,
     5         615,622,623,625,626,635,663,674,675,682,
     6         683,690,941/
*****************************************************************************
      DATA EFPT/2,  3, 12, 13, 38, 54, 59,177,183,184,
     1         190,191,197,284,290,291,297,316,317,318,
     2         324,325,331,332,339,352,358,359,365,384,
     3         385,386,392,399,407,418,419,541,547,548,
     4         554,555,556,573,580,581,583,584,593,614,
     5         621,622,624,625,634,662,673,674,681,682,
     6         689,940,942/
*****************************************************************************
*  initilize fname(i) and kept(i)
*****************************************************************************
      DATA KEPT/
     * '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     1 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     2 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     3 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     4 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     5 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     6 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     7 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     8 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     9 '(all)','(drop)','(all)','(drop)','(all)','(drop)',
     * '(all)','(drop)','(all)'/

      DATA fname/
     * 'Acct-Sta',    ' ', 'Account',    ' ',     'Name','skip',
     1 'S-A-bloc','skip',   'Rates',    ' ','Old-Rate',    ' ',
     2 'R-C-Date','skip','WCI-Date',    ' ','WCO-Date','skip',
     3 'W-T-Code',    ' ','W-T-Date',    ' ','Ins-Date',    ' ',
     4 'W-Q-Cons','skip','GCI-Date',    ' ','GCO-Date','skip',
     5 'G-T-Code',    ' ','G-T-Date','skip','G-Q-Read','skip',
     6 'G-R-Read','skip','P-R-Date',    ' ','C-R-Date',    ' ',
     7 'Est-Flag','skip','W-Consum',    ' ','W-U-Days',    ' ',
     8    'W-Amt','skip','G-Consum',    ' ','G-U-Days',    ' ',
     9    'G-Amt','skip', 'G-T-Amt',    ' ','T-W-Cons',    ' ',
     * 'T-G-Cons','skip','S-A-Zcod'/
*****************************************************************************
* give output filenames and open output files
*****************************************************************************
      outfile='gfile'
      DATA masfile/'mas.out'/
      err1file='err1file'
      err2file='err2file'
      recfile='recfile'
*****************************************************************************
* open output files
*****************************************************************************
      open(unit=6,file=outfile,status='unknown')
      open(unit=7,file='ctrlfile',status='unknown')
       open(unit=9,file=masfile,status='unknown')
      open(unit=10,file=err1file,status='unknown')
      open(unit=11,file=err2file,status='unknown')
      open(unit=12,file=recfile,status='unknown')
*****************************************************************************
*  get the infile names
*****************************************************************************
      write(*,*) ' infile=? '
      read(*,'(A12)') infile
*      write(*,*) ' labelln=? '
*      read(*,'(I1)') endlabel
      begin_time = secnds()
      open(unit=5,file=infile,status='old')
*****************************************************************************
*  initilize the SLCT
*****************************************************************************
      NSLT=0
      INSLT=0
      OUTSLT=0
      DSLT=0
*************************************GENERAL
      Do 30 i=1,63
        cnt(i)=0.
```

```
          outcnt(i)=0.
          if (ctrl(i) .eq. 1) then
            NSLT=NSLT+1
            slct(NSLT)=i
          endif
****************************************OUTPATIENT
          if (outctrl(i) .eq. 1) then
            outNSLT=outNSLT+1
            outslct(outNSLT)=i
          endif
30      continue
        low=1
        do 40 i=1,nslt
          length=efpt(slct(i))-bfpt(slct(i))
***         write(6,'(5hfield,i2,4i4)')
***      +     slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length
          low=low+length+1
40      continue
*******************************************************************************
*  initialize low, length, remain, etc.
*******************************************************************************
        errchk=0
        bchk=0
        low=0
        length=1065
        remain=0
        tlline=0
        linenum=0
        nrcrd=0
        wrtchk=0
**********************************************************************
* quick initialization
**********************************************************************
        trcrd=0
        do i=1,3
          read(5,'(80A1)',err=100) (line(j),j=1,80)
        enddo
*******************************************************************************
*  data cutting loop (1) Read in 80 characters in a line
*                    (2) write them into a record (1065 characters long)
*******************************************************************************
50      read(5,'(80A1)',err=100) (line(i),i=1,80)
 ******************************************************************************
         remind=0
         tlline=tlline+1.
         linenum=linenum+1
               if(line(1) .eq. 'T' .and. line(2) .eq. 'X' .and.
     1        tlline .gt. 1 .and. tlline .lt. 6) then
           tlline=3
         endif
               if(line(26) .eq. 'T' .and. line(27) .eq. 'X' .and.
     1        tlline .gt. 13 .and. tlline .lt. 19) then
           tlline=16
         endif
               if(line(51) .eq. 'T' .and. line(52) .eq. 'X' .and.
     1        tlline .gt. 26 .and. tlline .lt. 32) then
           tlline=29
         endif
               if(line(76) .eq. 'T' .and. line(77) .eq. 'X' .and.
     1        tlline .gt. 39 .and. tlline .lt. 45) then
           tlline=42
         endif
               if(line(21) .eq. 'T' .and. line(22) .eq. 'X' .and.
     1        tlline .gt. 53 .and. tlline .lt. 59) then
           tlline=56
         endif
               if(line(46) .eq. 'T' .and. line(47) .eq. 'X' .and.
     1        tlline .gt. 66 .and. tlline .lt. 72) then
           tlline=69
         endif
               if(line(71) .eq. 'T' .and. line(72) .eq. 'X' .and.
     1        tlline .gt. 79 .and. tlline .lt. 85) then
           tlline=82
         endif
               if(line(16) .eq. 'T' .and. line(17) .eq. 'X' .and.
     1        tlline .gt. 93 .and. tlline .lt. 99) then
           tlline=96
         endif
               if(line(41) .eq. 'T' .and. line(42) .eq. 'X' .and.
     1        tlline .gt. 106 .and. tlline .lt. 112) then
           tlline=109
```

```
      endif
            if(line(66) .eq. 'T' .and. line(67) .eq. 'X' .and.
     1      tlline .gt. 119 .and. tlline .lt. 125) then
        tlline=122
      endif
            if(line(11) .eq. 'T' .and. line(12) .eq. 'X' .and.
     1      tlline .gt. 133 .and. tlline .lt. 139) then
        tlline=136
      endif
            if(line(36) .eq. 'T' .and. line(37) .eq. 'X' .and.
     1      tlline .gt. 146 .and. tlline .lt. 152) then
        tlline=149
      endif
            if(line(61) .eq. 'T' .and. line(62) .eq. 'X' .and.
     1      tlline .gt. 159 .and. tlline .lt. 165) then
        tlline=162
      endif
            if(line(6) .eq. 'T' .and. line(7) .eq. 'X' .and.
     1      tlline .gt. 173 .and. tlline .lt. 179) then
        tlline=176
      endif
            if(line(31) .eq. 'T' .and. line(32) .eq. 'X' .and.
     1      tlline .gt. 186 .and. tlline .lt. 192) then
        tlline=189
      endif
            if(line(56) .eq. 'T' .and. line(57) .eq. 'X' .and.
     1      tlline .gt. 199 .and. tlline .lt. 205) then
        tlline=202
      endif
            if(line(1) .eq. 'T' .and. line(2) .eq. 'X' .and.
     1      tlline .gt. 213 .and. tlline .lt. 219) then
        tlline=216
      endif
            if(line(26) .eq. 'T' .and. line(27) .eq. 'X' .and.
     1      tlline .gt. 226 .and. tlline .lt. 232) then
        tlline=229
      endif
            if(line(51) .eq. 'T' .and. line(52) .eq. 'X' .and.
     1      tlline .gt. 239 .and. tlline .lt. 245) then
        tlline=242
      endif
            if(line(76) .eq. 'T' .and. line(77) .eq. 'X' .and.
     1      tlline .gt. 252 .and. tlline .lt. 258) then
        tlline=255
      endif
            if(line(21) .eq. 'T' .and. line(22) .eq. 'X' .and.
     1      tlline .gt. 266 .and. tlline .lt. 272) then
        tlline=269
      endif
            if(line(46) .eq. 'T' .and. line(47) .eq. 'X' .and.
     1      tlline .gt. 279 .and. tlline .lt. 285) then
        tlline=282
      endif
            if(line(71) .eq. 'T' .and. line(72) .eq. 'X' .and.
     1      tlline .gt. 292 .and. tlline .lt. 298) then
        tlline=295
      endif
            if(line(16) .eq. 'T' .and. line(17) .eq. 'X' .and.
     1      tlline .gt. 306 .and. tlline .lt. 312) then
        tlline=309
      endif
            if(line(41) .eq. 'T' .and. line(42) .eq. 'X' .and.
     1      tlline .gt. 319 .and. tlline .lt. 325) then
        tlline=322
      endif
            if(line(66) .eq. 'T' .and. line(67) .eq. 'X' .and.
     1      tlline .gt. 332 .and. tlline .lt. 338) then
        tlline=335
      endif
            if(line(11) .eq. 'T' .and. line(12) .eq. 'X' .and.
     1      tlline .gt. 346 .and. tlline .lt. 352) then
        tlline=349
      endif
            if(line(36) .eq. 'T' .and. line(37) .eq. 'X' .and.
     1      tlline .gt. 359 .and. tlline .lt. 365) then
        tlline=362
      endif
            if(line(61) .eq. 'T' .and. line(62) .eq. 'X' .and.
     1      tlline .gt. 372 .and. tlline .lt. 378) then
        tlline=375
      endif
```

```
            if(line(6) .eq. 'T' .and. line(7) .eq. 'X' .and.
     1         tlline .gt. 386 .and. tlline .lt. 392) then
             tlline=389
           endif

           if(tlline .eq. 213) then
             remind=1
           else
           if(tlline .eq. 400) then
             remind=1
              tlline=0
           endif
           endif
         chk=length-80
         if(chk .gt. 0) then
           length=length-80
           do i=1,80
             record(i+low)=line(i)
           enddo
           low=low+80
           goto 50
         else
******************************************************************************
*  length < 80, the record is completed below
******************************************************************************
           remain=80-length
           do i=1,length
             record(i+low)=line(i)
           enddo
         endif
***        write(status,'(20A1)') (record(i),i=1,20)
******************************************************************************
*  chk to see if MOD(nrcrecord/23)=0 *chk to see if MOD(nrcrecord/30)=0
******************************************************************************
         nrcrd=nrcrd+1
***        write(12,*) 'status=',status
***        write(*,*) 'nrcrd=',nrcrd
***        write(*,*) 'status=',status
******************************************************************************
*   the following section chks to see if this record is correct
******************************************************************************
150      if(record(546) .ne. '9' .or. record(553) .ne. '9'
     1     .or. record(161) .eq. ' ' .or. record(162) .eq. ' '
     1     .or. record(160) .ne. ' ' .or. record(163) .ne. ' ') then
         if(record(546) .ne. '8' .or. record(553) .ne. '8'
     1     .or. record(161) .eq. ' ' .or. record(162) .eq. ' '
     1     .or. record(160) .ne. ' ' .or. record(163) .ne. ' ') then
         if(record(161) .ne. 'T' .or. record(162) .ne. 'X'    .or.
     1     record(160) .ne. ' ' .or. record(163) .ne. ' ') then
         if(record(161) .ne. 'C' .or. record(162) .ne. 'A'    .or.
     1     record(160) .ne. ' ' .or. record(163) .ne. ' ') then
         if(record(161) .ne. 'F' .or. record(162) .ne. 'L'    .or.
     1     record(160) .ne. ' ' .or. record(163) .ne. ' ') then
           linenum=0
***          write(10,'(1065A1)') (record(i),i=1,1065)
           errchk=errchk+1
           bchk=1   ! bchk=1 to indicate fixsub is called
           call fixsub(line,tlline,record,length,
     1             low)
           goto 50
         endif
         endif
         endif
         endif
         endif
******************************************************************************
*  start with next record's processing
******************************************************************************
*          if(nrcrd .gt. 94300) then
           wrtchk=wrtchk+1
*180          write(9,'(1065A1)') (record(i),i=1,1065)
******************************************************************************
*  using subroutine wrtsub to write records to event files
******************************************************************************
***          call wrtsub(slct,outslct,bfpt,efpt,record,nslt,
 ***     1               outnslt,exchange,backward)
*          endif
*          endif
         linenum=0
******************************************************************************
*  start with next record's processing
```

```
**************************************************************************
75      low=0
        if(remind .eq. 1) then
           remain=0
        endif
        if(remain .ne. 0) then
          do i=1,remain
            record(low+i)=line(80-remain+i)
          enddo
          low=low+remain
        endif
        length=1065-remain
        goto 50
**************************************************************************
100     continue
        write(7,*) 'trcrd=', trcrd, 'errchk', errchk
*        write(7,*) 'errln=', errline, 'errchk=',errchk
***        write(6,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
***        write(*,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
*********************************************FOR GENERAL FILE***********
          write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
          low=1
          do 200 i=1,nslt
            if (trcrd .ne. 0.) then
              cnt(i)=cnt(i)/float(trcrd)*100.
            endif
            length=efpt(slct(i))-bfpt(slct(i))
            write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +      slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length,
     +      length+1,cnt(i),kept(slct(i)),fname(slct(i))
            low=low+length+1
200       continue
*********************************************FOR outpatientfile *******
        write(7,*) 'trcrd=',trcrd, 'errchk', errchk, 'wrtchk', wrtchk
        k=1
*        write(7,*) 'OutFile=', ' # of rcd=',fcnt
        write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
        low=1
        do 220 i=1,outnslt
          if (trcrd .ne. 0.) then
            outcnt(i)=outcnt(i)/float(trcrd)*100.
          endif
          length=efpt(outslct(i))-bfpt(outslct(i))
          write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +    outslct(i),bfpt(outslct(i)),efpt(outslct(i)),low,low+length,
     +    length+1,outcnt(i),kept(outslct(i)),fname(outslct(i))
          low=low+length+1
220     continue
        end_time=secnds()
        dif_time = end_time - begin_time
        write(*,'(1x,6hstart:,i10,2x,4hend:,i10,2x,6hlapse:,i5,1hs)')
     +  begin_time,end_time,dif_time
        close(5)
        close(9)
        close(10)
        close(11)
        close(12)
         stop
        end
**************************************************************************
*  This section was completed at 01:12:27AM;11-Jun-1994
**************************************************************************

        real FUNCTION  secnds()
        INTEGER*2 hour, minute, second, hundredth
        CALL GETTIM( hour, minute, second, hundredth )
        secnds = ((DBLE( hour ) * 3600.0) + (DBLE( minute) * 60.0) +
     +            DBLE( second) + (DBLE( hundredth ) / 100.0))
        END
**************************************************************************
**************************************************************************
*  Subroutine 'Fixsub' is going to check if the record is a bad record
*  which means that "record(161) .ne. 'T' .or. record(162) .ne. 'X'" has
*  been found and then the record is put into a file which is specially
*  prepared for bad records. The program will continue to search the right
*  position of T and X untill it finds them that means a new good record has
*  been found
*
*
```

```
*
*************************************************************************
*************************************************************************
      subroutine fixsub(lines,tllines,records,lengths,
     1                  lows)
      real tllines
      integer lows,lengths,state
      integer onlythre,remain
      character*1 lines(80), records(1065)
      character*1 line1(80),line2(80),line3(80)
*************************************************************************
*  initialize low, length, remain
*************************************************************************
      lows=0
      lengths=1065
      onlythre=0
      do i=1,80
        line3(i)=lines(i)
        line2(i)=lines(i)
        line1(i)=lines(i)
      enddo
5     read(5,'(80A1)',err=20) (lines(i),i=1,80)
      tllines=tllines+1
            if(lines(1) .eq. 'T' .and. lines(2) .eq. 'X' .and.
     1     tllines .gt. 1 .and. tllines .lt. 6) then
        tllines=3
      endif
            if(lines(26) .eq. 'T' .and. lines(27) .eq. 'X' .and.
     1     tllines .gt. 13 .and. tllines .lt. 19) then
        tllines=16
      endif
            if(lines(51) .eq. 'T' .and. lines(52) .eq. 'X' .and.
     1     tllines .gt. 26 .and. tllines .lt. 32) then
        tllines=29
      endif
            if(lines(76) .eq. 'T' .and. lines(77) .eq. 'X' .and.
     1     tllines .gt. 39 .and. tllines .lt. 45) then
        tllines=42
      endif
            if(lines(21) .eq. 'T' .and. lines(22) .eq. 'X' .and.
     1     tllines .gt. 53 .and. tllines .lt. 59) then
        tllines=56
      endif
             if(lines(46) .eq. 'T' .and. lines(47) .eq. 'X' .and.
     1     tllines .gt. 66 .and. tllines .lt. 72) then
        tllines=69
      endif
            if(lines(71) .eq. 'T' .and. lines(72) .eq. 'X' .and.
     1     tllines .gt. 79 .and. tllines .lt. 85) then
        tllines=82
      endif
            if(lines(16) .eq. 'T' .and. lines(17) .eq. 'X' .and.
     1     tllines .gt. 93 .and. tllines .lt. 99) then
        tllines=96
      endif
            if(lines(41) .eq. 'T' .and. lines(42) .eq. 'X' .and.
     1     tllines .gt. 106 .and. tllines .lt. 112) then
        tllines=109
      endif
            if(lines(66) .eq. 'T' .and. lines(67) .eq. 'X' .and.
     1     tllines .gt. 119 .and. tllines .lt. 125) then
        tllines=122
      endif
            if(lines(11) .eq. 'T' .and. lines(12) .eq. 'X' .and.
     1     tllines .gt. 133 .and. tllines .lt. 139) then
        tllines=136
      endif
            if(lines(36) .eq. 'T' .and. lines(37) .eq. 'X' .and.
     1     tllines .gt. 146 .and. tllines .lt. 152) then
        tllines=149
      endif
            if(lines(61) .eq. 'T' .and. lines(62) .eq. 'X' .and.
     1     tllines .gt. 159 .and. tllines .lt. 165) then
        tllines=162
      endif
            if(lines(6) .eq. 'T' .and. lines(7) .eq. 'X' .and.
     1     tllines .gt. 173 .and. tllines .lt. 179) then
        tllines=176
      endif
            if(lines(31) .eq. 'T' .and. lines(32) .eq. 'X' .and.
     1     tllines .gt. 186 .and. tllines .lt. 192) then
```

```
          tllines=189
        endif
              if(lines(56) .eq. 'T' .and. lines(57) .eq. 'X' .and.
     1        tllines .gt. 199 .and. tllines .lt. 205) then
          tllines=202
        endif
              if(lines(1) .eq. 'T' .and. lines(2) .eq. 'X' .and.
     1        tllines .gt. 213 .and. tllines .lt. 219) then
          tllines=216
        endif
              if(lines(26) .eq. 'T' .and. lines(27) .eq. 'X' .and.
     1        tllines .gt. 226 .and. tllines .lt. 232) then
          tllines=229
        endif
              if(lines(51) .eq. 'T' .and. lines(52) .eq. 'X' .and.
     1        tllines .gt. 239 .and. tllines .lt. 245) then
          tllines=242
        endif
              if(lines(76) .eq. 'T' .and. lines(77) .eq. 'X' .and.
     1        tllines .gt. 252 .and. tllines .lt. 258) then
          tllines=255
        endif
              if(lines(21) .eq. 'T' .and. lines(22) .eq. 'X' .and.
     1        tllines .gt. 266 .and. tllines .lt. 272) then
          tllines=269
        endif
              if(lines(46) .eq. 'T' .and. lines(47) .eq. 'X' .and.
     1        tllines .gt. 279 .and. tllines .lt. 285) then
          tllines=282
        endif
              if(lines(71) .eq. 'T' .and. lines(72) .eq. 'X' .and.
     1        tllines .gt. 292 .and. tllines .lt. 298) then
          tllines=295
        endif
              if(lines(16) .eq. 'T' .and. lines(17) .eq. 'X' .and.
     1        tllines .gt. 306 .and. tllines .lt. 312) then
          tllines=309
        endif
              if(lines(41) .eq. 'T' .and. lines(42) .eq. 'X' .and.
     1        tllines .gt. 319 .and. tllines .lt. 325) then
          tllines=322
        endif
              if(lines(66) .eq. 'T' .and. lines(67) .eq. 'X' .and.
     1        tllines .gt. 332 .and. tllines .lt. 338) then
          tllines=335
        endif
              if(lines(11) .eq. 'T' .and. lines(12) .eq. 'X' .and.
     1        tllines .gt. 346 .and. tllines .lt. 352) then
          tllines=349
        endif
              if(lines(36) .eq. 'T' .and. lines(37) .eq. 'X' .and.
     1        tllines .gt. 359 .and. tllines .lt. 365) then
          tllines=362
        endif
              if(lines(61) .eq. 'T' .and. lines(62) .eq. 'X' .and.
     1        tllines .gt. 372 .and. tllines .lt. 378) then
          tllines=375
        endif
              if(lines(6) .eq. 'T' .and. lines(7) .eq. 'X' .and.
     1        tllines .gt. 386 .and. tllines .lt. 392) then
          tllines=389
        endif
        if(tllines .ge. 400) then
          tllines=0
        endif
        do i=1,80
          line3(i)=line2(i)
          line2(i)=line1(i)
          line1(i)=lines(i)
        enddo
**************************************************************************
*  search for the patten
**************************************************************************
        do i=2,80
        if(lines(i-1) .eq. 'T' .and. lines(i) .eq. 'X') then
110           lows=0
              state=i-1                  ! patten found
              remain1=80-state+1
              lengths=1065-remain1
              do j=1,remain1
                records(j+lows)=line3(80-remain1+j)
```

```
            enddo
            lows=lows+remain1
            lengths=lengths-80
            do j=1,80
              records(j+lows)=line2(j)
            enddo
            lows=lows+80
            lengths=lengths-80
            do j=1,80
              records(j+lows)=line1(j)
            enddo
             lows=lows+80
            bchks=0
            goto 20
          endif
        enddo
        lows=0
        lengths=1065
        goto 5
20      continue
        return
        end

*******************************************************************************
* subroutine wrtsub takes record(382),slct,bfpt,efpt,nslt from CUTCLAIM main
* program, and writes the selected fields (characters) to outstr(382) before
* it writes outstr to events files based on the values in the events identify-
* ing field.
*******************************************************************************
* SLCT(i) returns the series # of the selected field(i)  1<=SLCT(i)<=72
* bfpt(k) returns the BEGGINNING point of field(k)
* EFPT(k) returns the ENDING point of field(k)  1=<BFPT(k),EFPT(k)<=382
*******************************************************************************
        subroutine wrtsub(slct,outslct,bfpt,efpt,record,
     1  nslt,outnslt,exchange,backward)
       integer nslt,outnslt,kout,trcrd,errcnt
       integer bfpt,efpt,slct,outslct,chk,exchange,backward
       real outcnt,cnt
       character*1 record(1),outstr(1065)
*       character*3 cntycode
*       character*12 plantype
       dimension bfpt(1),efpt(1),slct(1),outslct(1),
     1 cnt(1),outcnt(1),exchange(9),backward(9)
       common /ctrlctrl/ ctrl0
*       write(cntycode,'(3A1)') (record(i),i=25,27)
*       write(plantype,'(12A1)') (record(i),i=90,101)
*******************************************************************************
*   write them out to general file
*******************************************************************************
************************GENERAL FILE***************
       do i=1,9
         if (record(exchange(i)) .eq. '{' .or.
     1        record(exchange(i)) .eq. '}') then
           record(exchange(i))='0'
         else
         if (record(exchange(i)) .eq. 'A') then
           record(exchange(i))='1'
         else
         if (record(exchange(i)) .eq. 'B') then
           record(exchange(i))='2'
         else
         if (record(exchange(i)) .eq. 'C') then
           record(exchange(i))='3'
         else
         if (record(exchange(i)) .eq. 'D') then
           record(exchange(i))='4'
         else
         if (record(exchange(i)) .eq. 'E') then
           record(exchange(i))='5'
         else
         if (record(exchange(i)) .eq. 'F') then
           record(exchange(i))='6'
         else
         if (record(exchange(i)) .eq. 'G') then
           record(exchange(i))='7'
          else
         if (record(exchange(i)) .eq. 'H') then
           record(exchange(i))='8'
         else
         if (record(exchange(i)) .eq. 'I') then
```

```
            record(exchange(i))='9'
          else
          if (record(exchange(i)) .eq. 'J') then
            record(exchange(i))='1'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'K') then
            record(exchange(i))='2'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'L') then
            record(exchange(i))='3'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'M') then
            record(exchange(i))='4'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'N') then
            record(exchange(i))='5'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'O') then
            record(exchange(i))='6'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'P') then
            record(exchange(i))='7'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'Q') then
            record(exchange(i))='8'
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'R') then
            record(exchange(i))='9'
            record(exchange(i)-backward(i))='-'
          else
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
        enddo
        IF (ctrl0 .eq. 0. .or. ctrl0 .eq. 3.) then      ! WIF1
        kout=0
         do 20 i=1,nslt
          chk=0
          do 15 k=bfpt(slct(i)),efpt(slct(i))
*            if (chk .eq. 0) then                       ! WIF1-1
*              if(record(k) .ne. ' ' .and. record(k) .ne. '0') then    ! WIF1-2
*               cnt(i)=cnt(i)+1.0
*               chk=1
*              endif                                                   ! WIF1-2
*            endif                                                     ! WIF1-1
          kout=kout+1
          outstr(kout)=record(k)
15        continue
20      continue
c        write(6,'(80A1)') (outstr(i),i=1,kout)
        write(6,'(1065A1)') (outstr(i),i=1,kout)
        ENDIF                                          ! WIF1
*        IF (ctrl0 .eq. 1. .or. ctrl0 .eq. 3.) THEN  ! WIF2
*************************OUTPATIENT FILE****************
*         if (ctrl0 .eq. 3) goto 100                 ! added so that outpat is not
written
         kout=0
```

```
       do 50 i=1,outnslt
        chk=0
        do 45 k=bfpt(outslct(i)),efpt(outslct(i))
*          if (chk .eq. 0) then
*            if(record(k) .ne. ' ' .and. record(k) .ne. '0') then
*             outcnt(i)=outcnt(i)+1.0
*             chk=1
*            endif
*          endif
        kout=kout+1
        outstr(kout)=record(k)
45      continue
50     continue
*       if (record(34) .eq. ' ' .or. record(34) .eq. '3' .or.
*    1      record(34) .eq. '5' .or. record(34) .eq. '6' .or.
*    2      record(34) .eq. 'C' .or. record(34) .eq. 'E' .or.
*    3      record(34) .eq. 'R') then
         write(9,'(1065A1)') (outstr(i),i=1,kout)
*       endif
*      ENDIF                                          ! WIF2
100   continue
      return
      end
```

3. HIS250.FOR

```
*************************************************************************
* LOW = the number of elements of RECORD(1065) that has been written so far
* RECORD(1065) = an array holding each record
* REMAIN = the number of elements of LINE(80) for next RECORD(1065)
* CHK = chk if the length of 1065 has been reached
* BCHK = chk if fixline has been called so that LINE(161) and LINE(162) can be chked
* TLLINE = total number of lines read
* ERRLINE = the number of lines that are thrown away due to record error
* NSLT = the number of fields selected
* OUTNSLT = the number of fields selected for outpatient
* NRCRD = the number of records read in the block
* CTRL(12) = ctrl the field selection
* outctrl(*) = field selection control for outpatient
* CNT(12) = chk the number of non-zero entries
* FCNT(4,3) = rcd count for 4 cntgroup 3 file types
* ERRCNT(3) = count err records for 3 file types
* OUCNT(12) = chk the number of non-zero entries for outpatient
* BFPT(12) = returns a field's beginning point
* EFPT(12) = returns a field's ending point
* EFPT(i)-BFPT(i)+1 = the width of field(i)
* SLCT(12) = collect all the fields that are selected
* fname(12)= fieldnames
* kept(12)=kept/drop: all=all, drop=drop
* errfile= file which contains the error record content checked out by program
* state=the comlumn number of TX
*************************************************************************
$DEBUG
      integer begin_time, end_time, dif_time
      real tlline
      character*20 status
      character*12 infile,recfile
      character*12 hisfile,err1file,err2file
      character*1 line, line1, line2, record, record1, record2
      dimension  record(250),record1(250),record2(250)
      dimension  line(80),line1(80),line2(80)
      integer low,remain,length,chk,errchk,errline,nrcrd,trcrd,
     1  bchk,nslt,outnslt,errcnt,k,fcnt
      integer ctrl,outctrl,bfpt,efpt,slct,endlabel,
     1 outslct,exchange,backward
      real outcnt
      character*12 outfile
      character*11 kept(78)
      character*16 fname(78)
      dimension ctrl(78),bfpt(78),efpt(78),slct(78),cnt(78),
     1  outslct(78),exchange(9),backward(9),
     2  outctrl(78),outcnt(78)
      common /ctrlctrl/ ctrl0
*************************************************************************
*   ctrl(i)=0 -> field(i) is not selected, 1 -> field(i) is selected
*  Ctrl0=0, print GFILE only
*  Ctrl0=3, print both
*************************************************************************
      data ctrl0/3./
      DATA CTRL/0,0,0,0,0,0,0,0,0,0,0,
     1           0,0,0,0,0,0,0,0,0,0,0,
```

```
     2            0,0,0,0,0,0,0,0,0,0,
     3            0,0,0,0,0,0,0,0,0,0,
     4            0,0,0,0,0,0,0,0,0,0,
     5            0,0,0,0,0,0,0,0,0,0,
     6            0,0,0,0,0,0,0,0,0,0,
     7            0,0,0,0,0,0,0,0/
      DATA OUTCTRL/1,0,1,1,0,0,1,0,0,0,
     1               1,0,1,0,1,0,1,0,1,0,
     2               1,0,1,0,1,0,1,0,0,0,
     3               0,0,0,0,0,0,0,0,0,0,
     4               0,0,0,0,0,0,0,0,0,0,
     5               0,0,0,0,0,0,0,0,0,0,
     6               0,0,0,0,0,0,0,0,0,0,
     7               0,0,0,0,0,0,0,0/
      DATA exchange/17,39,47,55,65,69,77,85,95/
      DATA backward/5,2,6,6,8,2,6,6,8/
*****************************************************************************
      DATA BFPT/1,  2,  3, 12, 18, 21, 22, 28, 29, 33,
     1           34, 36, 37, 40, 41, 48, 49, 56, 57, 66,
     2           67, 70, 71, 78, 79, 86, 87, 96, 97,100,
     3          101,108,109,110,111,112,113,116,117,124,
     4          125,132,133,140,141,142,143,148,149,156,
     5          157,162,163,170,171,178,179,182,183,190,
     6          191,198,199,202,203,210,211,222,223,224,
     7          225,234,235,246,247,248,249,250/
*****************************************************************************
      DATA EFPT/1,  2, 11, 17, 20, 21, 27, 28, 32, 33,
     1           35, 36, 39, 40, 47, 48, 55, 56, 65, 66,
     2           69, 70, 77, 78, 85, 86, 95, 96, 99,100,
     3          107,108,109,110,111,112,115,116,123,124,
     4          131,132,139,140,141,142,147,148,155,156,
     5          161,162,169,170,177,178,181,182,189,190,
     6           197,198,201,202,209,210,221,222,223,224,
     7           233,234,245,246,247,248,249,250/
*****************************************************************************
*  initilize fname(i) and kept(i)
*****************************************************************************
      DATA KEPT/
     *  '(all)','(drop)', '(all)', '(all)','(drop)','(drop)', '(all)',
     1 '(drop)','(drop)','(drop)', '(all)','(drop)', '(all)','(drop)',
     2  '(all)','(drop)', '(all)','(drop)', '(all)','(drop)', '(all)',
     3 '(drop)', '(all)','(drop)', '(all)','(drop)', '(all)','(drop)',
     4 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     5 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     6 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     7 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     8 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)'/

      DATA fname/
     *    'Dlet',' ','Acct-Num',    'Pro-Date','Seq',' ','Billdate',' ',
     1'Pro-Time',' ','Tran-Cod',' ', 'W-U-Day',       ' ', 'W-Read',' ',
     2  'W-Cons',' ',    'W-Amt',' ', 'G-U-Day',       ' ', 'G-Read',' ',
     3  'G-Cons',' ',    'G-Amt',' ', 'S-U-Day',       ' ',  'S-Amt',' ',
     4'W-S-Code',' ','G-S-Code',' ','Sw-U-Day',       ' ','Sw-Read',' ',
     5 'Sw-Cons',' ',   'Sw-Amt',' ', 'SwWW-Fl',       ' ', 'Sw-Bod',' ',
     6'Sw-B-Amt',' ',    'Sw-Ss',' ','Sw-S-Amt',       ' ','W-W-Tot',' ',
     7'Gb-U-Day',' ',   'Gb-Amt',' ', 'Icr-Tot',       ' ','Bund-Nr',' ',
     8 'Depo-Nr',' ','Tl-T-Amt',' ','Tra-Code',       ' ', 'Tra-No',' ',
     9 'Arrears',' ','Tape-Flg',' ','G-T-EFlg',       ' '/
*****************************************************************************
* give output filenames and open output files
*****************************************************************************
      outfile='gfile'
      DATA hisfile/'his.out'/
      err1file='err1file'
      err2file='err2file'
*       recfile='recfile'
*****************************************************************************
* open output files
*****************************************************************************
      open(unit=6,file=outfile,status='unknown')
      open(unit=7,file='ctrlfile',status='unknown')
      open(unit=9,file=hisfile,status='unknown')
      open(unit=10,file=err1file,status='unknown')
      open(unit=11,file=err2file,status='unknown')
*       open(unit=12,file=recfile,status='unknown')
*****************************************************************************
*  get the infile names
```

```
*****************************************************************************
       write(*,*) ' infile=? '
       read(*,'(A12)') infile
*       write(*,*) ' labelln=? '
*       read(*,'(I1)') endlabel
       begin_time = secnds()
       open(unit=5,file=infile,status='old')
*****************************************************************************
*  initilize the SLCT
*****************************************************************************
       NSLT=0
       INSLT=0
       OUTSLT=0
       DSLT=0
****************************************GENERAL
       Do 30 i=1,78
         cnt(i)=0.
         outcnt(i)=0.
         if (ctrl(i) .eq. 1) then
           NSLT=NSLT+1
           slct(NSLT)=i
         endif
****************************************OUTPATIENT
         if (outctrl(i) .eq. 1) then
           outNSLT=outNSLT+1
           outslct(outNSLT)=i
         endif
30     continue
       low=1
       do 40 i=1,nslt
         length=efpt(slct(i))-bfpt(slct(i))
         write(6,'(5hfield,i2,4i4)')
     +     slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length
         low=low+length+1
40     continue
*****************************************************************************
*  initialize low, length, remain, etc.
*****************************************************************************
       errchk=0
       bchk=0
       low=0
       length=250
       remain=0
       tlline=0
       nrcrd=0
*********************************************************************
* quick initialization
*********************************************************************
       trcrd=0
*       do i=1,endlabel
*         read(5,'(80A1)',err=100) (line(j),j=1,80)
*       enddo
*****************************************************************************
*  data cutting loop (1) Read in 80 characters in a line
*                    (2) write them into a record (400 characters long) !!This is an OLD
say
*                    (2) write them into a record (1065 characters long)
 *****************************************************************************
50     read(5,'(250A1)',err=100) (record(i),i=1,250)
*****************************************************************************
       tlline=tlline+1.
       write(status,'(20A1)') (record(i),i=1,20)
*****************************************************************************
*  chk to see if MOD(nrcrecord/23)=0 *chk to see if MOD(nrcrecord/30)=0
*****************************************************************************
       nrcrd=nrcrd+1
       write(*,*) 'status=',status
       write(*,*) 'nrcrd=',nrcrd
*****************************************************************************
*   the following section chks to see if this record is correct
*****************************************************************************
*150    if(record(34) .eq. 'Z' .and. record(35) .eq. 'Z' .or.
150    if(record(245) .eq. ' ') then
         write(10,'(250A1)') (record(i),i=1,250)
         errchk=errchk+1
         goto 50
       endif
*****************************************************************************
*  start with next record's processing
*****************************************************************************
*       if(trcrd .gt. 120000) then
```

```
*       write(9,'(250A1)') (record(i),i=1,250)
*************************************************************************
*  using subroutine wrtsub to write records to event files
*************************************************************************
180         call wrtsub(slct,outslct,bfpt,efpt,record,nslt,
     1  outnslt,exchange,backward)
*       endif
*       endif
*************************************************************************
*  start with next record's processing
*************************************************************************
        low=0
        length=250
        goto 50
*************************************************************************
100     continue
        write(7,*) 'trcrd=', trcrd, 'errchk', errchk
*        write(7,*) 'errln=', errline, 'errchk=',errchk
        write(6,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
        write(*,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
*********************************************FOR GENERAL FILE***********
          write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
          low=1
          do 200 i=1,nslt
            if (trcrd .ne. 0.) then
              cnt(i)=cnt(i)/float(trcrd)*100.
            endif
            length=efpt(slct(i))-bfpt(slct(i))
            write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +      slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length,
     +      length+1,cnt(i),kept(slct(i)),fname(slct(i))
            low=low+length+1
200       continue
********************************************FOR outpatientfile *******
        write(7,*) 'OutTotal=',trcrd
        k=1
*        write(7,*) 'OutFile=', ' # of rcd=',fcnt
        write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     +  1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
        low=1
         do 220 i=1,outnslt
          if (trcrd .ne. 0.) then
            outcnt(i)=outcnt(i)/float(trcrd)*100.
          endif
          length=efpt(outslct(i))-bfpt(outslct(i))
          write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +    outslct(i),bfpt(outslct(i)),efpt(outslct(i)),low,low+length,
     +    length+1,outcnt(i),kept(outslct(i)),fname(outslct(i))
          low=low+length+1
220     continue
        end_time=secnds()
        dif_time = end_time - begin_time
        write(*,'(1x,6hstart:,i10,2x,4hend:,i10,2x,6hlapse:,i5,1hs)')
     +  begin_time,end_time,dif_time
        close(5)
        close(9)
        close(10)
        close(11)
        close(12)
        stop
        end
*************************************************************************
*************************************************************************

        real FUNCTION  secnds()
        INTEGER*2 hour, minute, second, hundredth
        CALL GETTIM( hour, minute, second, hundredth )
        secnds = ((DBLE( hour ) * 3600.0) + (DBLE( minute) * 60.0) +
     +            DBLE( second) + (DBLE( hundredth ) / 100.0))
        END
*************************************************************************

*************************************************************************
* subroutine wrtsub takes record(382),slct,bfpt,efpt,nslt from CUTCLAIM main
* program, and writes the selected fields (characters) to outstr(382) before
* it writes outstr to events files based on the values in the events identify-
* ing field.
*************************************************************************
* SLCT(i) returns the series # of the selected field(i)  1<=SLCT(i)<=72
* bfpt(k) returns the BEGGINNING point of field(k)
```

```
* EFPT(k) returns the ENDING point of field(k)  1=<BFPT(k),EFPT(k)<=382
******************************************************************************
        subroutine wrtsub(slct,outslct,bfpt,efpt,record,
     1  nslt,outnslt,exchange,backward)
       integer nslt,outnslt,kout,trcrd,errcnt
       integer bfpt,efpt,slct,outslct,chk,exchange,backward
       real outcnt,cnt
       character*1 record(1),outstr(250)
*       character*3 cntycode
*       character*12 plantype
       dimension bfpt(1),efpt(1),slct(1),outslct(1),
     1 cnt(1),outcnt(1),exchange(9),backward(9)
       common /ctrlctrl/ ctrl0
*       write(cntycode,'(3A1)') (record(i),i=25,27)
*       write(plantype,'(12A1)') (record(i),i=90,101)
******************************************************************************
*   write them out to general file
******************************************************************************
************************GENERAL FILE****************
       do i=1,9
         if (record(exchange(i)) .eq. '{' .or.
     1        record(exchange(i)) .eq. '}') then
           record(exchange(i))='0'
         else
         if (record(exchange(i)) .eq. 'A') then
            record(exchange(i))='1'
         else
         if (record(exchange(i)) .eq. 'B') then
           record(exchange(i))='2'
         else
         if (record(exchange(i)) .eq. 'C') then
           record(exchange(i))='3'
         else
         if (record(exchange(i)) .eq. 'D') then
           record(exchange(i))='4'
         else
         if (record(exchange(i)) .eq. 'E') then
           record(exchange(i))='5'
         else
         if (record(exchange(i)) .eq. 'F') then
           record(exchange(i))='6'
         else
         if (record(exchange(i)) .eq. 'G') then
           record(exchange(i))='7'
         else
         if (record(exchange(i)) .eq. 'H') then
           record(exchange(i))='8'
         else
         if (record(exchange(i)) .eq. 'I') then
           record(exchange(i))='9'
         else
         if (record(exchange(i)) .eq. 'J') then
           record(exchange(i))='1'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'K') then
           record(exchange(i))='2'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'L') then
           record(exchange(i))='3'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'M') then
           record(exchange(i))='4'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'N') then
           record(exchange(i))='5'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'O') then
           record(exchange(i))='6'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'P') then
           record(exchange(i))='7'
           record(exchange(i)-backward(i))='-'
         else
         if (record(exchange(i)) .eq. 'Q') then
           record(exchange(i))='8'
```

```
            record(exchange(i)-backward(i))='-'
          else
          if (record(exchange(i)) .eq. 'R') then
            record(exchange(i))='9'
            record(exchange(i)-backward(i))='-'
          else
          endif
          endif
          endif
           endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
        enddo
        IF (ctrl0 .eq. 0. .or. ctrl0 .eq. 3.) then      ! WIF1
        kout=0
        do 20 i=1,nslt
          chk=0
          do 15 k=bfpt(slct(i)),efpt(slct(i))
*             if (chk .eq. 0) then                        ! WIF1-1
*               if(record(k) .ne. ' ' .and. record(k) .ne. '0') then    ! WIF1-2
*                cnt(i)=cnt(i)+1.0
*                chk=1
*               endif                                                   ! WIF1-2
*             endif                                                     ! WIF1-1
          kout=kout+1
          outstr(kout)=record(k)
15        continue
20      continue
c        write(6,'(80A1)') (outstr(i),i=1,kout)
        write(6,'(250A1)') (outstr(i),i=1,kout)
        ENDIF                                           ! WIF1
*        IF (ctrl0 .eq. 1. .or. ctrl0 .eq. 3.) THEN   ! WIF2
*************************OUTPATIENT FILE****************
*         if (ctrl0 .eq. 3) goto 100                 ! added so that outpat is not
written
         kout=0
         do 50 i=1,outnslt
          chk=0
          do 45 k=bfpt(outslct(i)),efpt(outslct(i))
*             if (chk .eq. 0) then
*               if(record(k) .ne. ' ' .and. record(k) .ne. '0') then
*                outcnt(i)=outcnt(i)+1.0
*                chk=1
*               endif
*             endif
          kout=kout+1
          outstr(kout)=record(k)
45        continue
50       continue
         if (record(34) .eq. ' ' .or. record(34) .eq. '3' .or.
     1       record(34) .eq. '5' .or. record(34) .eq. '6' .or.
     2       record(34) .eq. 'C' .or. record(34) .eq. 'E' .or.
     3       record(34) .eq. 'R') then
           write(9,'(250A1)') (outstr(i),i=1,kout)
         endif
*        ENDIF                                        ! WIF2
100     continue
        return
        end
```

4. HIS80.FOR

```
***************************************************************************
* LOW = the number of elements of RECORD(1065) that has been written so far
* RECORD(1065) = an array holding each record
* REMAIN = the number of elements of LINE(80) for next RECORD(1065)
* CHK = chk if the length of 1065 has been reached
```

```
* BCHK = chk if fixline has been called so that LINE(161) and LINE(162) can be chked
* TLLINE = total number of lines read
* ERRCHK = the number of times FIXSUB is called
* ERRLINE = the number of lines that are thrown away due to record error
* NSLT = the number of fields selected
* INNSLT = the number of fields selected for inpatient
* OUTNSLT = the number of fields selected for outpatient
* DNSLT = the numbet of fields selected for drug vendor
* NRCRD = the number of records read in the block
* TRCRD(i) = total number of records read,1=General file
*           2=inpatient,3=outpatient,4=drug
* CTRL(12) = ctrl the field selection
* INCTRL(*) = field selection control for inpatient
* outctrl(*) = field selection control for outpatient
* dctrl(*) = field selection control for drugvendor
* CNT(12) = chk the number of non-zero entries
* FCNT(4,3) = rcd count for 4 cntgroup 3 file types (inp,outp,drug)
* ERRCNT(3) = count err records for 3 file types
* INCNT(12) = chk the number of non-zero entries for inpatient
* OUCNT(12) = chk the number of non-zero entries for outpatient
* DCNT(12) = chk the number of non-zero entries for drug vendor
* BFPT(12) = returns a field's beginning point
* EFPT(12) = returns a field's ending point
* EFPT(i)-BFPT(i)+1 = the width of field(i)
* SLCT(12) = collect all the fields that are selected
* fname(12)= fieldnames
* kept(12)=kept/drop: 1=inpatient, 2=outpatient,3=drug,all=all 3, drop=drop
* errfile= file which contains the error record content checked out by program
* rckind= the number used to indicate the subroutine has been called
* state=the comlumn number of TX
******************************************************************************
$DEBUG
       integer begin_time, end_time, dif_time
       real tlline
       character*20 status
       character*12 infile,recfile
       character*12 hisfile,err1file,err2file
       character*1 line, line1, line2, record, record1, record2
       dimension  record(250),record1(250),record2(250)
       dimension  line(80),line1(80),line2(80)
       integer low,remain,length,chk,errchk,errline,nrcrd,trcrd,
     1  bchk,nslt,outnslt,errcnt,k,fcnt
       integer ctrl,outctrl,bfpt,efpt,slct,endlabel,
     1 outslct,exchange,backward
       real outcnt
       character*12 outfile
       character*11 kept(78)
       character*16 fname(78)
       dimension ctrl(78),bfpt(78),efpt(78),slct(78),cnt(78),
     1  outslct(78),exchange(9),backward(9),
     2  outctrl(78),outcnt(78)
       common /ctrlctrl/ ctrl0
******************************************************************************
*   ctrl(i)=0 -> field(i) is not selected, 1 -> field(i) is selected
*  Ctrl0=0, print GFILE only, Ctrl0=1, print Inpatient, etc, files only
*  Ctrl0=3, print both
******************************************************************************
       data ctrl0/3./
       DATA CTRL/0,0,0,0,0,0,0,0,0,0,
     1          0,0,0,0,0,0,0,0,0,0,0,
     2          0,0,0,0,0,0,0,0,0,0,0,
     3          0,0,0,0,0,0,0,0,0,0,0,
     4          0,0,0,0,0,0,0,0,0,0,0,
     5          0,0,0,0,0,0,0,0,0,0,0,
     6          0,0,0,0,0,0,0,0,0,0,0,
     7          0,0,0,0,0,0,0,0,0/
       DATA OUTCTRL/0,0,1,1,0,0,0,0,0,0,
     1             1,0,1,0,1,0,1,0,1,0,
     2             1,0,1,0,1,0,1,0,0,0,
     3             0,0,0,0,0,0,0,0,0,0,0,
     4             0,0,0,0,0,0,0,0,0,0,0,
     5             0,0,0,0,0,0,0,0,0,0,0,
     6             0,0,0,0,0,0,0,0,0,0,0,
     7             0,0,0,0,0,0,0,0,0/
       DATA exchange/17,39,47,55,65,69,77,85,95/
       DATA backward/5,2,6,6,8,2,6,6,8/
******************************************************************************
       DATA BFPT/1,  2,  3, 12, 18, 21, 22, 28, 29, 33,
     1         34, 36, 37, 40, 41, 48, 49, 56, 57, 66,
     2         67, 70, 71, 78, 79, 86, 87, 96, 97,100,
     3        101,108,109,110,111,112,113,116,117,124,
```

```
     4          125,132,133,140,141,142,143,148,149,156,
     5          157,162,163,170,171,178,179,182,183,190,
     6          191,198,199,202,203,210,211,222,223,224,
     7          225,234,235,246,247,248,249,250/
*****************************************************************************
      DATA EFPT/1,  2, 11, 17, 20, 21, 27, 28, 32, 33,
     1           35, 36, 39, 40, 47, 48, 55, 56, 65, 66,
     2           69, 70, 77, 78, 85, 86, 95, 96, 99,100,
     3          107,108,109,110,111,112,115,116,123,124,
     4          131,132,139,140,141,142,147,148,155,156,
     5          161,162,169,170,177,178,181,182,189,190,
     6           197,198,201,202,209,210,221,222,223,224,
     7           233,234,245,246,247,248,249,250/
*****************************************************************************
*   initilize fname(i) and kept(i)
*****************************************************************************
      DATA KEPT/
     * '(drop)','(drop)', '(all)', '(all)','(drop)','(drop)','(drop)',
     1 '(drop)','(drop)','(drop)', '(all)','(drop)', '(all)','(drop)',
     2  '(all)','(drop)', '(all)','(drop)', '(all)','(drop)', '(all)',
     3 '(drop)', '(all)','(drop)', '(all)','(drop)', '(all)','(drop)',
     4 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     5 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     6 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     7 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     8 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)','(drop)','(drop)','(drop)','(drop)','(drop)','(drop)',
     9 '(drop)'/

      DATA fname/
     *      'Dlet',' ','Acct-Num',    'Pro-Date','Seq',' ',    'Date',' ',
     1 'Pro-Time',' ','Tran-Cod',' ', 'W-U-Day',        ' ', 'W-Read',' ',
     2   'W-Cons',' ',    'W-Amt',' ', 'G-U-Day',        ' ', 'G-Read',' ',
     3   'G-Cons',' ',    'G-Amt',' ', 'S-U-Day',        ' ',   'S-Amt',' ',
     4 'W-S-Code',' ','G-S-Code',' ','Sw-U-Day',        ' ','Sw-Read',' ',
     5  'Sw-Cons',' ',   'Sw-Amt',' ', 'SwWW-Fl',        ' ', 'Sw-Bod',' ',
     6 'Sw-B-Amt',' ',    'Sw-Ss',' ','Sw-S-Amt',        ' ','W-W-Tot',' ',
     7 'Gb-U-Day',' ',   'Gb-Amt',' ', 'Icr-Tot',        ' ','Bund-Nr',' ',
     8  'Depo-Nr',' ','Tl-T-Amt',' ','Tra-Code',        ' ', 'Tra-No',' ',
      9  'Arrears',' ','Tape-Flg',' ','G-T-EFlg',         ' '/
*****************************************************************************
* give output filenames and open output files
*****************************************************************************
      outfile='gfile'
      DATA hisfile/'his.out'/
      err1file='err1file'
      err2file='err2file'
      recfile='recfile'
*****************************************************************************
* open output files
*****************************************************************************
      open(unit=6,file=outfile,status='unknown')
      open(unit=7,file='ctrlfile',status='unknown')
      open(unit=9,file=hisfile,status='unknown')
      open(unit=10,file=err1file,status='unknown')
      open(unit=11,file=err2file,status='unknown')
      open(unit=12,file=recfile,status='unknown')
*****************************************************************************
*   get the infile names
*****************************************************************************
      write(*,*) ' infile=? '
      read(*,'(A12)') infile
      write(*,*) ' labelln=? '
      read(*,'(I1)') endlabel
      begin_time = secnds()
      open(unit=5,file=infile,status='old')
*****************************************************************************
*   initilize the SLCT
*****************************************************************************
      NSLT=0
      INSLT=0
      OUTSLT=0
      DSLT=0
****************************************GENERAL
      Do 30 i=1,78
        cnt(i)=0.
        outcnt(i)=0.
        if (ctrl(i) .eq. 1) then
          NSLT=NSLT+1
          slct(NSLT)=i
```

```
         endif
****************************************OUTPATIENT
         if (outctrl(i) .eq. 1) then
           outNSLT=outNSLT+1
           outslct(outNSLT)=i
         endif
30     continue
       low=1
       do 40 i=1,nslt
         length=efpt(slct(i))-bfpt(slct(i))
         write(6,'(5hfield,i2,4i4)')
     +     slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length
         low=low+length+1
40     continue
************************************************************************
*  initialize low, length, remain, etc.
************************************************************************
       errchk=0
       bchk=0
       low=0
       length=250
       remain=0
       tlline=0
       nrcrd=0
 *****************************************************************
* quick initialization
*****************************************************************
       trcrd=0
       do i=1,endlabel
         read(5,'(80A1)',err=100) (line(j),j=1,80)
       enddo
************************************************************************
*  data cutting loop (1) Read in 80 characters in a line
*                    (2) write them into a record (400 characters long) !!This is an OLD
say
*                    (2) write them into a record (1065 characters long)
************************************************************************
50     read(5,'(80A1)',err=100) (line(i),i=1,80)
***********************************************************************
       tlline=tlline+1.
        if(tlline .gt. 19 .and. tlline .lt. 40 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=25
        else
        if(tlline .gt. 39 .and. tlline .lt. 65 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=50
        else
        if(tlline .gt. 64 .and. tlline .lt. 90 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=75
        else
        if(tlline .gt. 89 .and. tlline .lt. 115 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=100
        else
        if(tlline .gt. 114 .and. tlline .lt. 140 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=125
        else
        if(tlline .gt. 139 .and. tlline .lt. 165 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=150
        else
        if(tlline .gt. 164 .and. tlline .lt. 190 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=175
        else
        if(tlline .gt. 189 .and. tlline .lt. 215 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=200
        else
        if(tlline .gt. 214 .and. tlline .lt. 240 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=225
        else
        if(tlline .gt. 239 .and. tlline .lt. 265 .and.
     1      line(12) .eq. '9' .and. line(26) .eq. '9') then
           tlline=250
        else
        if(tlline .gt. 264 .and. tlline .lt. 290 .and.
```

```
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
      tlline=275
    else
    if(tlline .gt. 289 .and. tlline .lt. 315 .and.
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
      tlline=300
    else
    if(tlline .gt. 314 .and. tlline .lt. 340 .and.
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
        tlline=325
    else
    if(tlline .gt. 339 .and. tlline .lt. 365 .and.
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
      tlline=350
    else
    if(tlline .gt. 364 .and. tlline .lt. 390 .and.
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
      tlline=375
    else
    if(tlline .gt. 389 .and. tlline .lt. 410 .and.
1       line(12) .eq. '9' .and. line(26) .eq. '9') then
      tlline=400
    else
    if(tlline .gt. 389  .and.
1     line(32) .eq. '9' .and. line(46) .eq. '9') then
      tlline=407
    else
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif
    endif

    if(tlline .eq. 25) then
      remind=1
    else
    if(tlline .eq. 50) then
      remind=1
    else
    if(tlline .eq. 75) then
      remind=1
    else
    if(tlline .eq. 100) then
      remind=1
    else
    if(tlline .eq. 125) then
      remind=1
    else
    if(tlline .eq. 150) then
      remind=1
    else
    if(tlline .eq. 175) then
      remind=1
    else
    if(tlline .eq. 200) then
      remind=1
    else
    if(tlline .eq. 225) then
      remind=1
    else
    if(tlline .eq. 250) then
      remind=1
     else
    if(tlline .eq. 275) then
      remind=1
    else
    if(tlline .eq. 300) then
      remind=1
    else
```

```
          if(tlline .eq. 325) then
            remind=1
          else
          if(tlline .eq. 350) then
            remind=1
          else
          if(tlline .eq. 375) then
            remind=1
          else
          if(tlline .eq. 400) then
            remind=1
          else
          if(tlline .eq. 410) then
            remind=1
            tlline=0
          else
            remind=0
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
          endif
*         if(line(2) .eq. '9' .and. line(16) .eq. '9') then
*           remind=1
*         endif
*         if(tlline .gt. 390 .and.
*     1     line(12) .eq. '9' .and. line(26) .eq. '9') then
*           remind=1
*           tlline=401
*         else
*         endif
*       if (nrcrd .eq. 131) then
*          stop
*       endif
**         if(line(24) .eq. '6' .and. line(25) .eq. '1' .and.
**     1      line(26) .eq. '3' .and. line(27) .eq. '9' .and.
**     1      line(28) .eq. '3' .and. line(29) .eq. '4' .and.
**     1      line(30) .eq. '9' .and. line(31) .eq. '3' .and.
**     1      line(32) .eq. '9' .and. line(33) .eq. '6' .and.
**     1      line(34) .eq. '0' .and. line(35) .eq. '3' .and.
**     1      line(36) .eq. '0' .and. line(37) .eq. '8' .and.
**     1      line(38) .eq. '7') then
**            tlline=406
**         endif


        chk=length-80
        if(chk .gt. 0) then
          length=length-80
          do i=1,80
            record(i+low)=line(i)
          enddo
          low=low+80
          goto 50
        else
*******************************************************************************
*  length < 80, the record is completed below
*******************************************************************************
          remain=80-length
          do i=1,length
            record(i+low)=line(i)
          enddo
        endif
        write(status,'(20A1)') (record(i),i=1,20)
*        if(status .eq. '  180113724940707900') then
*          tlline=85
*        endif
*        if(status .eq. '  190317701950224700') then
```

```
*         tlline=404
*       endif
*       if(status .eq. '  200926504941129100') then
*         tlline=376
*       endif
*       if(status .eq. '  201000102940629700') then
*         tlline=404
*       endif
*       if(status .eq. '  730309206930203900') then
*         tllines=404
*       endif
*****************************************************************************
*  chk to see if MOD(nrcrecord/23)=0 *chk to see if MOD(nrcrecord/30)=0
*****************************************************************************
      nrcrd=nrcrd+1
      write(12,*) 'status=',status
*      write(*,*) 'trcrd=',trcrd
      write(*,*) 'nrcrd=',nrcrd
      write(*,*) 'status=',status
*      if (tlline-(INT(tlline/410)*410) .eq. 0) then
*         remain=0
*         trcrd=trcrd+131
*         write(12,*) 'trcrd=',trcrd
*         write(12,*) 'tlline=',tlline
*         write(*,*) 'trcrd=',trcrd
*         write(12,*) 'status=',status
*         write(*,*) 'status=',status
*         tlline=0
*       endif
*****************************************************************************
*   the following section chks to see if this record is correct
*****************************************************************************
150    if(record(12) .ne. '9' .or. record(26) .ne. '9'
     1   .or. record(232) .eq. ' ' .or. record(2) .ne. ' '
     1   .or. record(3) .eq. ' ') then
       if(record(12) .eq. '9' .and. record(26) .eq. '9'
     1   .and. record(221) .eq. '{' .and. record(2) .eq. ' '
     1   .and. record(3) .ne. ' ') then
         goto 180
       else
*     1   .or. record(245) .eq. ' ') then
*         if(record(245) .eq. 'F' .or. record(245) .eq. 'B') then
*            goto 180
*         endif
         write(10,'(250A1)') (record(i),i=1,250)
         errchk=errchk+1
         bchk=1   ! bchk=1 to indicate fixsub is called
         call fixsub(line,record,length,
     1            low,tlline,status)
         goto 50
       endif
       endif
*****************************************************************************
*  start with next record's processing
*****************************************************************************
*180    if(record(12) .ne. '9' .or. record(26) .ne. '9'
*     1   .or. record(232) .eq. ' ' .or. record(2) .ne. ' '
*     1   .or. record(3) .eq. ' ') then
*       if(record(12) .eq. '9' .and. record(26) .eq. '9'
*     1   .and. record(221) .eq. '{' .and. record(2) .eq. ' '
*     1   .and. record(3) .ne. ' ') then
*         goto 185
*       else
*     1   .or. record(245) .eq. ' ') then
*         goto 150
*       endif
*       if(trcrd .gt. 120000) then
*185         write(9,'(250A1)') (record(i),i=1,250)
*****************************************************************************
*  using subroutine wrtsub to write records to event files
*****************************************************************************
180        call wrtsub(slct,outslct,bfpt,efpt,record,nslt,
     1  outnslt,exchange,backward)
*       endif
*       endif
*****************************************************************************
*  start with next record's processing
*****************************************************************************
75      low=0
        if(remind .eq. 1) then
           remain=0
```

```
      endif
      if(remain .ne. 0) then
        do i=1,remain
          record(low+i)=line(80-remain+i)
        enddo
        low=low+remain
      endif
      length=250-remain
      goto 50
*****************************************************************************
100   continue
      write(7,*) 'trcrd=', trcrd, 'errchk', errchk
*      write(7,*) 'errln=', errline, 'errchk=',errchk
      write(6,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
      write(*,*) 'trcrd=',trcrd,'errln=', errline, 'errchk=',errchk
**************************************************FOR GENERAL FILE***********
        write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     + 1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
        low=1
        do 200 i=1,nslt
          if (trcrd .ne. 0.) then
            cnt(i)=cnt(i)/float(trcrd)*100.
          endif
          length=efpt(slct(i))-bfpt(slct(i))
          write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +      slct(i),bfpt(slct(i)),efpt(slct(i)),low,low+length,
     +       length+1,cnt(i),kept(slct(i)),fname(slct(i))
          low=low+length+1
200     continue
*************************************************FOR outpatientfile *******
      write(7,*) 'OutTotal=',trcrd
      k=1
*      write(7,*) 'OutFile=', ' # of rcd=',fcnt
      write(7,'(1x,6hfield#,2x,3hRBF,1x,3hREF,1x,3hCBF,1x,3hCEF,
     + 1x,3hFWD,2x,6hvalid%,3x,9hkeep/drop,6x,5hFNAME)')
      low=1
      do 220 i=1,outnslt
        if (trcrd .ne. 0.) then
          outcnt(i)=outcnt(i)/float(trcrd)*100.
        endif
        length=efpt(outslct(i))-bfpt(outslct(i))
        write(7,'(5hfield,i2,5i4,3x,f6.2,3x,A11,3x,A16)')
     +  outslct(i),bfpt(outslct(i)),efpt(outslct(i)),low,low+length,
     +  length+1,outcnt(i),kept(outslct(i)),fname(outslct(i))
        low=low+length+1
220   continue
      end_time=secnds()
      dif_time = end_time - begin_time
      write(*,'(1x,6hstart:,i10,2x,4hend:,i10,2x,6hlapse:,i5,1hs)')
     + begin_time,end_time,dif_time
      close(5)
      close(9)
      close(10)
      close(11)
      close(12)
      stop
      end
*****************************************************************************
*  This section was completed at 01:12:27AM;11-Jun-1994
*****************************************************************************

      real FUNCTION  secnds()
      INTEGER*2 hour, minute, second, hundredth
      CALL GETTIM( hour, minute, second, hundredth )
      secnds = ((DBLE( hour ) * 3600.0) + (DBLE( minute) * 60.0) +
     +          DBLE( second) + (DBLE( hundredth ) / 100.0))
      END
*****************************************************************************
*****************************************************************************
*  Subroutine 'Fixsub' is going to check if the record is a bad record
*  which means that "record(161) .ne. 'T' .or. record(162) .ne. 'X'" has
*  been found and then the record is put into a file which is specially
*  prepared for bad records. The program will continue to search the right
*  position of T and X untill it finds them that means a new good record has
*  been found
*
*
*
*****************************************************************************
      subroutine fixsub(lines,records,lengths,
    1                  lows,tllines,status)
```

```
        real ttlines
        integer lows,lengths,brace,j,nrcrds
        integer remains, chkline
        character*20 status
        character*1 lines(80), records(250)
        character*1 line1(80),line2(80),line3(80),line4(80)
******************************************************************************
*  initialize low, length, remain
******************************************************************************
        lows=0
         lengths=250
*        chkline=0
        do i=1,80
*          line4(i)=lines(i)
          line3(i)=lines(i)
          line2(i)=lines(i)
          line1(i)=lines(i)
        enddo
5       read(5,'(80A1)',err=20) (lines(i),i=1,80)
******************************************************************************
*  search for the patten
******************************************************************************
        tllines=tllines+1.
        if(tllines .gt. 410) then
          tllines=0
        else
        endif
*        if(tllines .eq. 25) then
*          remind=1
*        else
*        if(tllines .eq. 50) then
*          remind=1
*        else
*        if(tllines .eq. 75) then
*          remind=1
*        else
*        if(tllines .eq. 100) then
*          remind=1
*        else
*        if(tllines .eq. 125) then
*          remind=1
*        else
*        if(tllines .eq. 150) then
*          remind=1
*        else
*        if(tllines .eq. 175) then
*          remind=1
*        else
*        if(tllines .eq. 200) then
*          remind=1
*        else
*        if(tllines .eq. 225) then
*          remind=1
*        else
*        if(tllines .eq. 250) then
*          remind=1
*        else
*        if(tllines .eq. 275) then
*          remind=1
*        else
*        if(tllines .eq. 300) then
*          remind=1
*        else
*        if(tllines .eq. 325) then
*          remind=1
*        else
*        if(tllines .eq. 350) then
*          remind=1
*        else
*        if(tllines .eq. 375) then
*          remind=1
*        else
*        if(tllines .eq. 400) then
*          remind=1
*        else
*        if(tllines .eq. 410) then
*          remind=1
*          tllines=0
*        else
*          remind=0
*        endif
```

```
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*         endif
*       if(status .eq. '  180113724940707900') then
*         tllines=85
*       endif
*       if(status .eq. '  190317701950224700') then
*         tllines=404
*       endif
*       if(status .eq. '  200926504941129100') then
*         tllines=376
*       endif
*       if(status .eq. '  201000102940629700') then
*         tllines=404
*       endif
*       if(status .eq. '  730309206930203900') then
*         tllines=404
*       endif
*        if(tllines .gt. 390 .and.
*     1    lines(12) .eq. '9' .and. lines(26) .eq. '9') then
*          remind=1
*          tllines=401
*        else
*        endif
        if(tllines .gt. 395 .and.
     1    lines(32) .eq. '9' .and. lines(46) .eq. '9') then
*          remind=1
          tllines=407
        else
        endif

        do i=1,80
*          line4(i)=line3(i)
          line3(i)=line2(i)
          line2(i)=line1(i)
          line1(i)=lines(i)
        enddo
        do i=15,80
        if(line2(i-14) .eq. '9' .and. line2(i) .eq. '9') then
          brace=i-14
          if(brace .eq. 2) then
            lows=0
            remain1=10
            lengths=250-remain1
            do j=1,remain1
              records(j+lows)=line3(80-remain1+j)
             enddo
            lows=lows+remain1
            lengths=lengths-80
            do j=1,80
              records(j+lows)=line2(j)
            enddo
            lows=lows+80
            lengths=lengths-80
            do j=1,80
              records(j+lows)=line1(j)
            enddo
            lows=lows+80
            goto 20
          endif
          if(brace .ne. 12 .and. brace .ne. 22 .and.
     1        brace .ne. 32 .and. brace .ne. 42 .and.
     1        brace .ne. 52 .and. brace .ne. 62) then
            brace=brace+3
            if(brace .ne. 12 .and. brace .ne. 22 .and.
     1          brace .ne. 32 .and. brace .ne. 42 .and.
     1          brace .ne. 52 .and. brace .ne. 62) then
              goto 120
```

```
            endif
          endif
110       lows=0
          remain1=80-brace+12
          lengths=250-remain1
          do j=1,remain1
            records(j+lows)=line2(80-remain1+j)
          enddo
          lows=lows+remain1
          lengths=lengths-80
          do j=1,80
            records(j+lows)=line1(j)
          enddo
          lows=lows+80
          goto 20
        endif
120     enddo
        do i=70,80
          if(line3(i) .eq. '9' .and. line2(i-66) .eq. '9') then
            brace=i
            if(brace .eq. 72) then
              lows=0
              remain1=20
              lengths=250-remain1
              do j=1,remain1
                records(j+lows)=line3(80-remain1+j)
              enddo
              lows=lows+remain1
              lengths=lengths-80
              do j=1,80
                records(j+lows)=line2(j)
              enddo
              lows=lows+80
              lengths=lengths-80
              do j=1,80
                records(j+lows)=line1(j)
              enddo
              lows=lows+80
              goto 20
            endif
          endif
        enddo

         lows=0
        lengths=250
        goto 5
20      continue
        return
        end

*****************************************************************************
* subroutine wrtsub takes record(382),slct,bfpt,efpt,nslt from CUTCLAIM main
* program, and writes the selected fields (characters) to outstr(382) before
* it writes outstr to events files based on the values in the events identify-
* ing field.
*****************************************************************************
* SLCT(i) returns the series # of the selected field(i)  1<=SLCT(i)<=72
* bfpt(k) returns the BEGGINNING point of field(k)
* EFPT(k) returns the ENDING point of field(k)  1=<BFPT(k),EFPT(k)<=382
*****************************************************************************
        subroutine wrtsub(slct,outslct,bfpt,efpt,record,
     1  nslt,outnslt,exchange,backward)
       integer nslt,outnslt,kout,trcrd,errcnt
       integer bfpt,efpt,slct,outslct,chk,exchange,backward
       real outcnt,cnt
       character*1 record(1),outstr(250)
*       character*3 cntycode
*       character*12 plantype
       dimension bfpt(1),efpt(1),slct(1),outslct(1),
     1 cnt(1),outcnt(1),exchange(9),backward(9)
       common /ctrlctrl/ ctrl0
*       write(cntycode,'(3A1)') (record(i),i=25,27)
*       write(plantype,'(12A1)') (record(i),i=90,101)
*****************************************************************************
*   write them out to general file
*****************************************************************************
************************GENERAL FILE****************
       do i=1,9
         if (record(exchange(i)) .eq. '{' .or.
     1        record(exchange(i)) .eq. '}') then
```

```
  record(exchange(i))='0'
else
if (record(exchange(i)) .eq. 'A') then
  record(exchange(i))='1'
else
if (record(exchange(i)) .eq. 'B') then
  record(exchange(i))='2'
else
if (record(exchange(i)) .eq. 'C') then
  record(exchange(i))='3'
else
if (record(exchange(i)) .eq. 'D') then
  record(exchange(i))='4'
else
if (record(exchange(i)) .eq. 'E') then
  record(exchange(i))='5'
else
if (record(exchange(i)) .eq. 'F') then
  record(exchange(i))='6'
else
if (record(exchange(i)) .eq. 'G') then
  record(exchange(i))='7'
else
if (record(exchange(i)) .eq. 'H') then
  record(exchange(i))='8'
else
if (record(exchange(i)) .eq. 'I') then
   record(exchange(i))='9'
else
if (record(exchange(i)) .eq. 'J') then
  record(exchange(i))='1'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'K') then
  record(exchange(i))='2'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'L') then
  record(exchange(i))='3'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'M') then
  record(exchange(i))='4'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'N') then
  record(exchange(i))='5'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'O') then
  record(exchange(i))='6'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'P') then
  record(exchange(i))='7'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'Q') then
  record(exchange(i))='8'
  record(exchange(i)-backward(i))='-'
else
if (record(exchange(i)) .eq. 'R') then
  record(exchange(i))='9'
  record(exchange(i)-backward(i))='-'
else
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
endif
```

```
          endif
          endif
          endif
        enddo
        IF (ctrl0 .eq. 0. .or. ctrl0 .eq. 3.) then     ! WIF1
        kout=0
        do 20 i=1,nslt
          chk=0
          do 15 k=bfpt(slct(i)),efpt(slct(i))
*            if (chk .eq. 0) then                       ! WIF1-1
*              if(record(k) .ne. ' ' .and. record(k) .ne. '0') then     ! WIF1-2
 *               cnt(i)=cnt(i)+1.0
*               chk=1
*              endif                                                    ! WIF1-2
*            endif                                                      ! WIF1-1
          kout=kout+1
          outstr(kout)=record(k)
15        continue
20      continue
c        write(6,'(80A1)') (outstr(i),i=1,kout)
        write(6,'(250A1)') (outstr(i),i=1,kout)
        ENDIF                                          ! WIF1
*        IF (ctrl0 .eq. 1. .or. ctrl0 .eq. 3.) THEN  ! WIF2
************************OUTPATIENT FILE***************
*         if (ctrl0 .eq. 3) goto 100                 ! added so that outpat is not
written
         kout=0
         do 50 i=1,outnslt
          chk=0
          do 45 k=bfpt(outslct(i)),efpt(outslct(i))
*            if (chk .eq. 0) then
*              if(record(k) .ne. ' ' .and. record(k) .ne. '0') then
*               outcnt(i)=outcnt(i)+1.0
*               chk=1
*              endif
*            endif
          kout=kout+1
          outstr(kout)=record(k)
45        continue
50       continue
         if (record(34) .eq. ' ' .or. record(34) .eq. '3' .or.
     1       record(34) .eq. '5' .or. record(34) .eq. '6' .or.
     2       record(34) .eq. 'C' .or. record(34) .eq. 'E' .or.
     3       record(34) .eq. 'R') then
           write(9,'(250A1)') (outstr(i),i=1,kout)
         endif
*        ENDIF                                        ! WIF2
100     continue
        return
        end
```

Appendix G. A Process for Estimating Water Demand

Aggregations of water demand used in this study are described in Table G.1. Real-time forecasts of water demand are created using spreadsheet software and readily available data series. The data required to forecast water demand are described in Table G.2.

An Example of How to Forecast Treated Water Demand

Forecasts are developed by substituting rainfall, temperature, and time into equation G.1 with the coefficients listed in Table 4.1 of the main report. The forecast of per capita treated water sales for May 1996 (Y_{197}) is created by substituting the variables for that month into the equation and applying the model coefficients (Tables 4.1 and 4.3):

$$\hat{Y}_{197} = 16.649 \bullet 0.363(87.6) + 0.0027(87.6)^2 \bullet 0.042(1.14) + 0.003(197) + v_{197} = 6.09$$

$$v_{197} = 0.372\,u_{196} + 0.211\,u_{194} \bullet 0.132\,u_{187} + 0.409\,u_{185}$$

The mean maximum temperature during May was 87.6° Fahrenheit and there were 1.14 inches of rain at the Corpus Christi International Airport. The trend variable for May is defined as 197 because May is 197th in the sequence of months in the data series. While the assignment of indexes is somewhat arbitrary because the series could begin at any point in time, changes in the initial assignment of indices must be completed before estimation of model parameters. The second equation is the autoregressive error term. A series of coefficients is multiplied by the difference in predicted and actual values at significantly correlated lags.

For a forecast of water use for more than one time period over the drought management period or after the drought management period has begun, the residuals of lagged forecasts will not be available because there is no measurement of water use in the absence of the drought management program. This problem is resolved by substituting the value of the error term at each lag for which the lagged residual is missing (equation G.2). For example, a forecast for August 1996 is missing the first and third lagged residual.

$$\hat{Y}_{200} = 16.649 \bullet 0.363(94.21) + 0.0027(94.21)^2 \bullet 0.042(6.26) + 0.003(200) + v_{197} = 6.59$$

$$v_{200} = 0.372\,v_{199} + 0.211\,v_{197} \bullet 0.132\,u_{190} + 0.409\,u_{188}$$

The effect of the error term on the forecast decreases as the number of successive months in the forecast increases.

Creating Forecasts for Water-User Sectors

The only difference between creating forecasts for water demand sectors and creating forecasts for total water use is the inclusion of a price term. The coefficients for water-user sectors are listed in Table 4.3 of the main report. Residential water prices are divided by the consumer price index before being multiplied by model coefficients. Commercial and industrial water prices are divided by an adjusted producer price index (1982 minus 4 = 1.00). The adjusted producer price index is calculated by dividing the raw producer price index (1982 = 1.00) by 1.01667. Marginal water prices for the residential water-user sector are defined as the price of an additional thousand gallons after the customer has purchased 7,000 gallons and for the commercial/industrial water-user sector as the price of an additional thousand gallons after the customer has purchased 100,000 gallons of water.

How to Interpret Results

The result of the forecasting equation expresses water demand on a per capita or a per account basis. Estimates of total and treated water demand are expressed on a per capita basis. The next step is to convert the per capita or per account estimates to a total volume of water and multiply total and treated water demand estimates by the population of Corpus Christi MSA and municipal water demand. This can be done by multiplying the per capita use by the city's estimate of population inside the city limits or the per account use by the number of accounts. For example, the estimate of treated water demand for August 1996 is 6.59 thousand gallons per capita. The population of the Corpus Christi Metropolitan Statistical Area in that year was estimated to be 382,710 from a Regional Economic Information System data series of the Bureau of Economic Analysis, U.S. Department of Commerce (Table 2.2 of the main report). The demand for treated water during August is therefore 382.71 thousand people times 6.59 thousand gallons of water per person, or 2,522 million gallons. Estimates of water demand in the three water-user sectors are expressed in per account terms. The number of accounts was obtained from utility billing reports produced by the City of Corpus Christi.

Table G.1. Description of Aggregations of Water Demand

Data Series	Data Description
Total water demand	All treated and raw water sales by the City of Corpus Christi to retail and wholesale customers including industrial customers and wholesale customers purchasing raw water supplies for treatment and sale to the surrounding communities in Mathis, Port Aransas, Beeville, San Patricio, and other places. Total water sales are divided by the population of the Corpus Christi Metropolitan Statistical Area, which is defined as the entire counties of Nueces and San Patricio. The measure is expressed in thousand gallons per capita per month.
Treated water demand	All treated water sales to retail and wholesale customers including residential, commercial, and industrial customers. Treated water sales are divided by the population of the Corpus Christi Metropolitan Statistical Area, which is defined as the entire counties of Nueces and San Patricio. The measure is expressed in thousand gallons per capita per month.
Municipal water demand	Residential and commercial water sales inside the city limits divided by an estimate of the population inside the city limits and again divided by the number of days each month. Population estimates are generated by the City of Corpus Christi planning department. The measure is expressed in gallons per capita per day.
Residential water demand	Retail treated water sales by the Corpus Christi Water Division to end-user residential customers inside and outside the city limits. Retail water sales include sales to single-family accounts and duplexes but exclude water sales to apartments and condominiums. Residential water sales are divided by the number of residential retail accounts reported in the monthly utility billing report. The measure is expressed in thousand gallons per account per month.
Commercial water demand	Retail treated water sales by the Corpus Christi Water Division to end-user commercial customers inside and outside the city limits. Commercial water sales include apartments and condominiums, and are distinguished from industrial water customers by the diameter of the water meter connection. Commercial water sales are divided by the number of commercial retail accounts reported in the monthly utility billing report. The measure is expressed in thousand gallons per account per month.
Industrial water demand	Retail and wholesale treated and raw water sales by the Corpus Christi Water Division to end-user industrial customers inside and outside the city limits. Industrial water sales are distinguished from commercial water sales by the size of the meter connection. Industrial water sales are divided by the number of industrial retail accounts reported in the monthly utility billing report. The measure is expressed in thousand gallons per account per month.

Table G.2. Description of Data Required to Forecast Water Demand

Data Series	Description
Mean maximum temperature	The average of daily high temperature is available from the National Weather Service's meteorological station at Corpus Christi International Airport. The mean maximum temperature is expressed in degrees Fahrenheit. Data can be obtained for a week/month on the first day of the subsequent month.
Aggregate rainfall	Aggregate rainfall is the sum of rainfall during the month to be forecast. These data are available from the National Weather Service's meteorological station at Corpus Christi International Airport. Aggregate rainfall is expressed in inches of rain per month. Data can be obtained for a week/month on the first day of the subsequent month.
Marginal water price	The marginal price of water in the residential sector is the price of the eighth thousand gallon of water to residential customers and the 101st thousand gallon of water to commercial and industrial customers. The marginal water price is expressed in dollars per thousand gallons.
Consumer price index	The monthly consumer price index is used to convert nominal prices to real prices for the residential demand analysis. The index is calculated by dividing average prices in one month by average prices during the period 1982-1984 so that the average price index for the period 1982-1984 = 1.00. The index reflects the relative cost of common purchases to all urban consumers throughout the nation in one month relative to that average at some other point in time. This data series is available from the Bureau of Labor Statistics (BLS) online information center on the World Wide Web (http://www.bls.gov) and has the series identification number "cuur0000sa0." From the BLS home page choose "Data" (from below the buttons), then choose "Series Report," enter the series identification number, request the appropriate years, and request the desired format.
Producer price index	The monthly producer price index is used to convert nominal prices to real prices in commercial and industrial demand analyses. The raw index is based on an average monthly producer price index for 1982. The raw index reflects the weighted average price of all commodities purchased by producers throughout the nation relative to the weighted average price in 1982. The average is weighted by the value of shipments. For consistency with the consumer price index, the 1982 index is converted to an average base year of 1982-1994 by dividing by 1.01667. This data series is available from the Bureau of Labor Statistics (BLS) online information center on the World Wide Web (http://www.bls.gov) and has the series identification number "wpu00000000." From the BLS home page choose "Data" (from below the buttons), then choose "Series Report," enter the series identification number, request the appropriate years, and request the desired format.
Sequence of forecast month	The sequence of the forecast month is the numerical sequence of the month in question; the base month, January 1982, is defined as 25. For example, May 1996 is defined as 197 because it is the 172nd month after January 1982. This sequence variable is used to describe trends in water use.