The Economic Impact of Potential Water Shortages on San Antonio's Economy

San Antonio Chamber of Commerce
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Mr. Richard Perez
President
San Antonio Chamber of Commerce
602 E. Commerce
San Antonio, Texas 78205

Dear Mr. Perez:

Thank you for the opportunity to provide consulting services to the Chamber related to the potential economic impacts of failing to insure an adequate water supply in San Antonio.

The economic analysis that follows provides illustration of the potential economic pitfalls of failing to secure adequate water supply to meet the needs of a growing region. In that light, this work is designed to be illustrative, rather than predictive, as San Antonio has an opportunity to make policy and investment decisions that can turn water availability from a potential challenge into an opportunity to create a competitive advantage versus other areas that have not adequately provided for future water needs. Decisions made today will have an enormous impact on the economy of tomorrow, with investments in basic infrastructure likely to pay increasing dividends going forward.

Best regards,

Jon Hockenyos
President

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Summary

This analysis relies on a combination of projections from SAWS regarding demand and supply of water in its service territory, secondary information from several sources regarding the sensitivity of different sectors of the economy to changes in the availability of water, and standard regional economic impact models to provide an assessment of the potential implications to the local economy of differing levels of water shortages. This effort is designed to provide illustration in support of policy development, rather precise projections, and therefore makes a series of simplifying assumptions that are unlikely to occur as actual events unfold. In reality, droughts occur at uncertain intervals, individual customers respond in unique ways to water shortages, and the capacity to reduce demand through conservation and technology continues to evolve. Nevertheless, some important conclusions can be drawn.

1) **There are likely to be negative economic impacts associated with sustained water shortages at even modest levels.** The key here is the duration of the shortage, as most companies can find ways to adjust operations and/or production processes to accommodate temporary shortfalls. However, demand does harden at some point, reducing the capacity to adjust and creating economic consequences.
2) **Negative impacts accelerate as the level of shortage increases.** As the severity of shortage rises, the impacts increase exponentially before leveling off to some degree. At 11.0 percent shortage, total jobs lost are estimated at approximately 6,700, 23.9 percent shortage yields a loss of almost 34,000, and 43.2 percent pushes total lost jobs to just under 135,000 in San Antonio. While these estimates are approximations, they illustrate the order of magnitude of the potential negative consequences of inadequate water supply to the local economy.
3) **Additional supply is a necessary part of the solution.** A combination of technologies, utility programs and incentives, changes in business practice, and overall customer awareness have served to facilitate increased conservation in recent years. While there is good reason to believe that gains can continue to be made in this area, there is also little doubt that additional supply is critical to insuring that San Antonio has adequate water to meet future needs.

As San Antonio considers its water planning future, there has been much discussion surrounding the need for additional water supplies to meet the needs of a growing population and economy. This analysis suggests that water shortages can have a direct negative impact on the economy, and that the duration and severity will directly influence the size and scope of that negative impact. However, if both individuals and business are assured an adequate water supply, an area of potential weakness could turn into an advantage at a time when many other communities are struggling to provide water infrastructure. As a result, San Antonio should seek to maximize its competitive advantage by investing in additional supply.

Overview

In some ways, the combination of drought, continued population and economic growth, and infrastructure financing constraints have created a "perfect storm" around water supply in San Antonio. TXP has been tasked by the San Antonio Chamber of Commerce with evaluating the local economic implications of failing to provide an adequate water supply. Over the past five years, residential customers have averaged about 71.3 percent of San Antonio Water System (SAWS) demand, commercial has been 23.5 percent, industrial accounted for 3.9 percent, and municipal/other represented the remaining 1.3 percent. For purposes of this analysis, shortages are assumed to be allocated proportionately across all customer classes. SAWS is the source of water supply and demand projections (which are driven by estimates of population growth and de facto per capita usage); this information is used to create forecasts of different levels of water shortage that can then be modeled. However, in order to isolate the impact of water shortages on the economy, the analysis is predicated on the estimated economy of the SAWS service territory as of 2012.

Project Inputs

SAWS has produced a series of projections on overall water demand using their population forecast for their service territory the driving factor. These projections also assume a baseline consumption level that is the equivalent of 135 gallons per capita per day (gpcpd). This is based on consumption patterns from 2011, a dry year consistent with the drought of record. An alternative scenario that assumes the equivalent of 169 gallons per capita per day is also provided, based on a wider range of historical data.

Currently, the Edwards Aquifer accounts for the vast majority of SAWS supply. Over the period 2012-2020, SAWS projects that Edwards supply would be reduced by an average of 28 percent annually due to the impact of a drought of record. In combination with projected population growth, this will create shortages; even with a number of sources of additional supply included in the current planning process, demand will exceed supply by 2020. The following table shows the percentage shortfall for the two scenarios outlined above. Note that these are point estimates for individual years, and should not be considered cumulative.

TABLE 1
Percentage Shortfall under Two Scenarios (Assumes No New Supply)

	135 gpcpd	169 gpdpd
2020	11.0%	29.0%
2025	17.4%	34.0%
2030	20.2%	36.2%
2035	23.9%	39.2%
2040	28.9%	43.2%

Sources: SAWS, TXP

Estimation of Direct Impacts

As previously mentioned, the assumption is that patterns of demand by customer class remain consistent with recent SAWS history, and that any shortfall will also be allocated proportionately between and within customer classes. As a result, the bulk of the initial impact of any supply/demand imbalance will fall on households. There is some literature on the implications for overall household welfare, but household shortages have little direct link to the economy, at least in the short run. By the same token, the impacts to the non-residential side have been subject to relatively little analysis. Per a forthcoming study:

> The ability of the CII (commercial/industrial) sector to reduce water in future drought is less clear than for residential customers. Until the drivers of the ongoing decline in CII water use are better understood, water utilities should be cautious about asking CII customers to sharply curtail water use, other than landscaping, in all but severe drought conditions and water shortages.

While the impact of water shortages falls on both business and households, the focus of this analysis is on the implications for the non-residential sector.

Commercial and Industrial Impacts

The first step in the process of evaluating the impact of water shortages is to determine what industries or sectors will feel direct impacts, and at what level. Direct impacts are reductions in output by industries experiencing water shortages. For example, without adequate cooling and process water a refinery would have to cut back or cease operation, car washes may close, and hotels will struggle to adequately service their customers. Based on the literature and primary research, the following sectors are included as being directly affected (accounting for a little less than 24 percent of the SAWS territory economy), along with their estimated level of output (sales) for 2012.

TABLE 2
SAWS Service Territory Estimated Economic Output (2012)

Industrial Sector	2012 Output (Sales)
WATER-INFLUENCED	**$52,522,068,974**
Agriculture & Mining	$792,075,206
Manufacturing	$20,710,821,569
Food/Kindred Products	$3,674,141,292
Stone/Clay/Glass Products	$400,299,539
Electronic Components Mfg.	$292,041,026
Other Manufacturing	$16,344,339,712
Commercial	$31,019,172,199
Hotels	$1,289,937,453
Water-Intensive Consumer[1]	$609,039,135
Other Commercial[2]	$29,120,195,611
Total Estimated Other Sectors	$166,650,839,418
Total Estimated All Sectors	$219,172,908,392

[1] **Water-Intensive Consumer Industries**: includes landscape architects and services, car washes, golf courses, and laundries
[2] **Other Commercial**: includes medical, entertainment, and food services
Sources: Bureau of Economic Analysis, Census Bureau, TXP

Water Shortages and Direct Economic Activity

The impact of water shortages likely will vary based on severity and duration. Following the Texas Water Development Board (TWDB) convention, shortages are assumed to be point estimates for analysis purposes, but to have been somewhat durable in terms of customer response. By the same token, a small shortage relative to total water use would likely have a minimal impact, but large shortages could be critical. For example, hotels facing small shortages might combine new technology and incentives for customers to reduce demand for laundry facilities. However, more severe shortages will be more difficult to overcome. This "hardening" of demand translates into proportionately larger reductions in economic activity. This analysis addresses this issue through the concept of elasticity. Elasticity is a number that shows how a change in one variable will affect another. In this case, it measures the relationship between a percentage reduction in water availability and a percentage reduction in output. For example, an elasticity of 1.0 indicates that a 1.0 percent reduction in water availability would result in a 1.0 percent reduction in economic output. An elasticity of 0.50 would indicate that for every 1.0 percent of unavailable water, output is reduced by 0.50 percent and so on. There is relatively little information in the literature that quantifies the output elasticities of reduced water supply, and what is available is largely dated. For example, the estimates used in the 2010 TWDB Socioeconomic Impact Assessment of Water Shortages for Region L (which includes San Antonio) relies on estimates developed in California by Spectrum Economics more than 20 years ago. The TWDB parameters are listed below.

- if water needs are 0 to 5 percent of total water demand, no corresponding reduction in output is assumed;
- if water needs are 5 to 30 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.50 percent reduction in output;
- if water needs are 30 to 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.75 percent reduction in output; and
- if water needs are greater than 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 1.0 percent (i.e., a proportional reduction).

This study combines information from the Spectrum Study, a study by MHB Consultants for the San Francisco Public Utility Commission (SFPUC) on the impact on commercial and manufacturing customers with TXP's subsequent primary research for SFPUC to refine the information listed above. In addition, the impact of evolving technology to reduce demand is considered, although this impact is somewhat offset by conservation efforts that have already been implemented. The result is the following output elasticity estimates by sector. For example, a water shortage of 10 percent has no impact on hotels, but at 40 percent water shortage would reduce sales by 20 percentage points. Similarly, a 20 percent shortage of water would reduce agricultural output by 10 percent (2 percentage points), but shortages greater than 50 percent would reduce sales by a corresponding amount.

TABLE 3
Output Elasticities by Sector

	Level of Shortage				
Sector	**0-5%**	**6-15%**	**16-30%**	**31-50%**	**51%+**
Food/Kindred Products	0.00	0.10	0.33	0.65	1.00
Stone/Clay/Glass Products	0.00	0.10	0.33	0.65	1.00
Electronic Components	0.00	0.10	0.25	0.50	0.75
Other Manufacturing	0.00	0.10	0.25	0.50	0.75
Hotels	0.00	0.10	0.25	0.50	1.00
Water-Intensive Consumer	0.00	0.10	0.33	0.65	1.00
Other Commercial	0.00	0.05	0.10	0.25	0.50
Agriculture	0.00	0.10	0.50	0.75	1.00
Mining	0.00	0.10	0.33	0.50	0.75

Source: TXP

The following tables illustrate the direct economic impact of water shortages based on different scenarios on per capita consumption. As the tables indicate, the effects increase dramatically as the level of shortage rises, which is projected to occur if no new supply is added. For example, an eleven percent shortage yields slightly more than $417 million in direct losses in 2020 under the 135 gpcpd scenario, a figure that rises almost six-fold over the next twenty years, to over $2.6 billion. The situation is more grave under the 169 gpcpd scenario, as direct losses amount to over $8.5 billion in 2040. Using this data as inputs, it is then possible to calculate the overall regional economic impact of water shortages at different levels.

TABLE 4
Direct Output Losses by Sector: 135 gpcpd Scenario ($2012)

	2020	2030	2040
Sector	11.0%	20.2%	28.9%
Food/Kindred Products	$40,415,554	$244,918,259	$350,402,855
Stone/Clay/Glass Products	$4,403,295	$26,683,967	$38,176,567
Electronic Components	$3,212,451	$14,748,072	$21,099,964
Other Manufacturing	$179,787,737	$825,389,155	$1,180,878,544
Hotels	$14,189,312	$65,141,841	$93,197,981
Water-Intensive Consumer	$6,699,430	$40,598,549	$58,084,062
Other Commercial	$160,161,076	$588,227,951	$841,573,653
Agriculture	$972,776	$8,931,849	$12,778,735
Mining	$7,740,052	$46,904,713	$67,106,248
TOTALS	**$417,581,683**	**$1,861,544,356**	**$2,663,298,609**

Source: TXP

TABLE 5
Direct Output Losses by Sector: 169 gpcpd Scenario ($2012)

	2020	2030	2040
Sector	29.0%	36.2%	43.2%
Food/Kindred Products	$351,615,322	$864,525,446	$1,031,698,875
Stone/Clay/Glass Products	$38,308,666	$94,190,481	$112,404,110
Electronic Components	$21,172,974	$52,859,426	$63,080,862
Other Manufacturing	$1,184,964,629	$2,958,325,488	$3,530,377,378
Hotels	$93,520,465	$233,478,679	$278,626,490
Water-Intensive Consumer	$58,285,045	$143,306,908	$171,018,189
Other Commercial	$844,485,673	$2,635,377,703	$3,144,981,126
Agriculture	$12,822,952	$24,009,872	$28,652,665
Mining	$67,338,449	$127,359,031	$151,986,468
TOTALS	**$2,672,514,175**	**$7,133,433,034**	**$8,512,826,162**

Source: TXP

Economic Impact Methodology

In an input-output analysis of new economic activity, it is useful to distinguish three types of expenditure effects: direct, indirect, and induced.

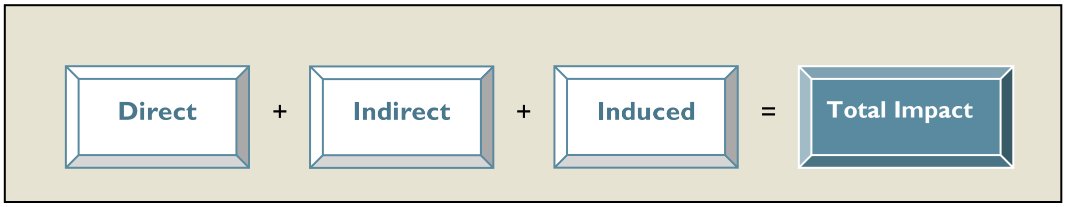
Direct effects are production changes associated with the immediate effects or final demand changes. The payment made by an out-of-town visitor to a hotel operator is an example of a direct effect, as would be the taxi fare that visitor paid to be transported into town from the airport.

Indirect effects are production changes in backward-linked industries caused by the changing input needs of directly affected industries – typically, additional purchases to produce additional output. Indirect impacts involve changes in inter-industry transactions as supplying industries respond to decreased demands for their services, and how seemingly non-related businesses are affected by decreased incomes and spending due to direct impacts. For example, if a car wash curtails operations due to a lack of water, they would likely reduce expenditures on supplies, labor and equipment, and businesses that provide these goods would suffer as well.

Induced effects are the changes in regional household spending patterns caused by changes in household income generated from the direct and indirect effects. Both the hotel operator and taxi driver experience increased income from the visitor's stay, for example, as do the cleaning supplies outlet and the gas station proprietor. Induced effects capture the way in which this increased income is in turn spent by them in the local economy.

The interdependence between different sectors of the economy is reflected in the concept of a "multiplier." An output multiplier, for example, divides the total (direct, indirect and induced) effects of an initial spending injection by the value of that injection – i.e., the direct effect. The higher the multiplier, the greater the interdependence among different sectors of the economy. An output multiplier of 1.4, for example, means that for every $1,000 injected into the economy, another $400 in output is produced in all other sectors.

FIGURE 1
The Flow of Economic Impacts



An economy can be measured in a number of ways. Three of the most common are "**Output**" which describes total economic activity and is equivalent to a firm's gross sales, "**Employee Earnings**" which corresponds to wages and benefits, and "**Employment**" which refers to permanent jobs that have been created in the local economy. Using these variables, the total impact of decreased output levels associated with several levels of water shortage are shown as follows in three scenarios; a water shortage of 11.0 percent, a shortage of 23.2 percent, and a shortage of 43.2 percent. These figures represent the range of shortage reported in Table One, as well as a midpoint.

TABLE 6
Total Annual Loss Due to an 11.0 Percent Water Shortage ($2012)

NAICS	Output	Earnings	Employment
Agriculture, Forestry, Fishing, & Hunting	$5,216,846	$889,853	56
Mining	$11,380,517	$2,834,908	34
Transportation/Utilities	$31,131,639	$9,778,024	202
Construction	$9,497,184	$3,627,926	93
Manufacturing	$274,137,866	$72,133,267	1,210
Trade	$54,934,534	$18,486,993	551
Information	$26,426,805	$6,211,222	98
Finance and Insurance	$49,344,554	$13,742,158	249
Real estate	$65,841,189	$4,993,784	216
Professional/Scientific/Technical Services	$27,929,337	$12,854,545	207
Management Companies & Enterprises	$15,003,600	$6,184,087	81
Admin./Waste Management Services	$25,988,738	$9,780,531	384
Educational Services	$4,274,251	$1,738,396	73
Health Care & Social Assistance	$33,098,523	$15,757,528	424
Arts, Entertainment, & Recreation	$4,049,523	$1,564,010	82
Accommodation & Food Services	$32,636,564	$10,160,065	513
Other Services	$179,010,837	$55,041,195	2,215
TOTALS	$849,902,508	$245,778,493	6,687

Source: TXP

TABLE 7

Total Annual Loss Due to an 23.9 Percent Water Shortage ($2012)

NAICS	Output	Earnings	Employment
Agriculture, Forestry, Fishing, & Hunting	$38,663,156	$6,598,107	414
Mining	$74,175,487	$18,694,261	230
Transportation/Utilities	$165,484,033	$51,810,191	1,072
Construction	$45,158,632	$17,257,366	441
Manufacturing	$1,562,011,099	$402,416,998	6,865
Trade	$289,011,835	$97,149,224	2,864
Information	$136,598,102	$32,156,365	505
Finance and Insurance	$248,911,716	$69,220,466	1,254
Real estate	$337,382,976	$25,795,551	1,110
Professional/Scientific/Technical Services	$143,427,503	$65,898,472	1,061
Management Companies & Enterprises	$84,277,077	$34,733,649	453
Admin./Waste Management Services	$147,397,456	$53,424,100	2,026
Educational Services	$21,955,243	$8,922,446	373
Health Care & Social Assistance	$171,141,157	$81,475,296	2,195
Arts, Entertainment, & Recreation	$20,916,364	$8,081,542	424
Accommodation & Food Services	$172,726,750	$53,742,526	2,702
Other Services	$791,804,092	$243,464,775	9,796
TOTALS	$4,451,042,675	$1,270,841,336	33,786

Source: TXP

TABLE 8

Total Annual Loss Due to an 43.2 Percent Water Shortage ($2012)

NAICS	Output	Earnings	Employment
Agriculture, Forestry, Fishing, & Hunting	$129,779,186	$22,143,790	1,388
Mining	$224,845,043	$55,987,160	673
Transportation/Utilities	$637,932,106	$200,087,055	4,130
Construction	$189,545,229	$72,412,096	1,853
Manufacturing	$5,686,983,763	$1,463,685,818	24,982
Trade	$1,118,761,461	$376,317,889	11,163
Information	$533,346,410	$125,362,855	1,969
Finance and Insurance	$994,590,571	$276,803,311	5,016
Real estate	$1,329,663,556	$100,992,962	4,368
Professional/Scientific/Technical Services	$564,991,801	$259,737,580	4,182
Management Companies & Enterprises	$314,038,521	$129,422,772	1,688
Admin./Waste Management Services	$565,310,121	$207,524,989	7,964
Educational Services	$86,234,112	$35,059,676	1,463
Health Care & Social Assistance	$668,242,937	$318,127,268	8,570
Arts, Entertainment, & Recreation	$81,757,233	$31,565,930	1,658
Accommodation & Food Services	$651,166,420	$202,743,937	10,271
Other Services	$3,525,378,039	$1,083,964,071	43,616
TOTALS	$17,302,566,508	$4,961,939,158	134,954

Source: TXP

Conclusions

This analysis relies on a combination of projections from SAWS regarding demand and supply of water in its service territory, secondary information from several sources regarding the sensitivity of different sectors of the economy to changes in the availability of water, and standard regional economic impact models to provide an assessment of the potential implications to the local economy of differing levels of water shortages. This effort is designed to provide illustration in support of policy development, rather precise projections, and therefore makes a series of simplifying assumptions that are unlikely to occur as actual events unfold. For example, the projections on supply and demand assume a "drought of record" occurs every five years for the period from 2020 to 2040. This convention is used to facilitate a reasonable "worst case" evaluation, which is the standard in water policy planning. In reality, droughts occur at uncertain intervals, individual customers respond in unique ways to water shortages, and the capacity to reduce demand through conservation and technology continues to evolve. Nevertheless, some important conclusions can be drawn.

1) **There are likely to be negative economic impacts associated with sustained water shortages at even modest levels.** The key here is the duration of the shortage, as most companies can find ways to adjust operations and/or production processes to accommodate temporary shortfalls. Over time, permanent changes can be implemented, along with new technologies that may further reduce need for water as an input or factor of the business. However, demand does harden at some point (especially for highly-water intensive sectors), reducing the capacity to adjust and creating economic consequences.
2) **Negative impacts accelerate as the level of shortage increases.** As the severity of shortage rises, the impacts increase exponentially before leveling off to some degree. At 11.0 percent shortage, total jobs lost are estimated at approximately 6,700, 23.9 percent shortage yields a loss of almost 34,000, and 43.2 percent pushes total lost jobs to just under 135,000 in San Antonio. While these estimates are approximations, they clearly illustrate the order of magnitude of the potential negative consequences of inadequate water supply to the local economy.
3) **Additional supply is a necessary part of the solution.** A combination of technologies, utility programs and incentives, changes in business practice, and overall customer awareness have served to facilitate increased conservation in recent years. While there is good reason to believe that gains can continue to be made in this area, there is also little doubt that additional supply is critical to insuring that San Antonio has adequate water to meet future needs.

As San Antonio considers its water planning future, there has been much discussion surrounding the need for additional water supplies to meet the needs of a growing population and economy. This analysis suggests that water shortages can have a direct negative impact on the economy, and that the duration and severity will directly influence the size and scope of that negative impact. However, if both individuals and business are assured an adequate water supply, an area of potential weakness could turn into an advantage at a time when many other communities are struggling to provide water infrastructure. As a result, San Antonio should seek to maximize its competitive advantage by investing in additional supply.

Appendix

Socioeconomic Impacts of Projected Water Shortages for the South Central Texas Regional Water Planning Area (Region L)

Prepared in Support of the 2011 South Central Texas Regional Water Plan

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Introduction

Water shortages during drought would likely curtail or eliminate economic activity in business and industries reliant on water. For example, without water farmers cannot irrigate; refineries cannot produce gasoline, and paper mills cannot make paper. Unreliable water supplies would not only have an immediate and real impact on existing businesses and industry, but they could also adversely affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages would disrupt activity in homes, schools and government and could adversely affect public health and safety. For all of the above reasons, it is important to analyze and understand how restricted water supplies during drought could affect communities throughout the state.

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process, and rules direct TWDB staff to provide technical assistance: "*The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs*" [(§357.7 (4)(A)]. Staff of the TWDB's Water Resources Planning Division designed and conducted this report in support of the South Central Texas Regional Water Planning Group (Region L).

This document summarizes the results of our analysis and discusses the methodology used to generate the results. Section 1 outlines the overall methodology and discusses approaches and assumptions specific to each water use category (i.e., irrigation, livestock, mining, steam-electric, municipal and manufacturing). Section 2 presents the results for each category where shortages are reported at the regional planning area level and river basin level. Results for individual water user groups are not presented, but are available upon request.

1. Methodology

Section 1 provides a general overview of how economic and social impacts were measured. In addition, it summarizes important clarifications, assumptions and limitations of the study.

1.1 Economic Impacts of Water Shortages

1.1.1 General Approach

Economic analysis as it relates to water resources planning generally falls into two broad areas. Supply side analysis focuses on costs and alternatives of developing new water supplies or implementing programs that provide additional water from current supplies. Demand side analysis concentrates on impacts or benefits of providing water to people, businesses and the environment. Analysis in this report focuses strictly on demand side impacts. When analyzing the economic impacts of water shortages as defined in Texas water planning, three potential scenarios are possible:

1) Scenario 1 involves situations where there are physical shortages of raw surface or groundwater due to drought of record conditions. For example, City A relies on a reservoir with average conservation storage of 500 acre-feet per year and a firm yield of 100 acre feet. In 2010, the city uses about 50 acre-feet per year, but by 2030 their demands are expected to increase to 200

acre-feet. Thus, in 2030 the reservoir would not have enough water to meet the city's demands, and people would experience a shortage of 100 acre-feet assuming drought of record conditions. Under normal or average climatic conditions, the reservoir would likely be able to provide reliable water supplies well beyond 2030.

2) Scenario 2 is a situation where despite drought of record conditions, water supply sources can meet existing use requirements; however, limitations in water infrastructure would preclude future water user groups from accessing these water supplies. For example, City B relies on a river that can provide 500 acre-feet per year during drought of record conditions and other constraints as dictated by planning assumptions. In 2010, the city is expected to use an estimated 100 acre-feet per year and by 2060 it would require no more than 400 acre-feet. But the intake and pipeline that currently transfers water from the river to the city's treatment plant has a capacity of only 200 acre-feet of water per year. Thus, the city's water supplies are adequate even under the most restrictive planning assumptions, but their conveyance system is too small. This implies that at some point – perhaps around 2030 - infrastructure limitations would constrain future population growth and any associated economic activity or impacts.

3) Scenario 3 involves water user groups that rely primarily on aquifers that are being depleted. In this scenario, projected and in some cases existing demands may be unsustainable as groundwater levels decline. Areas that rely on the Ogallala aquifer are a good example. In some communities in the region, irrigated agriculture forms a major base of the regional economy. With less irrigation water from the Ogallala, population and economic activity in the region could decline significantly assuming there are no offsetting developments.

Assessing the social and economic effects of each of the above scenarios requires various levels and methods of analysis and would generate substantially different results for a number of reasons; the most important of which has to do with the time frame of each scenario. Scenario 1 falls into the general category of static analysis. This means that models would measure impacts for a small interval of time such as a drought. Scenarios 2 and 3, on the other hand imply a dynamic analysis meaning that models are concerned with changes over a much longer time period.

Since administrative rules specify that planning analysis be evaluated under drought of record conditions (a static and random event), socioeconomic impact analysis developed by the TWDB for the state water plan is based on assumptions of Scenario 1. Estimated impacts under scenario 1 are point estimates for years in which needs are reported (2010, 2020, 2030, 2040, 2050 and 2060). They are independent and distinct "what if" scenarios for a particular year and shortages are assumed to be temporary events resulting from drought of record conditions. Estimated impacts measure what would happen if water user groups experience water shortages for a period of one year.

The TWDB recognize that dynamic models may be more appropriate for some water user groups; however, combining approaches on a statewide basis poses several problems. For one, it would require a complex array of analyses and models, and might require developing supply and demand forecasts under "normal" climatic conditions as opposed to drought of record conditions. Equally important is the notion that combining the approaches would produce inconsistent results across regions resulting in a so-called "apples to oranges" comparison.

A variety tools are available to estimate economic impacts, but by far, the most widely used today are input-output models (IO models) combined with social accounting matrices (SAMs). Referred to as IO/SAM models, these tools formed the basis for estimating economic impacts for agriculture (irrigation and livestock water uses) and industry (manufacturing, mining, steam-electric and commercial business activity for municipal water uses).

Since the planning horizon extends through 2060, economic variables in the baseline are adjusted in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Future values for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category.

The following steps outline the overall process.

Step 1*: Generate IO/SAM Models and Develop Economic Baseline*

IO/SAM models were estimated using propriety software known as IMPLAN PRO™ (Impact for Planning Analysis). IMPLAN is a modeling system originally developed by the U.S. Forestry Service in the late 1970s. Today, the Minnesota IMPLAN Group (MIG Inc.) owns the copyright and distributes data and software. It is probably the most widely used economic impact model in existence. IMPLAN comes with databases containing the most recently available economic data from a variety of sources.[1] Using IMPLAN software and data, transaction tables conceptually similar to the one discussed previously were estimated for each county in the region and for the region as a whole. Each transaction table contains 528 economic sectors and allows one to estimate a variety of economic statistics including:

- **total sales -** total production measured by sales revenues;
- **intermediate sales -** sales to other businesses and industries within a given region;
- **final sales –** sales to end users in a region and exports out of a region**;**
- **employment -** number of full and part-time jobs (annual average) required by a given industry including self-employment;
- **regional income -** total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments; and
- **business taxes -** sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include income taxes).

TWDB analysts developed an economic baseline containing each of the above variables using year 2000 data. Since the planning horizon extends through 2060, economic variables in the baseline were allowed to change in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Projections for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category. Monetary impacts in future years are reported in constant year 2006 dollars.

It is important to stress that employment, income and business taxes are the most useful variables when comparing the relative contribution of an economic sector to a regional economy. Total sales as reported in IO/SAM models are less desirable and can be misleading because they include sales to other industries in the region for use in the production of other goods. For example, if a mill buys grain from local farmers and uses it to produce feed, sales of both the processed feed and raw corn are counted

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[1]The IMPLAN database consists of national level technology matrices based on benchmark input-output accounts generated by the U.S. Bureau of Economic Analysis and estimates of final demand, final payments, industry output and employment for various economic sectors. IMPLAN regional data (i.e. states, a counties or groups of counties within a state) are divided into two basic categories: 1) data on an industry basis including value-added, output and employment, and 2) data on a commodity basis including final demands and institutional sales. State-level data are balanced to national totals using a matrix ratio allocation system and county data are balanced to state totals.

as "output" in an IO model. Thus, total sales double-count or overstate the true economic value of goods and services produced in an economy. They are not consistent with commonly used measures of output such as Gross National Product (GNP), which counts only final sales.

Another important distinction relates to terminology. Throughout this report, the term *sector* refers to economic subdivisions used in the IMPLAN database and resultant input-output models (528 individual sectors based on Standard Industrial Classification Codes). In contrast, the phrase *water use category* refers to water user groups employed in state and regional water planning including irrigation, livestock, mining, municipal, manufacturing and steam electric. Each IMPLAN sector was assigned to a specific water use category.

Step 2: *Estimate Direct and Indirect Economic Impacts of Water Needs*

Direct impacts are reductions in output by sectors experiencing water shortages. For example, without adequate cooling and process water a refinery would have to curtail or cease operation, car washes may close, or farmers may not be able to irrigate and sales revenues fall. Indirect impacts involve changes in inter-industry transactions as supplying industries respond to decreased demands for their services, and how seemingly non-related businesses are affected by decreased incomes and spending due to direct impacts. For example, if a farmer ceases operations due to a lack of irrigation water, they would likely reduce expenditures on supplies such as fertilizer, labor and equipment, and businesses that provide these goods would suffer as well.

Direct impacts accrue to immediate businesses and industries that rely on water and without water industrial processes could suffer. However, output responses may vary depending upon the severity of shortages. A small shortage relative to total water use would likely have a minimal impact, but large shortages could be critical. For example, farmers facing small shortages might fallow marginally productive acreage to save water for more valuable crops. Livestock producers might employ emergency culling strategies, or they may consider hauling water by truck to fill stock tanks. In the case of manufacturing, a good example occurred in the summer of 1999 when Toyota Motor Manufacturing experienced water shortages at a facility near Georgetown, Kentucky.[2] As water levels in the Kentucky River fell to historic lows due to drought, plant managers sought ways to curtail water use such as reducing rinse operations to a bare minimum and recycling water by funneling it from paint shops to boilers. They even considered trucking in water at a cost of 10 times what they were paying. Fortunately, rains at the end of the summer restored river levels, and Toyota managed to implement cutbacks without affecting production, but it was a close call. If rains had not replenished the river, shortages could have severely reduced output.[3]

To account for uncertainty regarding the relative magnitude of impacts to farm and business operations, the following analysis employs the concept of elasticity. Elasticity is a number that shows how a change in one variable will affect another. In this case, it measures the relationship between a percentage reduction in water availability and a percentage reduction in output. For example, an elasticity of 1.0 indicates that a 1.0 percent reduction in water availability would result in a 1.0 percent reduction in

[2] Royal, W. "*High And Dry - Industrial Centers Face Water Shortages*." in Industry Week, Sept, 2000.

[3] The efforts described above are not planned programmatic or long-term operational changes. They are emergency measures that individuals might pursue to alleviate what they consider a temporary condition. Thus, they are not characteristic of long-term management strategies designed to ensure more dependable water supplies such as capital investments in conservation technology or development of new water supplies.

economic output. An elasticity of 0.50 would indicate that for every 1.0 percent of unavailable water, output is reduced by 0.50 percent and so on. Output elasticities used in this study are:[4]

- if water needs are 0 to 5 percent of total water demand, no corresponding reduction in output is assumed;
- if water needs are 5 to 30 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.50 percent reduction in output;
- if water needs are 30 to 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.75 percent reduction in output; and
- if water needs are greater than 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 1.0 percent (i.e., a proportional reduction).

In some cases, elasticities are adjusted depending upon conditions specific to a given water user group.

Once output responses to water shortages were estimated, direct impacts to total sales, employment, regional income and business taxes were derived using regional level economic multipliers estimating using IO/SAM models. The formula for a given IMPLAN sector is:

$$D_{i,t} = Q_{i,t} *_{,} S_{i,t} * E_Q * RFD_i * DM_{i(Q, L, I, T)}$$

where:

$D_{i,t}$ = direct economic impact to sector *i* in period *t*

$Q_{i,t}$ = total sales for sector *i* in period *t* in an affected county

$RFD_{i,}$ = ratio of final demand to total sales for sector *i* for a given region

$S_{i,t}$ = water shortage as percentage of total water use in period *t*

E_Q = elasticity of output and water use

$DM_{i(L, I, T)}$ = direct output multiplier coefficients for labor (L), income (I) and taxes (T) for sector *i*.

Secondary impacts were derived using the same formula used to estimate direct impacts; however, indirect multiplier coefficients are used. Methods and assumptions specific to each water use sector are discussed in Sections 1.1.2 through 1.1.4.

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[4] Elasticities are based on one of the few empirical studies that analyze potential relationships between economic output and water shortages in the United States. The study, conducted in California, showed that a significant number of industries would suffer reduced output during water shortages. Using a survey based approach researchers posed two scenarios to different industries. In the first scenario, they asked how a 15 percent cutback in water supply lasting one year would affect operations. In the second scenario, they asked how a 30 percent reduction lasting one year would affect plant operations. In the case of a 15 percent shortage, reported output elasticities ranged from 0.00 to 0.76 with an average value of 0.25. For a 30 percent shortage, elasticities ranged from 0.00 to 1.39 with average of 0.47. For further information, see, California Urban Water Agencies, "*Cost of Industrial Water Shortages,*" Spectrum Economics, Inc. November, 1991.

General Assumptions and Clarification of the Methodology

As with any attempt to measure and quantify human activities at a societal level, assumptions are necessary and every model has limitations. Assumptions are needed to maintain a level of generality and simplicity such that models can be applied on several geographic levels and across different economic sectors. In terms of the general approach used here several clarifications and cautions are warranted:

1. Shortages as reported by regional planning groups are the starting point for socioeconomic analyses.

2. Estimated impacts are point estimates for years in which needs are reported (i.e., 2010, 2020, 2030, 2040, 2050 and 2060).They are independent and distinct "what if" scenarios for each particular year and water shortages are assumed to be temporary events resulting from severe drought conditions combined with infrastructure limitations. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals and resultant impacts are measured. Given, that reported figures are not cumulative in nature, it is inappropriate to sum impacts over the entire planning horizon. Doing so, would imply that the analysis predicts that drought of record conditions will occur every ten years in the future, which is not the case. Similarly, authors of this report recognize that in many communities needs are driven by population growth, and in the future total population will exceed the amount of water available due to infrastructure limitations, regardless of whether or not there is a drought. This implies that infrastructure limitations would constrain economic growth. However, since needs as defined by planning rules are based upon water supply and demand under the assumption of drought of record conditions, it improper to conduct economic analysis that focuses on growth related impacts over the planning horizon. Figures generated from such an analysis would presume a 50-year drought of record, which is unrealistic. Estimating lost economic activity related to constraints on population and commercial growth due to lack of water would require developing water supply and demand forecasts under "normal" or "most likely" future climatic conditions.

3. While useful for planning purposes, this study is not a benefit-cost analysis. Benefit cost analysis is a tool widely used to evaluate the economic feasibility of specific policies or projects as opposed to estimating economic impacts of unmet water needs. Nevertheless, one could include some impacts measured in this study as part of a benefit cost study if done so properly. Since this is not a benefit cost analysis, future impacts are not weighted differently. In other words, estimates are not discounted. If used as a measure of economic benefits, one should incorporate a measure of uncertainty into the analysis. In this type of analysis, a typical method of discounting future values is to assign probabilities of the drought of record recurring again in a given year, and weight monetary impacts accordingly. This analysis assumes a probability of one.

4. IO multipliers measure the strength of backward linkages to supporting industries (i.e., those who sell inputs to an affected sector). However, multipliers say nothing about forward linkages consisting of businesses that purchase goods from an affected sector for further processing. For example, ranchers in many areas sell most of their animals to local meat packers who process animals into a form that consumers ultimately see in grocery stores and restaurants. Multipliers do not capture forward linkages to meat packers, and since meat packers sell livestock purchased from ranchers as "final sales," multipliers for the ranching sector do fully account for all losses to a region's economy. Thus, as mentioned previously, in some cases closely linked sectors were moved from one water use category to another.

5. Cautions regarding interpretations of direct and secondary impacts are warranted. IO/SAM multipliers are based on "fixed-proportion production functions," which basically means that input use - including labor - moves in lockstep fashion with changes in levels of output. In a

scenario where output (i.e., sales) declines, losses in the immediate sector or supporting sectors could be much less than predicted by an IO/SAM model for several reasons. For one, businesses will likely expect to continue operating so they might maintain spending on inputs for future use; or they may be under contractual obligations to purchase inputs for an extended period regardless of external conditions. Also, employers may not lay-off workers given that experienced labor is sometimes scarce and skilled personnel may not be readily available when water shortages subside. Lastly people who lose jobs might find other employment in the region. As a result, direct losses for employment and secondary losses in sales and employment should be considered an upper bound. Similarly, since projected population losses are based on reduced employment in the region, they should be considered an upper bound as well.

6. IO models are static. Models and resultant multipliers are based upon the structure of the U.S. and regional economies in 2006. In contrast, water shortages are projected to occur well into the future. Thus, the analysis assumes that the general structure of the economy remains the same over the planning horizon, and the farther out into the future we go, this assumption becomes less reliable.

7. Impacts are annual estimates. If one were to assume that conditions persisted for more than one year, figures should be adjusted to reflect the extended duration. The drought of record in most regions of Texas lasted several years.

8. Monetary figures are reported in constant year 2006 dollars.

1.1.2 Impacts to Agriculture

Irrigated Crop Production

The first step in estimating impacts to irrigation required calculating gross sales for IMPLAN crop sectors. Default IMPLAN data do not distinguish irrigated production from dry-land production. Once gross sales were known other statistics such as employment and income were derived using IMPLAN direct multiplier coefficients. Gross sales for a given crop are based on two data sources:

1) county-level statistics collected and maintained by the TWDB and the USDA Farm Services Agency (FSA) including the number of irrigated acres by crop type and water application per acre, and

2) regional-level data published by the Texas Agricultural Statistics Service (TASS) including prices received for crops (marketing year averages), crop yields and crop acreages.

Crop categories used by the TWDB differ from those used in IMPLAN datasets. To maintain consistency, sales and other statistics are reported using IMPLAN crop classifications. Table 1 shows the TWDB crops included in corresponding IMPLAN sectors, and Table 2 summarizes acreage and estimated annual water use for each crop classification (five-year average from 2003-2007). Table 3 displays average (2003-2007) gross revenues per acre for IMPLAN crop categories.

Table 1: Crop Classifications Used in TWDB Water Use Survey and Corresponding IMPLAN Crop Sectors	
IMPLAN Category	**TWDB Category**
Oilseeds	Soybeans and “other oil crops”
Grains	Grain sorghum, corn, wheat and “other grain crops”
Vegetable and melons	“Vegetables” and potatoes
Tree nuts	Pecans
Fruits	Citrus, vineyard and other orchard
Cotton	Cotton
Sugarcane and sugar beets	Sugarcane and sugar beets
All “other” crops	“Forage crops”, peanuts, alfalfa, hay and pasture, rice and “all other crops”

Table 2: Summary of Irrigated Crop Acreage and Water Demand for the South Central Texas Regional Water Planning Area (average 2003-2007)

Sector	Acres (1000s)	Distribution of acres	Water use (1000s of AF)	Distribution of water use
Oilseeds	2	1%	2	1%
Grains	108	43%	123	38%
Vegetable and melons	34	14%	39	12%
Tree nuts	3	1%	7	2%
Fruits	<1	<1%	<1	<1%
Cotton	32	13%	45	14%
All “other” crops	70	28%	105	33%
Total	251	100%	321	100%

Source: Water demand figures are a 5- year average (2003-2007) of the TWDB’s annual Irrigation Water Use Estimates. Statistics for irrigated crop acreage are based upon annual survey data collected by the TWDB and the Farm Service Agency. Values do not include acreage or water use for the TWDB categories classified by the Farm Services Agency as “failed acres,” “golf course” or “waste water.”

Table 3: Average Gross Sales Revenues per Acre for Irrigated Crops for the South Central Texas Regional Water Planning Area (2003-2007)		
IMPLAN Sector	**Gross revenues per acre**	**Crops included in estimates**
Oilseeds	$178	Based on five-year (2003-2007) average weighted by acreage for “irrigated soybeans” and “irrigated ‘other’ oil crops.”
Grains	$235	Based on five-year (2003-2007) average weighted by acreage for “irrigated grain sorghum”, “irrigated corn”, “irrigated wheat” and “irrigated ‘other’ grain crops.”
Vegetable and melons	$5,725	Based on five-year (2003-2007) average weighted by acreage for “irrigated shallow and deep root vegetables”, “irrigated Irish potatoes” and “irrigated melons.”
Tree nuts	$3,374	Based on five-year (2003-2007) average weighted by acreage for “irrigated pecans.”
Fruits	$26,423	Based on five-year (2003-2007) average weighted by acreage for “irrigated citrus”, “irrigated vineyards” and “irrigated ‘other’ orchard.”
Cotton	$543	Based on five-year (2003-2007) average weighted by acreage for “irrigated cotton.”
All “other” crops	$359	Based on five-year (2003-2007) average weighted by acreage for “irrigated ‘forage’ crops”, “irrigated peanuts”, “irrigated alfalfa”, “irrigated ‘hay’ and pasture” and “irrigated ‘all other’ crops.”

*Figures are rounded. Source: Based on data from the Texas Agricultural Statistics Service, Texas Water Development Board, and Texas A&M University.

An important consideration when estimating impacts to irrigation was determining which crops are affected by water shortages. One approach is the so-called rationing model, which assumes that farmers respond to water supply cutbacks by fallowing the lowest value crops in the region first and the highest valued crops last until the amount of water saved equals the shortage.[5] For example, if farmer A grows vegetables (higher value) and farmer B grows wheat (lower value) and they both face a proportionate cutback in irrigation water, then farmer B will sell water to farmer A. Farmer B will fallow her irrigated acreage before farmer A fallows anything. Of course, this assumes that farmers can and do transfer enough water to allow this to happen. A different approach involves constructing farm-level profit maximization models that conform to widely-accepted economic theory that farmers make decisions based on marginal net returns. Such models have good predictive capability, but data requirements and complexity are high. Given that a detailed analysis for each region would require a substantial amount of farm-level data and analysis, the following investigation assumes that projected shortages are distributed equally across predominant crops in the region. Predominant in this case are crops that comprise at least one percent of total acreage in the region.

The following steps outline the overall process used to estimate direct impacts to irrigated agriculture:

1. *Distribute shortages across predominant crop types in the region*. Again, unmet water needs were distributed equally across crop sectors that constitute one percent or more of irrigated acreage.

2. *Estimate associated reductions in output for affected crop sectors*. Output reductions are based on elasticities discussed previously and on estimated values per acre for different crops. Values per acre stem from the same data used to estimate output for the year 2006 baseline. Using multipliers, we then generate estimates of forgone income, jobs, and tax revenues based on reductions in gross sales and final demand.

Livestock

The approach used for the livestock sector is basically the same as that used for crop production. As is the case with crops, livestock categorizations used by the TWDB differ from those used in IMPLAN datasets, and TWDB groupings were assigned to a given IMPLAN sector (Table 4). Then we:

1) *Distribute projected water needs equally among predominant livestock sectors and estimate lost output*: As is the case with irrigation, shortages are assumed to affect all livestock sectors equally; however, the category of "other" is not included given its small size. If water needs were small relative to total demands, we assume that producers would haul in water by truck to fill stock tanks. The cost per acre-foot ($24,000) is based on 2008 rates charged by various water haulers in Texas, and assumes that the average truck load is 6,500 gallons at a hauling distance of 60 miles.

3) *Estimate reduced output in forward processors for livestock sectors*. Reductions in output for livestock sectors are assumed to have a proportional impact on forward processors in the region such as meat packers. In other words, if the cows were gone, meat-packing plants or fluid milk manufacturers) would likely have little to process. This is not an unreasonable premise. Since the

[5] The rationing model was initially proposed by researchers at the University of California at Berkeley, and was then modified for use in a study conducted by the U.S. Environmental Protection Agency that evaluated how proposed water supply cutbacks recommended to protect water quality in the Bay/Delta complex in California would affect farmers in the Central Valley. See, Zilberman, D., Howitt, R. and Sunding, D. "*Economic Impacts of Water Quality Regulations in the San Francisco Bay and Delt*a." Western Consortium for Public Health. May 1993.

1950s, there has been a major trend towards specialized cattle feedlots, which in turn has decentralized cattle purchasing from livestock terminal markets to direct sales between producers and slaughterhouses. Today, the meat packing industry often operates large processing facilities near high concentrations of feedlots to increase capacity utilization.[6] As a result, packers are heavily dependent upon nearby feedlots. For example, a recent study by the USDA shows that on average meat packers obtain 64 percent of cattle from within 75 miles of their plant, 82 percent from within 150 miles and 92 percent from within 250 miles.[7]

Table 4: Description of Livestock Sectors

IMPLAN Category	TWDB Category
Cattle ranching and farming	Cattle, cow calf, feedlots and dairies
Poultry and egg production	Poultry production.
Other livestock	Livestock other than cattle and poultry (i.e., horses, goats, sheep, hogs)
Milk manufacturing	Fluid milk manufacturing, cheese manufacturing, ice cream manufacturing etc.
Meat packing	Meat processing present in the region from slaughter to final processing

1.1.3 Impacts to Municipal Water User Groups

Disaggregation of Municipal Water Demands

Estimating the economic impacts for the municipal water user groups is complicated for a number of reasons. For one, municipal use comprises a range of consumers including commercial businesses, institutions such as schools and government and households. However, reported water needs are not distributed among different municipal water users. In other words, how much of a municipal need is commercial and how much is residential (domestic)?

The amount of commercial water use as a percentage of total municipal demand was estimated based on "GED" coefficients (gallons per employee per day) published in secondary sources.[8] For example, if year 2006 baseline data for a given economic sector (e.g., amusement and recreation services) shows employment at 30 jobs and the GED coefficient is 200, then average daily water use by that sector

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[6] Ferreira, W.N. "*Analysis of the Meat Processing Industry in the United States*." Clemson University Extension Economics Report ER211, January 2003.

[7] Ward, C.E. "*Summary of Results from USDA's Meatpacking Concentration Study*." Oklahoma Cooperative Extension Service, OSU Extension Facts WF-562.

[8] Sources for GED coefficients include: Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G. Cushing, K.K., and Mann, A. "*Waste Not, Want Not*: *The Potential for Urban Water Conservation in California*." Pacific Institute. November 2003. U.S. Bureau of the Census. 1982 Census of Manufacturers: Water Use in Manufacturing. USGPO, Washington D.C. See also: "*U.S. Army Engineer Institute for Water Resources, IWR Report 88-R-6.*," Fort Belvoir, VA. See also, Joseph, E. S., 1982, "*Municipal and Industrial Water Demands of the Western United States*." Journal of the Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, v. 108, no. WR2, p. 204-216. See also, Baumann, D. D., Boland, J. J., and Sims, J. H., 1981, "*Evaluation of Water Conservation for Municipal and Industrial Water Supply*." U.S. Army Corps of Engineers, Institute for Water Resources, Contract no. 82-C1.

is (30 x 200 = 6,000 gallons) or 6.7 acre-feet per year. Water not attributed to commercial use is considered domestic, which includes single and multi-family residential consumption, institutional uses and all use designated as "county-other." Based on our analysis, commercial water use is about 5 to 35 percent of municipal demand. Less populated rural counties occupy the lower end of the spectrum, while larger metropolitan counties are at the higher end.

After determining the distribution of domestic versus commercial water use, we developed methods for estimating impacts to the two groups.

Domestic Water Uses

Input output models are not well suited for measuring impacts of shortages for domestic water uses, which make up the majority of the municipal water use category. To estimate impacts associated with domestic water uses, municipal water demand and needs are subdivided into residential, and commercial and institutional use. Shortages associated with residential water uses are valued by estimating proxy demand functions for different water user groups allowing us to estimate the marginal value of water, which would vary depending upon the level of water shortages. The more severe the water shortage, the more costly it becomes. For instance, a 2 acre-foot shortage for a group of households that use 10 acre-feet per year would not be as severe as a shortage that amounted to 8 acre-feet. In the case of a 2 acre-foot shortage, households would probably have to eliminate some or all outdoor water use, which could have implicit and explicit economic costs including losses to the horticultural and landscaping industry. In the case of an 8 acre-foot shortage, people would have to forgo all outdoor water use and most indoor water consumption. Economic impacts would be much higher in the latter case because people, and would be forced to find emergency alternatives assuming alternatives were available.

To estimate the value of domestic water uses, TWDB staff developed marginal loss functions based on constant elasticity demand curves. This is a standard and well-established method used by economists to value resources such as water that have an explicit monetary cost.

A constant price elasticity of demand is estimated using a standard equation:

$$w = kc^{(-\varepsilon)}$$

where:

- w is equal to average monthly residential water use for a given water user group measured in thousands of gallons;
- k is a constant intercept;
- c is the average cost of water per 1,000 gallons; and
- ε is the price elasticity of demand.

Price elasticities (-0.30 for indoor water use and -0.50 for outdoor use) are based on a study by Bell et al.[9] that surveyed 1,400 water utilities in Texas that serve at least 1,000 people to estimate demand elasticity for several variables including price, income, weather etc. Costs of water and average use per month per household are based on data from the Texas Municipal League's annual water and

[9] Bell, D.R. and Griffin, R.C. "*Community Water Demand in Texas as a Century is Turned*." Research contract report prepared for the Texas Water Development Board. May 2006.

wastewater rate surveys - specifically average monthly household expenditures on water and wastewater in different communities across the state. After examining variance in costs and usage, three different categories of water user groups based on population (population less than 5,000, cities with populations ranging from 5,000 to 99,999 and cities with populations exceeding 100,000) were selected to serve as proxy values for municipal water groups that meet the criteria (Table 5).[10]

Table 5: Water Use and Costs Parameters Used to Estimated Water Demand Functions (average monthly costs per acre-foot for delivered water and average monthly use per household)

Community Population	Water	Wastewater	Total monthly cost	Avg. monthly use (gallons)
Less than or equal to 5,000	$1,335	$1,228	$2,563	6,204
5,000 to 100,000	$1,047	$1,162	$2,209	7,950
Great than or equal to 100,000	$718	$457	$1,190	8,409

Source: Based on annual water and wastewater rate surveys published by the Texas Municipal League.

As an example, Table 6 shows the economic impact per acre-foot of domestic water needs for municipal water user groups with population exceeding 100,000 people. There are several important assumptions incorporated in the calculations:

1) Reported values are net of the variable costs of treatment and distribution such as expenses for chemicals and electricity since using less water involves some savings to consumers and utilities alike; and for outdoor uses we do not include any value for wastewater.

2) Outdoor and "non-essential" water uses would be eliminated before indoor water consumption was affected, which is logical because most water utilities in Texas have drought contingency plans that generally specify curtailment or elimination of outdoor water use during droughts.[11] Determining how much water is used for outdoor purposes is based on several secondary sources. The first is a major study sponsored by the American Water Works Association, which surveyed cities in states including Colorado, Oregon, Washington, California, Florida and Arizona. On average across all cities surveyed 58 percent of single family residential water use was for outdoor activities. In cities with climates comparable to large metropolitan areas of Texas, the average was 40 percent.[12] Earlier findings of the U.S. Water Resources Council showed a

[10] Ideally, one would want to estimate demand functions for each individual utility in the state. However, this would require an enormous amount of time and resources. For planning purposes, we believe the values generated from aggregate data are more than sufficient.

[11] In Texas, state law requires retail and wholesale water providers to prepare and submit plans to the Texas Commission on Environmental Quality (TCEQ). Plans must specify demand management measures for use during drought including curtailment of "non-essential water uses." Non-essential uses include, but are not limited to, landscape irrigation and water for swimming pools or fountains. For further information see the Texas Environmental Quality Code §288.20.

[12] See, Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W., Dziegielewski, D., Nelson, J.O. "*Residential End Uses of Water*." Research sponsored by the American Water Works Association and completed by Aquacraft, Inc. and Planning and Management Consultants, Ltd. (PMCL@CDM).

national average of 33 percent. Similarly, the United States Environmental Protection Agency (USEPA) estimated that landscape watering accounts for 32 percent of total residential and commercial water use on annual basis.[13] A study conducted for the California Urban Water Agencies (CUWA) calculated average annual values ranging from 25 to 35 percent.[14] Unfortunately, there does not appear to be any comprehensive research that has estimated non-agricultural outdoor water use in Texas. As an approximation, an average annual value of 30 percent based on the above references was selected to serve as a rough estimate in this study.

3) As shortages approach 100 percent values become immense and theoretically infinite at 100 percent because at that point death would result, and willingness to pay for water is immeasurable. Thus, as shortages approach 80 percent of monthly consumption, we assume that households and non-water intensive commercial businesses (those that use water only for drinking and sanitation would have water delivered by tanker truck or commercial water delivery companies. Based on reports from water companies throughout the state, we estimate that the cost of trucking in water is around $21,000 to $27,000 per acre-feet assuming a hauling distance of between 20 to 60 miles. This is not an unreasonable assumption. The practice was widespread during the 1950s drought and recently during droughts in this decade. For example, in 2000 at the heels of three consecutive drought years Electra - a small town in North Texas - was down to its last 45 days worth of reservoir water when rain replenished the lake, and the city was able to refurbish old wells to provide supplemental groundwater. At the time, residents were forced to limit water use to 1,000 gallons per person per month - less than half of what most people use - and many were having water delivered to their homes by private contractors.[15] In 2003 citizens of Ballinger, Texas, were also faced with a dwindling water supply due to prolonged drought. After three years of drought, Lake Ballinger, which supplies water to more than 4,300 residents in Ballinger and to 600 residents in nearby Rowena, was almost dry. Each day, people lined up to get water from a well in nearby City Park. Trucks hauling trailers outfitted with large plastic and metal tanks hauled water to and from City Park to Ballinger.[16]

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[13] U.S. Environmental Protection Agency. *"Cleaner Water through Conservation*." USEPA Report no. 841-B-95-002. April, 1995.

[14] Planning and Management Consultants, Ltd. "*Evaluating Urban Water Conservation Programs: A Procedures Manual*." Prepared for the California Urban Water Agencies. February 1992.

[15] Zewe, C. "*Tap Threatens to Run Dry in Texas Town*." July 11, 2000. CNN Cable News Network.

[16] Associated Press, "*Ballinger Scrambles to Finish Pipeline before Lake Dries Up*." May 19, 2003.

Table 6: Economic Losses Associated with Domestic Water Shortages in Communities with Populations Exceeding 100,000 people						
Water shortages as a percentage of total monthly household demands	**No. of gallons remaining per household per day**	**No of gallons remaining per person per day**	**Economic loss (per acre-foot)**		**Economic loss (per gallon)**	
1%	278	93	$748		$0.00005	
5%	266	89	$812		$0.0002	
10%	252	84	$900		$0.0005	
15%	238	79	$999		$0.0008	
20%	224	75	$1,110		$0.0012	
25%	210	70	$1,235		$0.0015	
30%[a]	196	65	$1,699		$0.0020	
35%	182	61	$3,825		$0.0085	
40%	168	56	$4,181		$0.0096	
45%	154	51	$4,603		$0.011	
50%	140	47	$5,109		$0.012	
55%	126	42	$5,727		$0.014	
60%	112	37	$6,500		$0.017	
65%	98	33	$7,493		$0.02	
70%	84	28	$8,818		$0.02	
75%	70	23	$10,672		$0.03	
80%	56	19	$13,454		$0.04	
85%	42	14	$18,091	($24,000)[b]	$0.05	($0.07)[b]
90%	28	9	$27,363	($24,000)	$0.08	($0.07)
95%	14	5	$55,182	($24,000)	$0.17	($0.07)
99%	3	0.9	$277,728	($24,000)	$0.85	($0.07)
99.9%	1	0.5	$2,781,377	($24,000)	$8.53	($0.07)
100%	0	0	Infinite	($24,000)	Infinite	($0.07)

[a] The first 30 percent of needs are assumed to be restrictions of outdoor water use; when needs reach 30 percent of total demands all outdoor water uses would be restricted. Needs greater than 30 percent include indoor use

[b] As shortages approach 100 percent the value approaches infinity assuming there are not alternatives available; however, we assume that communities would begin to have water delivered by tanker truck at an estimated cost of $24,000 per acre-foot when shortages breached 85 percent.

Commercial Businesses

Effects of water shortages on commercial sectors were estimated in a fashion similar to other business sectors meaning that water shortages would affect the ability of these businesses to operate. This is particularly true for "water intensive" commercial sectors that are need large amounts of water (in addition to potable and sanitary water) to provide their services. These include:

- car-washes,
- laundry and cleaning facilities,
- sports and recreation clubs and facilities including race tracks,
- amusement and recreation services,
- hospitals and medical facilities,
- hotels and lodging places, and
- eating and drinking establishments.

A key assumption is that commercial operations would not be affected until water shortages were at least 50 percent of total municipal demand. In other words, we assume that residential water consumers would reduce water use including all non-essential uses before businesses were affected.

An example will illustrate the breakdown of municipal water needs and the overall approach to estimating impacts of municipal needs. Assume City A experiences an unexpected shortage of 50 acre-feet per year when their demands are 200 acre-feet per year. Thus, shortages are only 25 percent of total municipal use and residents of City A could eliminate needs by restricting landscape irrigation. City B, on the other hand, has a deficit of 150 acre-feet in 2020 and a projected demand of 200 acre-feet. Thus, total shortages are 75 percent of total demand. Emergency outdoor and some indoor conservation measures could eliminate 50 acre-feet of projected needs, yet 50 acre-feet would still remain. To eliminate" the remaining 50 acre-feet water intensive commercial businesses would have to curtail operations or shut down completely.

Three other areas were considered when analyzing municipal water shortages: 1) lost revenues to water utilities, 2) losses to the horticultural and landscaping industries stemming for reduction in water available for landscape irrigation, and 3) lost revenues and related economic impacts associated with reduced water related recreation.

Water Utility Revenues

Estimating lost water utility revenues was straightforward. We relied on annual data from the "*Water and Wastewater Rate Survey*" published annually by the Texas Municipal League to calculate an average value per acre-foot for water and sewer. For water revenues, average retail water and sewer rates multiplied by total water needs served as a proxy. For lost wastewater, total unmet needs were adjusted for return flow factor of 0.60 and multiplied by average sewer rates for the region. Needs reported as "county-other" were excluded under the presumption that these consist primarily of self-supplied water uses. In addition, 15 percent of water demand and needs are considered non-billed or "unaccountable" water that comprises things such as leakages and water for municipal government functions (e.g., fire departments). Lost tax receipts are based on current rates for the "miscellaneous gross receipts tax, "which the state collects from utilities located in most incorporated cities or towns in Texas. We do not include lost water utility revenues when aggregating impacts of municipal water shortages to regional and state levels to prevent double counting.

Horticultural and Landscaping Industry

The horticultural and landscaping industry, also referred to as the "green Industry," consists of businesses that produce, distribute and provide services associated with ornamental plants, landscape and garden supplies and equipment. Horticultural industries often face big losses during drought. For example, the recent drought in the Southeast affecting the Carolinas and Georgia horticultural and landscaping businesses had a harsh year. Plant sales were down, plant mortality increased, and watering costs increased. Many businesses were forced to close locations, lay off employees, and even file for bankruptcy. University of Georgia economists put statewide losses for the industry at around $3.2 billion during the 3-year drought that ended in 2008.[17] Municipal restrictions on outdoor watering play a significant role. During drought, water restrictions coupled with persistent heat has a psychological effect on homeowners that reduces demands for landscaping products and services. Simply put, people were afraid to spend any money on new plants and landscaping.

In Texas, there do not appear to be readily available studies that analyze the economic effects of water shortages on the industry. However, authors of this report believe negative impacts do and would result in restricting landscape irrigation to municipal water consumers. The difficulty in measuring them is two-fold. First, as noted above, data and research for these types of impacts that focus on Texas are limited; and second, economic data provided by IMPLAN do not disaggregate different sectors of the green industry to a level that would allow for meaningful and defensible analysis.[18]

Recreational Impacts

Recreational businesses often suffer when water levels and flows in rivers, springs and reservoirs fall significantly during drought. During droughts, many boat docks and lake beaches are forced to close, leading to big losses for lakeside business owners and local communities. Communities adjacent to popular river and stream destinations such as Comal Springs and the Guadalupe River also see their business plummet when springs and rivers dry up. Although there are many examples of businesses that have suffered due to drought, dollar figures for drought-related losses to the recreation and tourism industry are not readily available, and very difficult to measure without extensive local surveys. Thus, while they are important, economic impacts are not measured in this study.

Table 7 summarizes impacts of municipal water shortages at differing levels of magnitude, and shows the ranges of economic costs or losses per acre-foot of shortage for each level.

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[17] Williams, D. *"Georgia landscapers eye rebound from Southeast drought."* Atlanta Business Chronicle, Friday, June 19, 2009

[18] Economic impact analyses prepared by the TWDB for 2006 regional water plans did include estimates for the horticultural industry. However, year 2000 and prior IMPLAN data were disaggregated to a finer level. In the current dataset (2006), the sector previously listed as "Landscaping and Horticultural Services" (IMPLAN Sector 27) is aggregated into "Services to Buildings and Dwellings" (IMPLAN Sector 458).

Table 7: Impacts of Municipal Water Shortages at Different Magnitudes of Shortages		
Water shortages as percent of total municipal demands	Impacts	Economic costs per acre-foot*
0-30%	✓ Lost water utility revenues ✓ Restricted landscape irrigation and non-essential water uses	$730 - $2,040
30-50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use	$2,040 - $10,970
>50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use ✓ Restriction or elimination of commercial water use ✓ Importing water by tanker truck	$10,970 - varies
*Figures are rounded		

1.1.4 Industrial Water User Groups

Manufacturing

Impacts to manufacturing were estimated by distributing water shortages among industrial sectors at the county level. For example, if a planning group estimates that during a drought of record water supplies in County A would only meet 50 percent of total annual demands for manufactures in the county, we reduced output for each sector by 50 percent. Since projected manufacturing demands are based on TWDB Water Uses Survey data for each county, we only include IMPLAN sectors represented in the TWBD survey database. Some sectors in IMPLAN databases are not part of the TWDB database given that they use relatively small amounts of water - primarily for on-site sanitation and potable purposes. To maintain consistency between IMPLAN and TWDB databases, Standard Industrial Classification (SIC) codes both databases were cross referenced in county with shortages. Non-matches were excluded when calculating direct impacts.

Mining

The process of mining is very similar to that of manufacturing. We assume that within a given county, shortages would apply equally to relevant mining sectors, and IMPLAN sectors are cross referenced with TWDB data to ensure consistency.

In Texas, oil and gas extraction and sand and gravel (aggregates) operations are the primary mining industries that rely on large volumes of water. For sand and gravel, estimated output reductions are straightforward; however, oil and gas is more complicated for a number of reasons. IMPLAN does not necessarily report the physical extraction of minerals by geographic local, but rather the sales revenues reported by a particular corporation.

For example, at the state level revenues for IMPLAN sector 19 (oil and gas extraction) and sector 27 (drilling oil and gas wells) totals $257 billion. Of this, nearly $85 billion is attributed to Harris County. However, only a very small fraction (less than one percent) of actual production takes place in the county. To measure actual potential losses in well head capacity due to water shortages, we relied on county level production data from the Texas Railroad Commission (TRC) and average well-head market prices for crude and gas to estimate lost revenues in a given county. After which, we used to IMPLAN ratios to estimate resultant losses in income and employment.

Other considerations with respect to mining include:

> 1) Petroleum and gas extraction industry only uses water in significant amounts for secondary recovery. Known in the industry as enhanced or water flood extraction, secondary recovery involves pumping water down injection wells to increase underground pressure thereby pushing oil or gas into other wells. IMPLAN output numbers do not distinguish between secondary and non-secondary recovery. To account for the discrepancy, county-level TRC data that show the proportion of barrels produced using secondary methods were used to adjust IMPLAN data to reflect only the portion of sales attributed to secondary recovery.
>
> 2) A substantial portion of output from mining operations goes directly to businesses that are classified as manufacturing in our schema. Thus, multipliers measuring backward linkages for a given manufacturer might include impacts to a supplying mining operation. Care was taken not to double count in such situations if both a mining operation and a manufacturer were reported as having water shortages.

Steam-electric

At minimum without adequate cooling water, power plants cannot safely operate. As water availability falls below projected demands, water levels in lakes and rivers that provide cooling water would also decline. Low water levels could affect raw water intakes and outfalls at electrical generating units in several ways. For one, power plants are regulated by thermal emission guidelines that specify the maximum amount of heat that can go back into a river or lake via discharged cooling water. Low water levels could result in permit compliance issues due to reduced dilution and dispersion of heat and subsequent impacts on aquatic biota near outfalls.[19] However, the primary concern would be a loss of head (i.e., pressure) over intake structures that would decrease flows through intake tunnels. This would affect safety related pumps, increase operating costs and/or result in sustained shut-downs. Assuming plants did shutdown, they would not be able to generate electricity.

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[19] Section 316 (b) of the Clean Water Act requires that thermal wastewater discharges do not harm fish and other wildlife.

Among all water use categories steam-electric is unique and cautions are needed when applying methods used in this study. Measured changes to an economy using input-output models stem directly from changes in sales revenues. In the case of water shortages, one assumes that businesses will suffer lost output if process water is in short supply. For power generation facilities this is true as well. However, the electric services sector in IMPLAN represents a corporate entity that may own and operate several electrical generating units in a given region. If one unit became inoperable due to water shortages, plants in other areas or generation facilities that do not rely heavily on water such as gas powered turbines might be able to compensate for lost generating capacity. Utilities could also offset lost production via purchases on the spot market.[20] Thus, depending upon the severity of the shortages and conditions at a given electrical generating unit, energy supplies for local and regional communities could be maintained. But in general, without enough cooling water, utilities would have to throttle back plant operations, forcing them to buy or generate more costly power to meet customer demands.

Measuring impacts end users of electricity is not part of this study as it would require extensive local and regional level analysis of energy production and demand. To maintain consistency with other water user groups, impacts of steam-electric water shortages are measured in terms of lost revenues (and hence income) and jobs associated with shutting down electrical generating units.

1.2 Social Impacts of Water Shortages

As the name implies, the effects of water shortages can be social or economic. Distinctions between the two are both semantic and analytical in nature – more so analytic in the sense that social impacts are harder to quantify. Nevertheless, social effects associated with drought and water shortages are closely tied to economic impacts. For example, they might include:

- demographic effects such as changes in population,
- disruptions in institutional settings including activity in schools and government,
- conflicts between water users such as farmers and urban consumers,
- health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations),
- mental and physical stress (e.g., anxiety, depression, domestic violence),
- public safety issues from forest and range fires and reduced fire fighting capability,
- increased disease caused by wildlife concentrations,
- loss of aesthetic and property values, and
- reduced recreational opportunities.[21]

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[20] Today, most utilities participate in large interstate "power pools" and can buy or sell electricity "on the grid" from other utilities or power marketers. Thus, assuming power was available to buy, and assuming that no contractual or physical limitations were in place such as transmission constraints; utilities could offset lost power that resulted from waters shortages with purchases via the power grid.

[21] Based on information from the website of the National Drought Mitigation Center at the University of Nebraska Lincoln. Available online at: http://www.drought.unl.edu/risk/impacts.htm. See also, Vanclay, F. "*Social Impact Assessment*." in Petts, J. (ed) International Handbook of Environmental Impact Assessment. 1999.

Social impacts measured in this study focus strictly on demographic effects including changes in population and school enrollment. Methods are based on demographic projection models developed by the Texas State Data Center and used by the TWDB for state and regional water planning. Basically, the social impact model uses results from the economic component of the study and assesses how changes in labor demand would affect migration patterns in a region. Declines in labor demand as measured using adjusted IMPLAN data are assumed to affect net economic migration in a given regional water planning area. Employment losses are adjusted to reflect the notion that some people would not relocate but would seek employment in the region and/or public assistance and wait for conditions to improve. Changes in school enrollment are simply the proportion of lost population between the ages of 5 and 17.

2. Results

Section 2 presents the results of the analysis at the regional level. Included are baseline economic data for each water use category, and estimated economics impacts of water shortages for water user groups with reported deficits. According to the 2011 *South Central Texas Regional Water Plan*, during severe drought irrigation, municipal, manufacturing, mining and steam-electric water user groups would experience water shortages in the absence of new water management strategies.

2.1 Overview of Regional Economy

On an annual basis, the South Central Texas economy generates $82 billion in gross state product for Texas ($76 billion in income and $6 billion worth of business taxes) and supports 1,163,680 jobs (Table 8). Generating about $11 billion worth of income per year manufacturing is the primary base economic sector in the region.[22] Municipal sectors also generate substantial amounts of income and are major employers. However, while municipal sectors are the largest employer and source of wealth, many businesses that make up the municipal category such as restaurants and retail stores are non-basic industries meaning they exist to provide services to people who work would in base industries such as manufacturing, agriculture and mining. In other words, without base industries such agriculture, many municipal jobs in the region would not exist.

[22] Base industries are those that supply markets outside of the region. These industries are crucial to the local economy and are called the economic base of a region. Appendix A shows how IMPLAN's 529 sectors were allocated to water use category, and shows economic data for each sector.

Table 8: The South Central Texas Regional Economy by Water User Group ($millions)*						
Water Use Category	**Total sales**	**Intermediate sales**	**Final sales**	**Jobs**	**Income**	**Business taxes**
Irrigation	$266.54	$47.35	$219.07	4,110	$174.18	$3.23
Livestock	$889.48	$644.74	$244.74	13,506	$134.69	$14.13
Manufacturing	$35,019.65	$4,677.32	$30,342.33	134,359	$11,132.59	$268.65
Mining	$3,841.83	$2,060.19	$1,781.64	9,733	$2,355.49	$194.87
Steam-electric	$534.13	$150.26	$383.87	1,312	$370.93	$63.26
Municipal	$104,098.04	$30,414.34	$73,683.69	1,000,660	$61,736.55	$5,406.62
Regional total	$144,649.67	$37,994.20	$106,655.34	1,163,680	$75,904.43	$5,950.76

[a] Appendix 1 displays data for individual IMPLAN sectors that make up each water use category. Based on data from the Texas Water Development Board, and year 2006 data from the Minnesota IMPLAN Group, Inc.

2.2 Impacts of Agricultural Water Shortages

According to the 2011 *South Central Texas Regional Water Plan*, during severe drought the counties of Atascosa, Medina and Zavala would experiences shortages of irrigation water. Shortages range from about 1 to 76 percent of annual irrigation demands over the planning horizon, and farmers would be short 68,465 acre-feet in 2010 and 41,782 in 2060. Shortages would reduce gross state product (income plus state and local business taxes) by an estimated $45 million per year in 2010 to $33 million in 2060.

Table 9: Economic Impacts of Water Shortages for Irrigation Water User Groups ($millions)			
Decade	**Lost income from reduced crop production** [a]	**Lost state and local tax revenues from reduced crop production**	**Lost jobs from reduced crop production**
2010	$43.32	$2.16	545
2020	$40.63	$2.03	511
2030	$38.04	$1.90	478
2040	$35.55	$1.77	447
2050	$33.17	$1.66	416
2060	$31.13	$1.55	391

*Changes to income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.3 Impacts of Municipal Water Shortages

Water shortages are projected to occur in a significant number of communities in the region. At the regional level, the estimated economic value of domestic water shortages totals $715 million in 2010 and $2,823 million in 2060 (Table 100). Due to curtailment of commercial business activity operation, municipal shortages would reduce gross state product (income plus taxes) by an estimated $53 million in 2020 and $3,780 million in 2060.

Table 10: Economic Impacts of Water Shortages for Municipal Water User Groups ($millions)

Decade	Monetary value of domestic water shortages	Lost income from reduced commercial business activity*	Lost state and local taxes from reduced commercial business activity	Lost jobs from reduced commercial business activity	Lost water utility revenues
2010	$715.54	$42.91	$5.67	1,067	$149.36
2020	$1,479.80	$1,417.03	$7.66	1,512	$212.55
2030	$1,331.33	$1,909.07	$82.41	17,808	$276.64
2040	$1,805.79	$2,547.77	$111.92	24,229	$340.64
2050	$2,426.71	$3,197.28	$134.26	29,081	$402.51
2060	$2,823.29	$3,621.31	$157.25	34,108	$468.01

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.4 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in Bexar, Calhoun, Comal and Victoria counties. In 2010, the planning group estimates that these manufacturers would be short about 6,539 acre-feet; and by 2060, this figure increases to nearly 43,072 acre-feet. Shortages of these magnitudes would reduce gross state product (income plus taxes) by an estimated $179 million in 2010 and $2,080 million in 2060 (Table 11).

Table 11: Economic Impacts of Water Shortages for Manufacturing Water User Groups ($millions)			
Decade	Lost income due to reduced manufacturing output	Lost state and local business tax revenues due to reduced manufacturing output	Lost jobs due to reduced manufacturing output
2010	$146.77	$22.22	8,274
2020	$324.94	$52.44	11,956
2030	$496.18	$81.52	15,436
2040	$948.36	$159.05	23,170
2050	$1,451.00	$245.34	31,553
2060	$1,777.09	$301.91	38,187

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.5 Impacts of Mining Water Shortages

Mining water shortages in Region L are projected to occur in Bexar, Comal and Hays counties and would primarily affect aggregates operations (e.g., sand and gravel producers). Combined shortages for each county would result in estimated losses in gross state product totaling $3 million dollars in 2010, and about $7 million 2060 (Table 12).

Table 12: Economic Impacts of Water Shortages for Mining Water User Groups ($millions)			
Decade	Lost income due to reduced mining output	Lost state and local business tax revenues due to reduced mining output	Lost jobs due to reduced mining output
2010	$2.67	$0.14	27
2020	$3.12	$0.17	31
2030	$4.64	$0.34	53
2040	$5.01	$0.37	57
2050	$6.44	$0.48	72
2060	$6.81	$0.51	77

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.6 Impacts of Steam-electric Water Shortages

Water shortages for electrical generating units are projected to occur in Atascosa and Victoria counties, and would result in estimated losses of gross state product totaling $72 million in 2020, and $4,011 million 2060 (Table 13).

Table 13: Economic Impacts of Water Shortages for Steam-electric Water User Groups ($millions)			
Decade	Lost income due to reduced electrical generation	Lost state and local business tax revenues due to reduced electrical generation	Lost jobs due to reduced electrical generation
2010	$63.17	$9.07	215
2020	$3,493.56	$501.45	5,938
2030	$3,495.55	$501.73	5,941
2040	$3,497.61	$502.03	5,945
2050	$3,503.90	$502.93	5,963
2060	$3,507.77	$503.49	5,973

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.7 Social Impacts of Water Shortages

As discussed previously, estimated social impacts focus on changes in population and school enrollment in the region. In 2010, estimated population losses total 12,886 with corresponding reductions in school enrollment of 3,635 students (Table 14). In 2060, population in the region would decline by 54,411 and school enrollment would fall by 10,064.

Table 14: Social Impacts of Water Shortages (2010-2060)		
Year	Population Losses	Declines in School Enrollment
2010	12,886	3,635
2020	43,823	12,433
2030	58,402	15,470
2040	74,857	13,835
2050	86,896	16,049
2060	54,411	10,064

2.8 Distribution of Impacts by Major River Basin

Administrative rules require that impacts are presented by both planning region and major river basin. To meet rule requirements, impacts were allocated among basins based on the distribution of water shortages in relevant basins. For example, if 50 percent of water shortages in River Basin A and 50 percent occur in River Basin B, then impacts were split equally among the two basins. Table 15 displays the results.

Table 15: Distribution of Impacts by Major River Basin (2010-2060)

River Basin	2010	2020	2030	2040	2050	2060
Colorado	<1%	<1%	<1%	<1%	<1%	<1%
Colorado-Lavaca	<1%	<1%	<1%	<1%	<1%	<1%
Guadalupe	7%	27%	27%	29%	30%	32%
Nueces	37%	22%	19%	16%	14%	12%
San Antonio	57%	51%	55%	57%	57%	58%