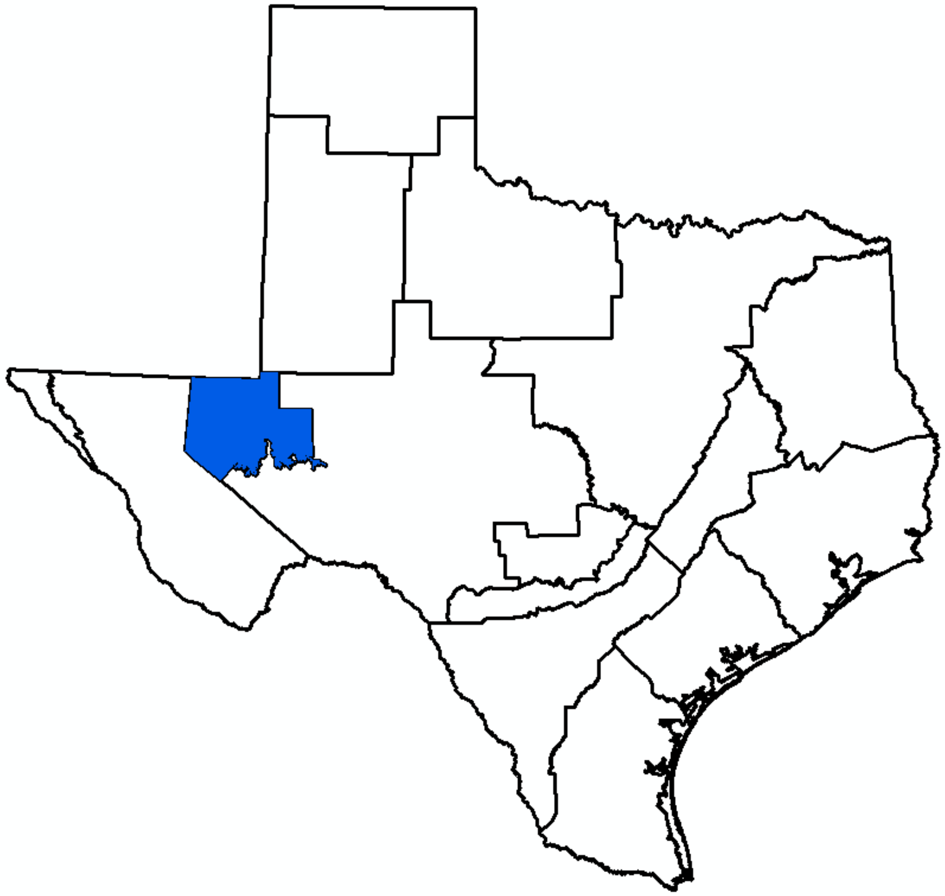
GMA 3 Explanatory Report – Revised Final

Pecos Valley and Edwards-Trinity (Plateau) Aquifer



Prepared for:

Groundwater Management Area 3

Prepared by:

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GMA 3 Explanatory Report (Revised Final)
Pecos Valley and Edwards-Trinity (Plateau) Aquifer

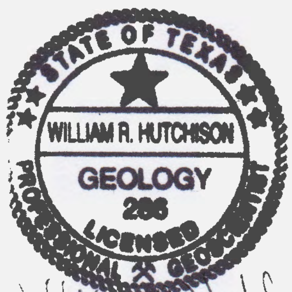
Geoscientist and Engineering Seal

This report documents the work and supervision of work of the following licensed Texas Professional Geoscientist and licensed Texas Professional Engineers:

William R. Hutchison, Ph.D., P.E. (96287), P.G. (286)

Dr. Hutchison completed the analyses and model simulations described in this report, and was the principal author of the final report.

William R Hutchison
12/14/2017



William R Hutchison
12/14/2017

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Appendices

1.0 Groundwater Management Area 3

Groundwater Management Area 3 is one of sixteen groundwater management areas in Texas, and covers that portion of west Texas that is underlain by the Pecos Valley Aquifer (Figure 1).

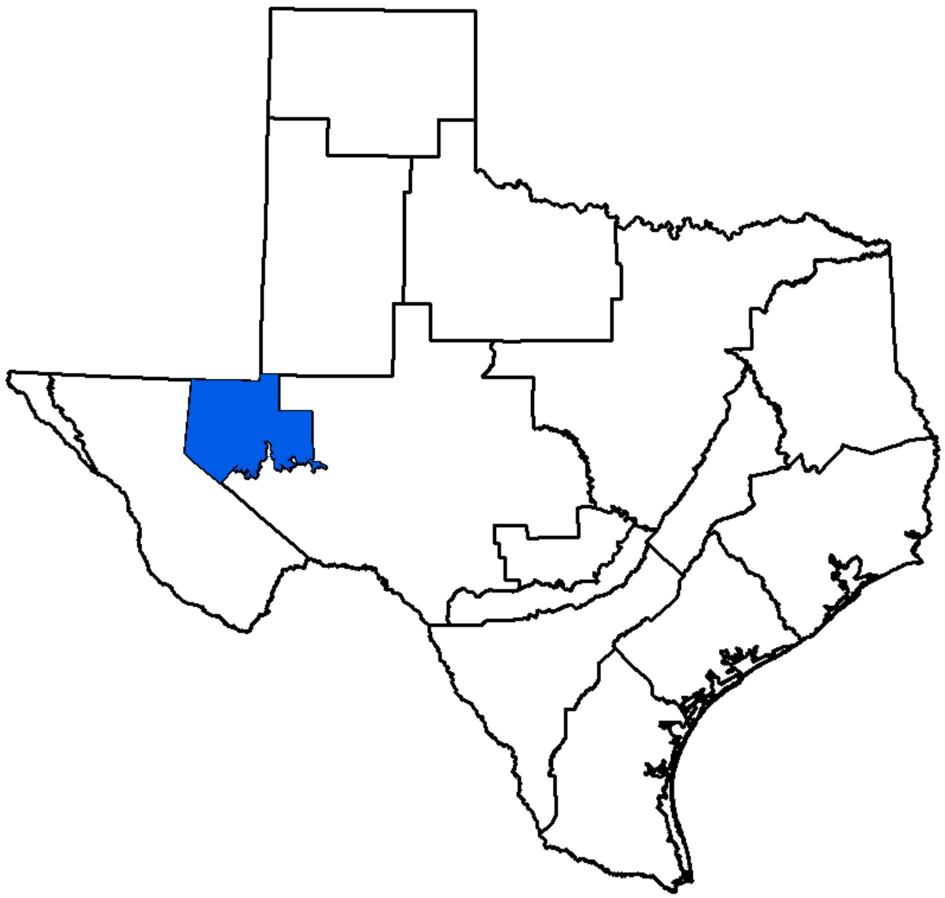

Figure 1. Groundwater Management Area 3

Groundwater Management Area 3 covers all or part of the following counties: Crane, Loving, Pecos, Reeves, Ward, and Winkler (Figure 2).

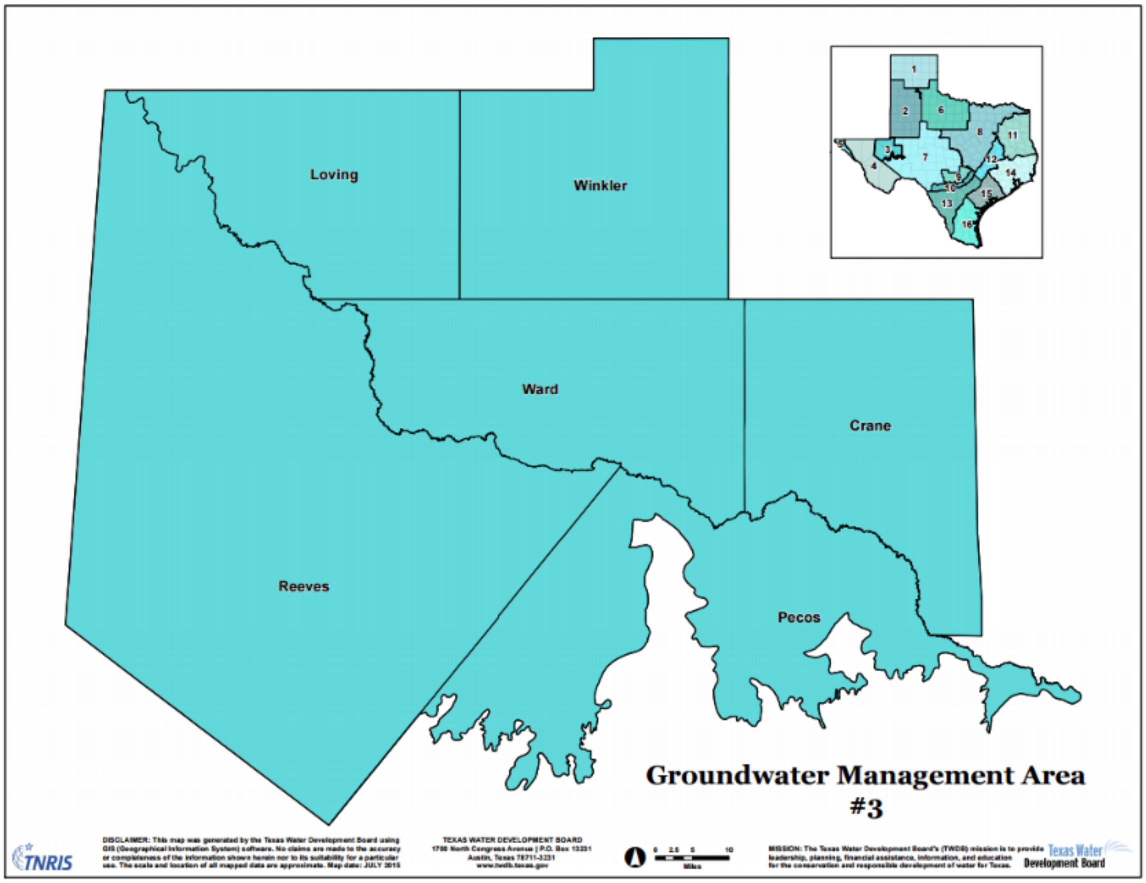

Figure 2. GMA 3 Counties (from TWDB)

There are two groundwater conservation districts in Groundwater Management Area 3: Middle Pecos Groundwater Conservation District and Reeves County Groundwater Conservation District (Figure 3).

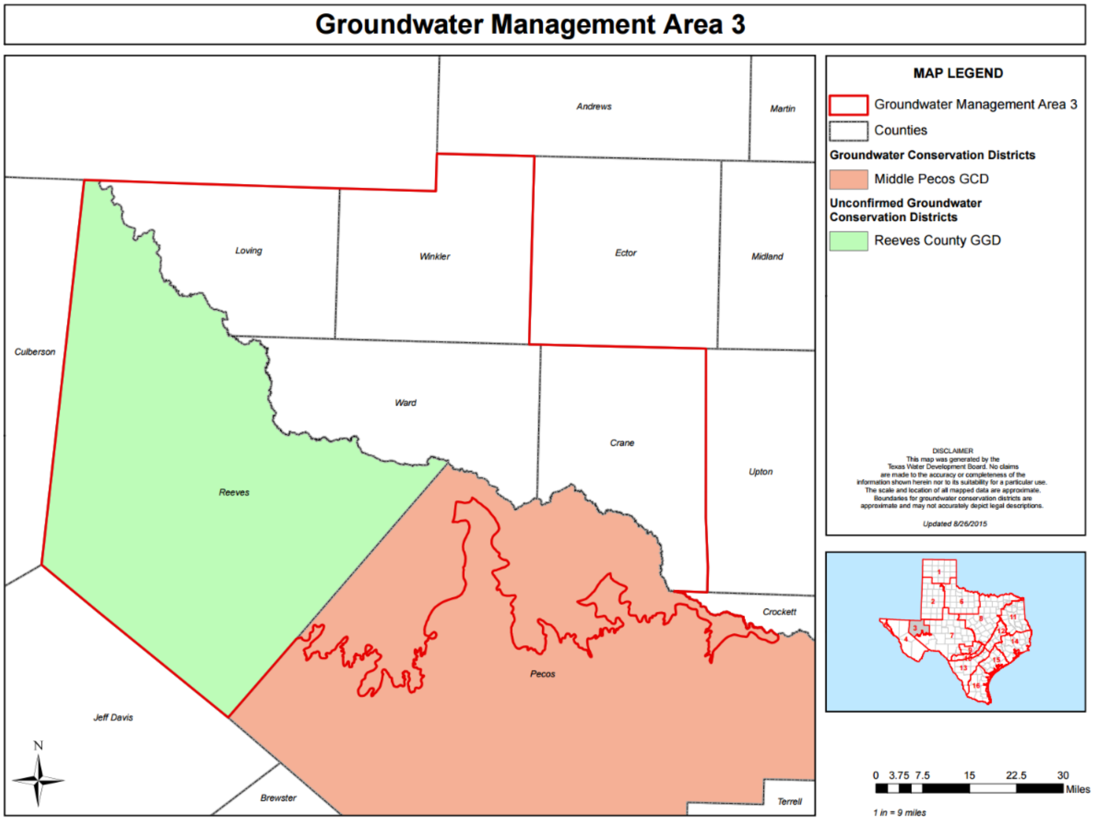

Figure 3. Groundwater Conservation Districts in GMA3 (from TWDB)

The explanatory report covers the Pecos Valley and Edwards-Trinity (Plateau) aquifers. As described in George and others (2011):

> ***The Pecos Valley Aquifer*** *is a major aquifer in West Texas. Water-bearing sediments include alluvial and windblown deposits in the Pecos River Valley. These sediments fill several structural basins, the largest of which are the Pecos Trough in the west and Monument Draw Trough in the east. Thickness of the alluvial fill reaches 1,500 feet, and freshwater saturated thickness averages about 250 feet. The water quality is highly variable, the water being typically hard, and generally better in the Monument Draw Trough than in the Pecos Trough. Total dissolved solids in groundwater from Monument Draw Trough are usually less than 1,000 milligrams per liter. The aquifer is characterized by high levels of chloride and sulfate in excess of secondary drinking water standards, resulting from previous oil field activities. In addition, naturally occurring arsenic and radionuclides occur in excess of primary drinking water standards. More than 80 percent of groundwater pumped from the aquifer is used for irrigation, and the rest is withdrawn for municipal supplies, industrial use, and power generation. Localized water level declines in south-central Reeves and northwest Pecos counties have moderated since the late 1970s as irrigation pumping has decreased; however, water levels continue to decline in central Ward County because of increased municipal and industrial pumping. The Region F Regional Water Planning Group recommended*

several water management strategies in their 2006 Regional Water Plan that would use the Pecos Valley Aquifer, including drilling new wells, developing two well fields in Winkler and Loving counties, and reallocating supplies.

***The Edwards-Trinity (Plateau) Aquifer** is a major aquifer extending across much of the southwestern part of the state. The water-bearing units are composed predominantly of limestone and dolomite of the Edwards Group and sands of the Trinity Group. Although maximum saturated thickness of the aquifer is greater than 800 feet, freshwater saturated thickness averages 433 feet. Water quality ranges from fresh to slightly saline, with total dissolved solids ranging from 100 to 3,000 milligrams per liter, and water is characterized as hard within the Edwards Group. Water typically increases in salinity to the west within the Trinity Group. Elevated levels of fluoride in excess of primary drinking water standards occur within Glasscock and Irion counties. Springs occur along the northern, eastern, and southern margins of the aquifer primarily near the bases of the Edwards and Trinity groups where exposed at the surface. San Felipe Springs is the largest exposed spring along the southern margin. Of groundwater pumped from this aquifer, more than two-thirds is used for irrigation, with the remainder used for municipal and livestock supplies. Water levels have remained relatively stable because recharge has generally kept pace with the relatively low amounts of pumping over the extent of the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, recommended water management strategies that use the Edwards Trinity (Plateau) Aquifer, including the construction of a well field in Kerr County and public supply wells in Real County.*

2.0 Desired Future Condition

2.1 Existing Desired Future Conditions

GMA 3 adopted a desired future condition for the Pecos Valley and Edwards-Trinity (Plateu) aquifers on August 9, 2010 as follows:

1. *The average total net decline in water levels within GMA 3, taken as a whole, at the end of the fifty-year period in 2060, shall not exceed 28 feet below water levels in the aquifers in the year 2010, and;*
2. *The results of Scenario 11 of the Texas Water Development Board GAM-Run 09-35 version 2 (single-layer model) used to develop the DFC for the Edwards-Trinity (Plateau)/Pecos Valley Aquifers within GMA 3 are adopted in their entirety.*

The county-by-county drawdowns were as follows:

County	Drawdown in 2060 (feet)
Crane	50
Loving	5
Pecos (GMA 3 portion only)	12
Reeves	6
Ward	56
Winkler	113
GMA 3 Average	**28**

As described in GAM Run 09-35, version 2 (Hutchison, 2010) the model used in the development of the DFCs was the modified and recalibrated groundwater availability model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Hutchison and others, 2011). The model used is also known as the single layer model, or the alternative groundwater availability model (GAM).

2.2 Alternative GAM

In 2010, GMA 3 evaluated the results of 11 alternative predictive scenarios using the alternative one-layer model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers. The model is documented in Hutchison and others (2011), and the simulation results are documented in Hutchison (2010). Scenario 11 was used in the development of the desired future condition for GMA 3.

Drawdowns calculated in Hutchison (2010) were for predictive simulations through the year 2060. The updated desired future conditions that was adopted in 2016 is expressed through the year 2070 in accordance with the requirements of the Texas Water Development Board.

The alternative GAM was used to complete a simulation that simply extended the time period of Scenario 11 of Hutchison (2010), except for a modification in GMA 7, and adding 10,000 AF/yr in Winkler County. Table 3 summarizes the results of the pumping and drawdown for Scenario 11 and for the extended simulation on a county-by-county basis.

2.3 Desired Future Condition

The desired future condition for the Pecos Valley and Edwards-Trinity (Plateau) Aquifer in GMA 3 is based on the updated Scenario 11 as described in GMA 3 Technical Memorandum 16-01. During review of the materials for administrative completeness, the Texas Water Development Board could not reproduce the average drawdowns that were used as the desired future conditions with the model files that were submitted. After several meetings and emails, the differences seem to be centered on the use of different "grid files".

The groundwater model simulations that were completed in 2010 during the initial round of desired future conditions used a version of the grid file that was developed in 2009. Since then, a 2011 version, a 2014 version, and a 2015 version were developed.

Due to an oversight, the groundwater model simulation that was the basis for the adopted desired future conditions used the outdated grid file from 2009 to calculate average drawdowns in each of the counties that comprise GMA 3 instead of the most recent grid file developed by TWDB in 2015.

GMA 3 Technical Memorandum 17-01 documents the updated average drawdown for each county within GMA 3 using the updated 2015 grid file. It is important to emphasize that the model run has not been changed, only the basis for calculating average drawdown. It is also important to note that the drawdown in individual cells has not changed, only the overall average in two counties.

GMA 3 adopted updated desired future conditions on December 13, 2017. The resolution adopted on December 13, 2017 is attached as Appendix A. The table of drawdowns by county are as follows:

County (GCD)	**Average Drawdown 2010 to 2070 (ft)**
Crane	58
Loving	5
Pecos (GMA 3 portion) (Middle Pecos GCD)	14
Reeves (Reeves County GCD)	8
Ward	63
Winkler	161

3.0 Policy Justification

As developed more fully in this report, the proposed desired future condition was adopted after considering:

- Aquifer uses and conditions within Groundwater Management Area 3
- Water supply needs and water management strategies included in the 2012 State Water Plan
- Hydrologic conditions within Groundwater Management Area 3 including total estimated recoverable storage, average annual recharge, inflows, and discharge
- Other environmental impacts, including spring flow and other interactions between groundwater and surface water
- The impact on subsidence
- Socioeconomic impacts reasonably expected to occur
- The impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in Groundwater Management Area 3 in groundwater as recognized under Texas Water Code Section 36.002
- The feasibility of achieving the desired future condition
- Other information

In addition, the proposed desired future condition provides a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater in Groundwater Management Area 3.

There is no set formula or equation for calculating groundwater availability. This is because an estimate of groundwater availability requires the blending of policy and science. Given that the tools for scientific analysis (groundwater models) contain limitations and uncertainty, policy provides the guidance and defines the bounds that science can use to calculate groundwater availability.

As developed more fully below, many of these factors could only be considered on a qualitative level since the available tools to evaluate these impacts have limitations and uncertainty.

4.0 Technical Justification

The process of using the groundwater model in developing desired future conditions revolves around the concept of incorporating many of the elements of the nine factors (e.g. current uses and water management strategies in the regional plan). For the Pecos Valley and Edwards-Trinity (Plateau) aquifers, 11 scenarios were completed in 2010, and the results discussed prior to adopting a desired future condition. After further discussion in 2016, the new DFC was adopted after considering the results of an extended version of Scenario 11 (the basis for the DFC in 2010).

Some critics of the process asserted that the districts used "reverse-engineering" to develop the desired future conditions by specifying pumping (e.g., the modeled available groundwater) and then adopting the resulting drawdown as the desired future condition. However, it must be remembered that among the input parameters for a predictive groundwater model run is pumping, and among the outputs of a predictive groundwater model run is drawdown. Thus, an iterative approach of running several predictive scenarios with models and then evaluating the results is a necessary (and time-consuming) step in the process of developing desired future conditions.

One part of the reverse-engineering critique of the process has been that "science" should be used in the development of desired future conditions. The critique plays on the unfortunate name of the groundwater models in Texas (Groundwater Availability Models) which could suggest that the models yield an availability number. This is simply a mischaracterization of how the models work (i.e. what is a model input and what is a model output).

The critique also relies on a narrow definition of the term *science* and fails to recognize that the adoption of a desired future condition is primarily a policy decision. The call to use science in the development of desired future conditions seems to equate the term *science* with the terms *facts* and *truth*. Although the Latin origin of the word means knowledge, the term *science* also refers to the application of the scientific method. The scientific method is discussed in many textbooks and can be used to quantify cause-and-effect relationships and to make useful predictions.

In the case of groundwater management, the scientific method can be used to understand the relationship between groundwater pumping and drawdown, or groundwater pumping and spring flow. A groundwater model is a tool that can be used to run "experiments" to better understand the cause-and-effect relationships within a groundwater system as they relate to groundwater management.

Much of the consideration of the nine statutory factors involves understanding the effects or the impacts of a desired future condition (e.g. groundwater-surface water interaction and property rights). The use of the models in this manner in evaluating the impacts of alternative futures is an effective means of developing information for the groundwater conservation districts as they develop desired future conditions.

5.0 Factor Consideration

Senate Bill 660, adopted by the legislature in 2011, changed the process by which groundwater conservation districts within a groundwater management area develop and adopt desired future conditions. The new process includes nine steps as presented below:

- The groundwater conservation districts within a groundwater management area consider nine factors outlined in the statute.
- The groundwater conservation districts adopt a "proposed" desired future condition
- The "proposed" desired future condition is sent to each groundwater conservation district for a 90-day comment period, which includes a public hearing by each district
- After the comment period, each district compiles a summary report that summarizes the relevant comments and includes suggested revisions. This summary report is then submitted to the groundwater management area.
- The groundwater management area then meets to vote on a desired future condition.
- The groundwater management area prepares an "explanatory report".
- The desired future condition resolution and the explanatory report are then submitted to the Texas Water Development Board and the groundwater conservation districts within the groundwater management area.
- Districts then adopt desired future conditions that apply to that district.

The nine factors that must be considered before adopting a proposed desired future condition are:

1. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another.
2. The water supply needs and water management strategies included in the state water plan.
3. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator (of the Texas Water Development Board), and the average annual recharge, inflows and discharge.
4. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water.
5. The impact on subsidence.
6. Socioeconomic impacts reasonably expected to occur.
7. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002 (of the Texas Water Code).
8. The feasibility of achieving the desired future condition.
9. Any other information relevant to the specific desired future condition.

In addition to these nine factors, statute requires that the desired future condition provide a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area.

5.1 Groundwater Demands and Uses

Groundwater demands and uses for GMA 3 counties from 1980 and 1984 to 2012 for the Edwards-Trinity (Plateau) Aquifer are presented in Appendix B, and for the Pecos Valley Aquifer in Appendix C. Data were obtained from the Texas Water Development Board historic pumping database:

http://www.twdb.state.tx.us/waterplanning/waterusesurvey/historical-pumpage.asp

The Modeled Available Groundwater values for the Edwards-Trinity Aquifer are summarized below in Table 1.

Table 1. Modeled Available Groundwater for the Edwards-Trinity (Aquifer)

County	Year					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Crane	4,998	4,998	4,998	4,998	4,998	4,998
Loving	2,984	2,984	2,984	2,984	2,984	2,984
Pecos	122,734	122,734	122,734	122,734	122,734	122,734
Reeves	190,111	190,111	190,111	190,111	190,111	190,111
Ward	50,010	50,010	50,010	50,010	50,010	50,010
Winkler	39,984	39,984	39,984	39,984	39,984	39,984
Total	**410,821**	**410,821**	**410,821**	**410,821**	**410,821**	**410,821**

5.2 Groundwater Supply Needs and Strategies

The 2016 Region F Plan lists county-by-county shortages and strategies. Shortages are identified when current supplies (e.g. existing wells) cannot meet future demands. Strategies are then recommended (e.g. new wells) to meet the future demands.

For the counties in GMA 3, the only county with a shortage is Winkler County (421 AF/yr), and a recommended strategy is to develop an additional 500 AF/yr of groundwater with three wells. In addition, although there is no shortage, a strategy for Pecos County is listed to develop an additional well pumping 250 AF/yr for Pecos County WCID No. 1 to improve system reliability.

5.3 Hydrologic Conditions, including Total Estimated Recoverable Storage

The groundwater budget as presented by Hutchison and others (2011) the entire model area of the Edwards-Trinity (Plateau) Aquifer and Pecos Valley Aquifer is presented in Table 2.

Jones and others (2013) documented the total estimated recoverable storage for the aquifers in GMA 7. Table 3 presents storage for the Edwards-Trinity (Plateau) Aquifer. Table 4 presents storage for the Pecos Aquifer.

Table 2. Groundwater Budget of Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers from One-Layer Model

	Water Budget 1930-1939 (acre-feet per year)	Water Budget 1940-1949 (acre-feet per year)	Water Budget 1950-1959 (acre-feet per year)	Water Budget 1960-1969 (acre-feet per year)	Water Budget 1970-1979 (acre-feet per year)	Water Budget 1980-1989 (acre-feet per year)	Water Budget 1990-1999 (acre-feet per year)	Water Budget 2000-2005 (acre-feet per year)
Inflow								
Rivers	993,229	1,009,160	1,054,950	1,107,275	1,092,402	1,048,220	1,033,690	1,033,726
Inter-aquifer Flow	1,095,795	1,100,269	1,112,419	1,123,952	1,135,663	1,131,445	1,137,506	1,136,281
Recharge	1,641,803	1,688,928	1,545,021	1,621,125	1,680,625	1,671,631	1,669,556	1,703,227
Total Inflow	3,730,827	3,798,357	3,712,390	3,852,352	3,908,690	3,851,296	3,840,752	3,873,234
Outflow								
Pumpage	-194,233	-570,080	-947,024	-1,210,949	-935,718	-651,331	-706,359	-677,860
Springs	-1,216,432	-1,210,615	-1,129,334	-1,082,433	-1,092,612	-1,101,266	-1,120,187	-1,093,636
Rivers	-1,893,959	-1,841,710	-1,767,816	-1,722,471	-1,715,415	-1,741,168	-1,756,911	-1,755,300
Inter-aquifer Flow	-560,262	-557,538	-546,381	-532,124	-526,554	-531,894	-533,580	-535,091
Total Outflow	-3,864,885	-4,179,943	-4,390,555	-4,547,978	-4,270,298	-4,025,658	-4,117,038	-4,061,887
In-Out	-134,058	-381,585	-678,165	-695,626	-361,608	-174,362	-276,286	-188,653
Storage Change	-133,865	-372,190	-678,034	-695,534	-358,631	-166,175	-250,497	-188,648
Model Error	-194	-9,395	-131	-92	-2,977	-8,187	-25,789	-5
Model Error (Percent)	-0.01	-0.25	0.00	0.00	-0.08	-0.21	-0.67	0.00

Table 3. Total Estimated Recoverable Storage - Edwards-Trinity (Plateau) Aquifer

County	Total Storage (acre-feet)	25 percent of Total Storage (acre-feet)	75 percent of Total Storage (acre-feet)
Crane	27,000	6,750	20,250
Reeves	360,000	90,000	270,000
Winkler	3,300	825	2,475
Total	390,300	97,575	292,725

Table 4. Total Estimated Recoverable Storage - Pecos Valley Aquifer

County	Total Storage (acre-feet)	25 percent of Total Storage (acre-feet)	75 percent of Total Storage (acre-feet)
Crane	13,000,000	3,250,000	9,750,000
Loving	32,000,000	8,000,000	24,000,000
Pecos	29,000,000	7,250,000	21,750,000
Reeves	180,000,000	45,000,000	135,000,000
Ward	34,000,000	8,500,000	25,500,000
Winkler	21,000,000	5,250,000	15,750,000
Total	309,000,000	77,250,000	231,750,000

5.4 Other Environmental Impacts, including Impacts on Spring Flow

As seen in Table 2, the water budget presents data and estimates of spring flow and surface water-groundwater interactions.

5.5 Subsidence

Subsidence is not an issue in the Pecos Valley nor in the Edwards-Trinity (Plateau) aquifers in GMA 3.

5.6 Socioeconomic Impacts

The Texas Water Development Board prepared reports on the socioeconomic impacts of not meeting water needs for each of the Regional Planning Groups during development of the 2011 Regional Water Plans. Because the development of this desired future condition used the State Water Plan demands and water management strategies as an important foundation, it is reasonable to conclude that the socioeconomic impacts associated with this proposed desired future condition can be evaluated in the context of not meeting the listed water management strategies. Groundwater Management Area 3 is covered by Regional Planning Group F. The socioeconomic impact report for Regions F is included in Appendix D.

5.7 Impact on Private Property Rights

The impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in Groundwater Management Area 3 in groundwater is recognized under Texas Water Code Section 36.002.

The desired future conditions adopted by GMA 3 are consistent with protecting property rights of landowners who are currently pumping groundwater and landowners who have chosen to conserve groundwater by not pumping. All current and projected uses (as defined in the 2015 Region F plan) can be met based on the simulations. In addition, the pumping associated with achieving the desired future condition (the modeled available groundwater) will cause impacts to exiting well owners and to surface water. However, as required by Chapter 36 of the Water Code, GMA 3 considered these impacts and balanced them with the increasing demand of water in the GMA 3 area, and concluded that, on balance and with appropriate monitoring and project specific review during the permitting process, the desired future condition is consistent with protection of private property rights.

5.8 Feasibility of Achieving the Desired Future Condition

Groundwater levels are routinely monitored by the districts and by the TWDB in GMA 3. Evaluating the monitoring data is a routine task for the districts, and the comparison of these data with the model results that were used to develop the DFCs is covered in each district's management plan. These comparisons will be useful to guide the update of the DFCs that are required every five years.

5.9 Other Information

GMA 3 did not consider any other information in developing these DFCs.

6.0 Discussion of Other Desired Future Conditions Considered

There were 11 GAM scenarios completed in 2010 that included a range of future pumping scenarios. In 2010, there was also comments received regarding the estimates of storativity used in the alternative GAM as documented in Hutchison (2010). After considering the range of possibilities, the groundwater conservation districts in GMA 3 adopted a set of DFCs that were modified only to extend the time of simulation, and with a slight modification to pumping in one county.

7.0 Discussion of Other Recommendations

Public comments were invited and each district held a public hearing on the proposed desired future condition as follows:

Groundwater Conservation District	Date of Public Hearing	Number of Comments Received
Middle Pecos GCD	July 19, 2016	None
Reeves County GCD	September 8, 2016	None

No comments were received on the desired future conditions for the any aquifer.

8.0 References

Hutchison, W.R., 2010. Draft GAM Run 09-035 (Version 2). Texas Water Development Board, Groundwater Resources Division, 10p.

Hutchison, W.R., Jones, I.C., and Anaya, R., 2011. Update of the Groundwater Availability Model of the Edwards-Trinity (Plateau) and Pecos Valley Aquifers of Texas. Texas Water Development Board Report, January 21, 2011, 61p.

Jones, I.C., Boghici, R., Kohlrenken, W., and Shi, J., 2013. GAM Task 13-027: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 3. Texas Water Development Board, Groundwater Resources Division, September 19, 2013, 28 p.

Appendix A

Desired Future Conditions Resolution

Groundwater Management Area 3
Resolution 17-01
Desired Future Conditions for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers in Groundwater Management Area 3

WHEREAS, Groundwater Conservation Districts (GCDs) located within or partially within Groundwater Management Area 3 (GMA 3) are required under Chapter 36.108, Texas Water Code to conduct joint planning and designate the Desired Future Conditions of aquifers within GMA 3 and;

WHEREAS, the Board Presidents or their Designated Representatives of GCDs in GMA 3 have met in various meetings and conducted joint planning in accordance with §36.108, Texas Water Code since September 2010; and

WHEREAS, the GMA 3 committee has received and considered Groundwater Availability Model runs and other technical advice regarding local aquifers, hydrology, geology, recharge characteristics, the nine factors set forth in§36.108(d) of the Texas Water Code, local groundwater demands and usage, population projections, total water supply and quality of water supply available from all aquifers within the respective GCDs, regional water plan water management strategies, ground and surface water interactions, that affect groundwater conditions through the year 2070; and

WHEREAS, the member GCDs of GMA 3, having given proper and timely notice, held an open meeting on April 26, 2016 at the Ward County Convention Center Room#2, 400 East 4th, Monahans, Texas to vote to adopt proposed Desired Future Conditions for the Edwards-Trinity (Plateau) and Pecos Valley aquifers within the boundaries of GMA 3; and

WHEREAS, the member GCDs in which the Edwards-Trinity (Plateau) and Pecos Valley aquifers are relevant for joint planning purposes held open meetings within each said district between July 19, 2016 and September 8, 2016 to take public comment on the proposed DFCs for that district; and

WHEREAS on this day of December 13, 2017, at an open meeting duly noticed and held in accordance with law at the Middle Pecos Groundwater Conservation District, 405 North Spring Drive, Fort Stockton, Texas, the GCDs within GMA 3, having considered at this meeting the review comments of the Texas Water Development Board regarding the desired future conditions adopted at the October 20, 2016 meeting of GMA 3, and the calculations that were presented in GMA 3 Technical Memorandum 17-01, have voted, 2 districts in favor, 0 districts opposed, to correct the DFCs in the following counties and districts through the year 2070 as follows:

> Average drawdown in the following GMA 3 counties not to exceed drawdowns from 2010 to 2070, as set forth in Table 5 of GMA 3 Technical Memo 17-01, Draft 1) attached hereto and fully incorporated herein:

County (GCD)	Average Drawdown 2010 to 2070 (ft)
Crane	58
Loving	5
Pecos (GMA 3 portion) (Middle Pecos GCD)	14
Reeves (Reeves County GCD)	8
Ward	63
Winkler	161

NOW THEREFORE BE IT RESOLVED, that Groundwater Management Area 3 does hereby document, record, and confirm the above-described Desired Future Conditions for the Edwards-Trinity (Plateau) and Pecos Valley aquifers which were adopted by vote of the following Designated Representatives of Groundwater Conservation Districts present and voting on December 13, 2017:

Ty Edwards

Middle Pecos GCD
Ty Edwards, General Manager
Designated Representative

Larry Turnbough

Reeves County GCD
Designated Representative

Appendix B

Historic Groundwater Pumping: Edwards-Trinity (Plateau) Aquifer GMA 3 Counties

Appendix B - Historic Groundwater Pumping - Edwards-Trinity (Plateau) Aquifer
GMA 3 Counties

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
1980	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,177	6	3,070	2,087	53,134	1,100	63,574
1984	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,440	10	5,176	2,391	70,000	760	82,777
1985	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,334	9	341	2,169	62,013	809	69,675
1986	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,199	9	207	2,184	51,450	291	58,340
1987	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,467	9	191	1,989	47,076	584	53,316
1988	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,166	8	204	1,969	45,727	495	52,569
1989	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,971	8	188	1,312	51,268	642	57,389
1990	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,543	6	197	1,509	49,098	667	55,020
1991	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	2,957	5	129	1,577	47,215	691	52,574
1992	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	2,807	5	149	1,610	46,496	845	51,912
1993	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,537	4	154	1,588	57,245	757	63,285
1994	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,719	4	171	1,319	44,227	849	50,289
1995	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,697	4	215	1,493	51,125	791	57,325
1996	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,149	4	249	1,267	46,794	861	53,324
1997	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,953	4	236	979	48,125	840	54,137
1998	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,348	1	71	0	49,293	693	53,406
1999	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,171	1	236	979	48,431	816	53,634
2000	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	5,373	263	6	938	43,237	718	50,535
2001	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,235	143	5	908	38,367	757	44,415
2002	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,100	54	2	908	36,575	669	42,308
2003	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,171	52	0	647	22,477	573	27,920
2004	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	3,667	88	0	0	25,364	630	29,749
2005	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,656	92	0	0	24,722	669	30,139
2006	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,415	79	0	0	36,964	749	42,207
2008	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	5,533	75	0	0	33,983	654	40,245
2009	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	5,203	73	0	0	54,244	603	60,123
2010	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	5,369	149	0	0	73,249	594	79,361
2011	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	6,925	152	0	0	74,691	586	82,354
2012	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,601	159	0	0	65,828	523	71,111
1980	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	8,655	1,000	9,685
1984	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	27	0	1	0	6,200	900	7,128
1985	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	25	0	0	0	4,746	856	5,627
1986	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	29	0	0	0	4,527	843	5,399
1987	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	28	0	0	0	3,048	772	3,848
1988	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	29	0	0	0	3,833	347	4,209
1989	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	27	0	0	0	5,535	382	5,944
1990	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	38	0	0	0	2,921	416	3,375
1991	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	39	0	0	0	2,521	424	2,984
1992	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	38	0	0	0	2,479	640	3,157
1993	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	41	0	0	0	30,704	670	31,415
1994	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	76	0	0	0	0	651	727
1995	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	74	0	0	0	0	564	638

1996	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	70	0	0	0	0	717	787
1997	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	57	0	0	0	0	723	780
1998	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	59	0	0	0	0	242	301
1999	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	57	0	0	0	0	290	347
2000	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	7,025	285	7,313
2001	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	6,318	259	6,579
2002	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	5,939	256	6,197
2003	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	2,448	177	2,627
2004	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	4,103	253	4,358
2005	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	2,093	292	2,387
2006	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	20	0	0	0	2,103	363	2,486
2008	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	18	0	0	0	0	203	221
2009	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	77	0	0	0	4,940	267	5,284
2010	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	261	0	0	0	4,543	128	4,932
2011	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	296	0	0	0	5,240	134	5,670
2012	REEVES	EDWARDS-TRINITY-PLATEAU AQUIFER	379	0	0	0	4,423	120	4,922
2000	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2001	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2002	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2003	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2004	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2005	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2006	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2008	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2009	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2010	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2011	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2
2012	WINKLER	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	2	2

Appendix C

Historic Groundwater Pumping:
Pecos Valley Aquifer
GMA 3 Counties

Appendix C - Historic Groundwater Pumping - Pecos Valley Aquifer
GMA 3 Counties

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
1980	CRANE	PECOS AQUIFER	1,020	0	1,600	0	0	63	2,683
1984	CRANE	PECOS AQUIFER	1,237	0	3,533	0	90	112	4,972
1985	CRANE	PECOS AQUIFER	1,264	0	1,415	0	75	76	2,830
1986	CRANE	PECOS AQUIFER	1,263	0	1,166	0	100	90	2,619
1987	CRANE	PECOS AQUIFER	993	0	1,725	0	100	114	2,932
1988	CRANE	PECOS AQUIFER	1,388	389	1,520	0	100	122	3,519
1989	CRANE	PECOS AQUIFER	1,177	0	1,389	0	7	123	2,696
1990	CRANE	PECOS AQUIFER	1,284	0	1,381	0	25	121	2,811
1991	CRANE	PECOS AQUIFER	1,222	0	2,527	0	50	124	3,923
1992	CRANE	PECOS AQUIFER	837	0	570	0	50	98	1,555
1993	CRANE	PECOS AQUIFER	1,068	0	333	0	22	97	1,520
1994	CRANE	PECOS AQUIFER	1,119	0	426	0	22	151	1,718
1995	CRANE	PECOS AQUIFER	1,101	0	450	0	22	137	1,710
1996	CRANE	PECOS AQUIFER	1,130	0	829	0	22	109	2,090
1997	CRANE	PECOS AQUIFER	1,088	0	1,385	0	337	83	2,893
1998	CRANE	PECOS AQUIFER	1,281	0	776	0	337	122	2,516
1999	CRANE	PECOS AQUIFER	1,151	0	1,385	0	337	122	2,995
2000	CRANE	PECOS AQUIFER	1,393	0	0	0	0	117	1,510
2001	CRANE	PECOS AQUIFER	1,351	0	0	0	0	144	1,495
2002	CRANE	PECOS AQUIFER	1,360	0	0	0	0	121	1,481
2003	CRANE	PECOS AQUIFER	1,408	0	1	0	0	80	1,489
2004	CRANE	PECOS AQUIFER	1,373	0	0	0	0	61	1,434
2005	CRANE	PECOS AQUIFER	1,407	0	0	0	0	61	1,468
2006	CRANE	PECOS AQUIFER	1,384	0	0	0	0	50	1,434
2008	CRANE	PECOS AQUIFER	1,383	0	0	0	0	82	1,465
2009	CRANE	PECOS AQUIFER	1,337	0	0	0	0	109	1,446
2010	CRANE	PECOS AQUIFER	1,323	0	0	0	0	49	1,372
2011	CRANE	PECOS AQUIFER	1,710	0	0	0	0	51	1,761
2012	CRANE	PECOS AQUIFER	1,416	0	0	0	0	47	1,463
1980	LOVING	PECOS AQUIFER	9	0	0	0	0	49	58
1984	LOVING	PECOS AQUIFER	7	0	0	0	0	24	31
1985	LOVING	PECOS AQUIFER	5	0	0	0	0	27	32
1986	LOVING	PECOS AQUIFER	9	0	0	0	0	27	36
1987	LOVING	PECOS AQUIFER	9	0	0	0	0	27	36
1988	LOVING	PECOS AQUIFER	9	0	0	0	0	30	39
1989	LOVING	PECOS AQUIFER	7	0	0	0	0	26	33
1990	LOVING	PECOS AQUIFER	6	0	0	0	0	26	32
1991	LOVING	PECOS AQUIFER	6	0	0	0	0	27	33
1992	LOVING	PECOS AQUIFER	6	0	0	0	0	39	45
1993	LOVING	PECOS AQUIFER	5	0	0	0	0	39	44
1994	LOVING	PECOS AQUIFER	5	0	0	0	0	52	57
1995	LOVING	PECOS AQUIFER	5	0	0	0	0	51	56
1996	LOVING	PECOS AQUIFER	5	0	0	0	0	39	44
1997	LOVING	PECOS AQUIFER	4	0	0	0	0	51	55

Appendix C - Historic Groundwater Pumping - Pecos Valley Aquifer
GMA 3 Counties

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
1998	LOVING	PECOS AQUIFER	4	0	0	0	0	39	43
1999	LOVING	PECOS AQUIFER	4	0	0	0	0	30	34
2000	LOVING	PECOS AQUIFER	6	0	0	0	0	27	33
2001	LOVING	PECOS AQUIFER	6	0	0	0	0	27	33
2002	LOVING	PECOS AQUIFER	6	0	0	0	0	24	30
2003	LOVING	PECOS AQUIFER	6	0	0	0	0	25	31
2004	LOVING	PECOS AQUIFER	5	0	0	0	0	12	17
2005	LOVING	PECOS AQUIFER	6	0	0	0	0	36	42
2006	LOVING	PECOS AQUIFER	6	0	0	0	0	42	48
2008	LOVING	PECOS AQUIFER	5	0	0	0	0	16	21
2009	LOVING	PECOS AQUIFER	4	0	0	0	0	17	21
2010	LOVING	PECOS AQUIFER	3	0	0	0	0	13	16
2011	LOVING	PECOS AQUIFER	21	0	0	0	0	14	35
2012	LOVING	PECOS AQUIFER	20	0	0	0	0	13	33
1980	PECOS	PECOS AQUIFER	87	0	0	0	50,000	282	50,369
1984	PECOS	PECOS AQUIFER	336	3	5,090	0	20,000	225	25,654
1985	PECOS	PECOS AQUIFER	326	3	58	0	17,718	240	18,345
1986	PECOS	PECOS AQUIFER	308	1	64	0	14,700	87	15,160
1987	PECOS	PECOS AQUIFER	304	0	53	0	13,450	173	13,980
1988	PECOS	PECOS AQUIFER	319	0	36	0	13,065	146	13,566
1989	PECOS	PECOS AQUIFER	257	0	48	0	14,648	164	15,117
1990	PECOS	PECOS AQUIFER	260	0	37	0	14,028	170	14,495
1991	PECOS	PECOS AQUIFER	293	0	29	0	13,490	176	13,988
1992	PECOS	PECOS AQUIFER	244	0	31	0	13,284	215	13,774
1993	PECOS	PECOS AQUIFER	317	0	42	0	16,355	193	16,907
1994	PECOS	PECOS AQUIFER	377	0	26	0	25,436	216	26,055
1995	PECOS	PECOS AQUIFER	431	0	37	0	29,403	201	30,072
1996	PECOS	PECOS AQUIFER	439	0	15	0	26,912	219	27,585
1997	PECOS	PECOS AQUIFER	395	0	17	0	27,677	214	28,303
1998	PECOS	PECOS AQUIFER	335	0	5	0	28,349	177	28,866
1999	PECOS	PECOS AQUIFER	317	0	17	0	27,853	208	28,395
2000	PECOS	PECOS AQUIFER	411	0	9	0	19,797	188	20,405
2001	PECOS	PECOS AQUIFER	382	0	7	0	17,567	198	18,154
2002	PECOS	PECOS AQUIFER	361	0	6	0	16,747	175	17,289
2003	PECOS	PECOS AQUIFER	328	0	6	0	10,292	149	10,775
2004	PECOS	PECOS AQUIFER	327	0	5	0	11,613	58	12,003
2005	PECOS	PECOS AQUIFER	328	0	5	0	11,320	61	11,714
2006	PECOS	PECOS AQUIFER	331	0	5	0	16,925	69	17,330
2008	PECOS	PECOS AQUIFER	425	63	2	0	15,560	60	16,110
2009	PECOS	PECOS AQUIFER	431	63	2	0	24,837	55	25,388
2010	PECOS	PECOS AQUIFER	45	65	0	0	33,539	54	33,703
2011	PECOS	PECOS AQUIFER	241	75	0	0	34,200	54	34,570
2012	PECOS	PECOS AQUIFER	208	76	13	0	30,142	48	30,487
1980	REEVES	PECOS AQUIFER	23	731	8,257	0	97,700	800	107,511

Appendix C - Historic Groundwater Pumping - Pecos Valley Aquifer
GMA 3 Counties

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
1984	REEVES	PECOS AQUIFER	20	324	45	0	70,000	1,380	71,769
1985	REEVES	PECOS AQUIFER	19	296	2,876	0	53,579	1,313	58,083
1986	REEVES	PECOS AQUIFER	23	554	2,385	0	51,106	1,293	55,361
1987	REEVES	PECOS AQUIFER	21	701	2,600	0	34,410	1,185	38,917
1988	REEVES	PECOS AQUIFER	23	685	1,896	0	43,276	533	46,413
1989	REEVES	PECOS AQUIFER	20	735	2,270	0	62,485	586	66,096
1990	REEVES	PECOS AQUIFER	50	703	2,209	0	32,972	638	36,572
1991	REEVES	PECOS AQUIFER	53	876	2,259	0	28,452	650	32,290
1992	REEVES	PECOS AQUIFER	186	906	1,949	0	27,973	982	31,996
1993	REEVES	PECOS AQUIFER	203	817	1,231	0	346,462	1,029	349,742
1994	REEVES	PECOS AQUIFER	264	1,182	1,333	0	100,639	1,000	104,418
1995	REEVES	PECOS AQUIFER	257	1,260	1,478	0	105,037	866	108,898
1996	REEVES	PECOS AQUIFER	287	1,258	868	0	98,497	1,101	102,011
1997	REEVES	PECOS AQUIFER	232	1,258	932	0	99,428	1,110	102,960
1998	REEVES	PECOS AQUIFER	239	449	97	0	99,536	372	100,693
1999	REEVES	PECOS AQUIFER	232	449	932	0	93,551	445	95,609
2000	REEVES	PECOS AQUIFER	702	0	449	0	49,956	296	51,403
2001	REEVES	PECOS AQUIFER	720	0	449	0	44,931	269	46,369
2002	REEVES	PECOS AQUIFER	802	0	449	0	42,237	266	43,754
2003	REEVES	PECOS AQUIFER	734	0	595	0	17,412	183	18,924
2004	REEVES	PECOS AQUIFER	712	0	495	0	29,177	223	30,607
2005	REEVES	PECOS AQUIFER	748	0	1,054	0	14,883	257	16,942
2006	REEVES	PECOS AQUIFER	681	0	1,144	0	14,953	320	17,098
2008	REEVES	PECOS AQUIFER	735	0	262	0	0	179	1,176
2009	REEVES	PECOS AQUIFER	744	0	600	0	35,132	235	36,711
2010	REEVES	PECOS AQUIFER	316	0	600	0	32,310	113	33,339
2011	REEVES	PECOS AQUIFER	715	0	751	0	37,262	118	38,846
2012	REEVES	PECOS AQUIFER	714	0	601	0	31,455	106	32,876
1980	WARD	PECOS AQUIFER	15,691	8	8,853	7,004	1,191	92	32,839
1984	WARD	PECOS AQUIFER	14,361	2	467	6,132	353	92	21,407
1985	WARD	PECOS AQUIFER	12,838	1	462	6,519	1,245	77	21,142
1986	WARD	PECOS AQUIFER	10,422	1	2	7,112	1,245	123	18,905
1987	WARD	PECOS AQUIFER	8,185	28	412	6,890	1,245	92	16,852
1988	WARD	PECOS AQUIFER	10,408	39	413	1,913	12	99	12,884
1989	WARD	PECOS AQUIFER	14,538	31	380	5,648	292	129	21,018
1990	WARD	PECOS AQUIFER	9,813	21	421	5,570	205	127	16,157
1991	WARD	PECOS AQUIFER	10,446	32	255	5,344	156	130	16,363
1992	WARD	PECOS AQUIFER	8,246	19	252	5,462	167	220	14,366
1993	WARD	PECOS AQUIFER	11,287	24	588	6,405	783	191	19,278
1994	WARD	PECOS AQUIFER	11,415	25	584	6,346	213	100	18,683
1995	WARD	PECOS AQUIFER	11,683	8	160	5,216	141	100	17,308
1996	WARD	PECOS AQUIFER	11,250	5	160	5,749	141	85	17,390
1997	WARD	PECOS AQUIFER	9,066	7	158	6,189	143	116	15,679
1998	WARD	PECOS AQUIFER	9,311	6	147	6,047	138	99	15,748

Appendix C - Historic Groundwater Pumping - Pecos Valley Aquifer
GMA 3 Counties

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
1999	WARD	PECOS AQUIFER	8,337	6	147	6,047	128	95	14,760
2000	WARD	PECOS AQUIFER	8,927	0	6	5,886	2,851	45	17,715
2001	WARD	PECOS AQUIFER	11,805	0	0	5,669	1,245	89	18,808
2002	WARD	PECOS AQUIFER	10,370	0	0	5,669	680	81	16,800
2003	WARD	PECOS AQUIFER	8,217	0	0	4,222	1,123	51	13,613
2004	WARD	PECOS AQUIFER	8,415	0	0	2,505	1,265	46	12,231
2005	WARD	PECOS AQUIFER	5,514	0	0	2,326	1,153	58	9,051
2006	WARD	PECOS AQUIFER	6,932	0	0	3,099	933	57	11,021
2008	WARD	PECOS AQUIFER	4,803	0	0	2,665	1,393	87	8,948
2009	WARD	PECOS AQUIFER	4,697	0	0	2,309	1,849	88	8,943
2010	WARD	PECOS AQUIFER	5,477	0	0	2,502	864	82	8,925
2011	WARD	PECOS AQUIFER	5,039	0	0	93	223	79	5,434
2012	WARD	PECOS AQUIFER	9,125	0	0	16	890	69	10,100
1980	WINKLER	PECOS AQUIFER	341	1	269	0	4,500	112	5,223
1984	WINKLER	PECOS AQUIFER	342	1	487	0	360	83	1,273
1985	WINKLER	PECOS AQUIFER	336	44	550	0	800	70	1,800
1986	WINKLER	PECOS AQUIFER	337	55	81	0	800	84	1,357
1987	WINKLER	PECOS AQUIFER	439	45	631	0	800	84	1,999
1988	WINKLER	PECOS AQUIFER	390	7	601	0	1,000	92	2,090
1989	WINKLER	PECOS AQUIFER	331	7	491	0	0	90	919
1990	WINKLER	PECOS AQUIFER	265	7	391	0	0	89	752
1991	WINKLER	PECOS AQUIFER	321	7	1,284	0	1,500	91	3,203
1992	WINKLER	PECOS AQUIFER	302	0	135	0	1,500	132	2,069
1993	WINKLER	PECOS AQUIFER	307	8	137	0	0	132	584
1994	WINKLER	PECOS AQUIFER	330	4	108	0	0	118	560
1995	WINKLER	PECOS AQUIFER	348	2	81	0	0	91	522
1996	WINKLER	PECOS AQUIFER	384	2	92	0	0	63	541
1997	WINKLER	PECOS AQUIFER	347	1	109	0	0	63	520
1998	WINKLER	PECOS AQUIFER	405	1	88	0	0	157	651
1999	WINKLER	PECOS AQUIFER	336	0	80	0	0	140	556
2000	WINKLER	PECOS AQUIFER	336	0	20	0	2,002	119	2,477
2001	WINKLER	PECOS AQUIFER	316	0	10	0	2,002	117	2,445
2002	WINKLER	PECOS AQUIFER	277	0	0	0	2,670	111	3,058
2003	WINKLER	PECOS AQUIFER	282	0	1	0	3,005	73	3,361
2004	WINKLER	PECOS AQUIFER	224	0	20	0	2,700	76	3,020
2005	WINKLER	PECOS AQUIFER	263	0	20	0	3,770	74	4,127
2006	WINKLER	PECOS AQUIFER	4,391	0	8	0	4,912	88	9,399
2008	WINKLER	PECOS AQUIFER	335	0	0	0	2,223	111	2,669
2009	WINKLER	PECOS AQUIFER	322	0	0	0	3,005	88	3,415
2010	WINKLER	PECOS AQUIFER	318	0	0	0	2,603	102	3,023
2011	WINKLER	PECOS AQUIFER	381	0	0	0	4,135	100	4,616
2012	WINKLER	PECOS AQUIFER	291	0	0	0	4,239	86	4,616

Appendix D

Region F Socioeconomic Impact Reports from TWDB

July 22, 2010

Mr. John Grant
Chairman, Region F Regional Water Planning Group
c/o Colorado River Municipal Water District
P.O. Box 869
Big Spring, Texas 79721-0869

Re: Socioeconomic Impact Analysis of Not Meeting Water Needs for the 2011 Region F Regional Water Plan

Dear Chairman Grant:

We have received your request for technical assistance to complete the socioeconomic impact analysis of not meeting water needs. In response, enclosed is a report that describes our methodology and presents the results. Section 1 provides an overview of the methodology. Section 2 presents results at the regional level, and Appendix 2 show results for individual water user groups.

If you have any questions or comments, please feel free to contact me at (512) 463-7928 or by email at stuart.norvell@twdb.state.tx.us.

Sincerely,

Stuart D. Norvell
Manager, Water Planning Research and Analysis
Water Resources Planning Division

SN/ao

Enclosure

c. Angela Kennedy, TWDB
S. Doug Shaw, TWDB

Economic Impacts of Projected Water Shortages for the Region F Regional Water Planning Area

Prepared in Support of the 2011 Region F Regional Water Plan

Stuart D. Norvell, Managing Economist
Water Resources Planning Division
Texas Water Development Board
Austin, Texas

S. Doug Shaw, Agricultural Economist
Water Resources Planning Division
Texas Water Development Board
Austin, Texas

July 2010

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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 Region F Regional Water Planning Group.

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 as "output" in an IO model. Thus, total sales double-count or overstate the true economic value of goods

[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.

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 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]

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[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.

[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

- 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.

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 Region F Water Planning Area (average 2003-2007)

Sector	Acres (1000s)	Distribution of acres	Water use (1000s of AF)	Distribution of water use
Oilseeds	<1	<1%	<1	<1%
Grains	45	20%	62	17%
Vegetable and melons	5	2%	9	<1%
Tree nuts	6	3%	13	<1%
Fruits	<1	<1%	1	<1%
Cotton	104	47%	154	42%
All “other” crops	61	28%	123	34%
Total	221	100%	363	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 Region F Water Planning Area (2003-2007)		
IMPLAN Sector	**Gross revenues per acre**	**Crops included in estimates**
Oilseeds	$177	Irrigated figure is based on five-year (2003-2007) average weighted by acreage for “irrigated soybeans” and “irrigated ‘other’ oil crops.”
Grains	$199	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	$6,053	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	$3,451	Based on five-year (2003-2007) average weighted by acreage for “irrigated pecans.”
Fruits	$5,902	Based on five-year (2003-2007) average weighted by acreage for “irrigated citrus”, “irrigated vineyards” and “irrigated ‘other’ orchard.”
Cotton	$488	Based on five-year (2003-2007) average weighted by acreage for “irrigated cotton.”
All other crops	$335	Irrigated figure is 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 is (30 x 200 = 6,000 gallons) or 6.7 acre-feet per year. Water not attributed to commercial use is considered

[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.

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 wastewater rate surveys - specifically average monthly household expenditures on water and wastewater

[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.

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 national

[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).

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]

[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 *Region F Regional Water Plan*, during severe drought irrigation, livestock 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 Region F economy generates $20.8 billion worth of gross state product for Texas ($19.1 billion in income and $1.7 billion in business taxes) and supports nearly 227,000 jobs (Table 8). Generating about $9.8 billion in gross state product, agriculture, manufacturing, and mining are the region's primary base economic sectors.[22] Municipal sectors also generate substantial amounts of income and are major employers in the region; however, 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. In other words, without base industries, many jobs categorized as municipal 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 Region F Economy by Water User Group ($millions)*						
Water Use Category	**Total sales**	**Intermediate sales**	**Final sales**	**Jobs**	**Income**	**Business taxes**
Irrigation	$131.11	$21.48	$109.67	2,267	$68.24	$1.79
Livestock	$801.61	$432.80	$368.82	11,083	$78.45	$11.11
Manufacturing	$8,793.15	$1,386.66	$7,406.49	36,089	$2,613.94	$51.57
Mining	$11,507.80	$5,279.12	$6,228.68	27,668	$6,415.53	$563.76
Steam-electric	$376.64	$105.96	$270.68	932	$261.54	$44.63
Municipal	$15,709.07	$3,801.30	$11,907.77	148,786	$9,682.07	$981.89
Regional total	$37,319.38	$11,027.32	$26,292.11	226,825	$19,119.77	$1,654.75

[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 *Region F Regional Water Plan*, during severe drought most counties in the region would experiences shortages of irrigation water ranging anywhere from about 5 to 90 percent of total annual irrigation demands. Shortages of these magnitudes would reduce gross state product (income plus state and local business taxes) by about $30 to 35 million depending upon the decade Table 9).

Table 9: Economic Impacts of Water Shortages for Irrigation Water User Groups ($millions)			
Decade	**Lost income from reduced crop production ***	**Lost state and local tax revenues from reduced crop production**	**Lost jobs from reduced crop production**
2010	$34.97	$1.70	454
2020	$34.45	$1.68	448
2030	$33.89	$1.65	442
2040	$33.02	$1.61	432
2050	$32.48	$1.58	426
2060	$31.97	$1.56	419

*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 throughout the region, and deficits range anywhere from 1 to 100 percent of total annual water demands. At the regional level, the estimated economic value of domestic water shortages totals $164 million in 2010 and $446 million in 2060 (Table 10). Due to curtailment of commercial business activity, municipal shortages would also reduce gross state product (income plus taxes) by $40 million in 2010 and $433 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	$164.31	$35.84	1,165	$3.58	$22.60
2020	$244.46	$36.34	1,180	$3.64	$38.89
2030	$275.39	$119.12	3,208	$9.52	$48.62
2040	$363.08	$366.53	9,367	$27.34	$62.99
2050	$432.97	$386.74	9,940	$29.00	$67.58
2060	$446.11	$403.41	10,360	$30.22	$72.94

*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 are projected to occur in the counties of Coleman, Ector, Howard, Kimble, Runnels, and Tom Green. Projected shortages would reduce gross state product (income plus taxes) by an estimated $891 million in 2020 and $1,356 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	$829.61	$62.12	15,723
2020	$936.77	$69.97	17,705
2030	$994.28	$75.07	19,076
2040	$1,092.03	$82.10	20,836
2050	$1,166.59	$87.70	22,261
2060	$1,261.31	$94.74	24,041

*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 are projected to occur in Coleman, Coke, and Howard counties, and would primarily affect oil extraction. Combined shortages for each county would result in estimated losses of gross state product totaling $13.5 million dollars in 2010 and $11.0 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	$12.50	$0.94	78
2020	$16.04	$1.21	101
2030	$2.26	$0.14	13
2040	$4.75	$0.33	29
2050	$6.70	$0.49	41
2060	$9.83	$0.73	61

*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 in Coke, Ector, Mitchell, Tom Green and Ward counties resulting in estimated losses of gross state product totaling $607 million dollars in 2010, and $2,017 billion in 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	$530.83	$76.19	1,805
2020	$691.34	$99.23	2,350
2030	$1,045.50	$150.07	3,554
2040	$1,232.24	$176.87	4,189
2050	$1,468.65	$210.80	4,993
2060	$1,763.75	$253.16	5,996

*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, social impacts focus on changes in population and school enrollment in the region. In 2010, estimated population losses total 25,050 with corresponding reductions in school enrollment of 7,065 students (Table 15). In 2060, population would decline by 49,236 and school enrollment would fall by 9,106.

Table 15: Social Impacts of Water Shortages (2010-2060)		
Year	**Population Losses**	**Declines in School Enrollment**
2010	25,050	7,065
2020	26,239	7,444
2030	31,670	8,389
2040	41,980	7,759
2050	45,362	8,378
2060	49,236	9,106

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 16 displays the results.

Table 16: Distribution of Impacts by Major River Basin (2010-2060)

River Basin	2010	2020	2030	2040	2050	2060
Brazos	1%	1%	1%	1%	1%	1%
Colorado	80%	82%	82%	83%	83%	83%
Rio Grande	19%	17%	17%	16%	16%	16%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Appendix 1: Economic Data for Individual IMPLAN Sectors

Economic Data for Agricultural Water User Groups ($millions)								
Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Irrigation	Cotton Farming	8	$53.73	$0.73	$53.04	919	$19.78	$0.48
Irrigation	Vegetable and Melon Farming	3	$27.14	$0.97	$26.17	233	$19.84	$0.24
Irrigation	Tree Nut Farming	4	$19.17	$1.01	$18.16	376	$13.34	$0.46
Irrigation	All “Other” Crop Farming	10	$18.30	$16.92	$1.38	206	$8.98	$0.35
Irrigation	Grain Farming	2	$8.96	$1.29	$7.67	446	$4.14	$0.16
Irrigation	Fruit Farming	5	$3.75	$0.57	$3.18	85	$2.13	$0.08
Irrigation	Oilseed Farming	1	$0.07	$0.00	$0.07	2	$0.03	$0.00
Livestock	Cattle ranching and farming	11	$401.54	$278.43	$123.11	7,838	$31.72	$8.44
Livestock	Animal- except poultry- slaughtering	67	$315.06	$84.24	$230.82	832	$31.15	$1.73
Livestock	Animal production- except cattle and poultry	13	$54.48	$46.20	$8.29	2,237	$5.30	$0.84
Livestock	Poultry and egg production	12	$30.53	$23.93	$6.60	176	$10.28	$0.10
	Total Agriculture		$932.73	$454.27	$478.50	13,350	$146.68	$12.90
Based on year 2006 data from the Minnesota IMPLAN Group, Inc.								

Economic Data for Mining and Steam-electric Water User Groups ($millions)								
Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Mining	Oil and gas extraction	19	$5,205.54	$4,834.32	$371.22	8,214	$3,001.63	$308.29
Mining	Drilling oil and gas wells	27	$3,371.52	$16.83	$3,354.69	5,299	$997.63	$131.53
Mining	Support activities for oil and gas operations	28	$2,408.86	$334.58	$2,074.28	11,698	$2,184.47	$98.47
Mining	Stone mining and quarrying	24	$348.51	$35.86	$312.65	2,055	$178.44	$13.95
Mining	Natural gas distribution	31	$134.21	$53.79	$80.42	261	$31.27	$10.24
Mining	Sand- gravel- clay- and refractory mining	25	$22.60	$2.39	$20.21	85	$13.55	$0.67
Mining	Other nonmetallic mineral mining	26	$13.05	$1.30	$11.74	30	$7.39	$0.49
Mining	Support activities for other mining	29	$3.52	$0.05	$3.47	26	$1.16	$0.14
Total Mining	NA		$11,507.80	$5,279.12	$6,228.68	27,668	$6,415.53	$563.76
Steam-electric	Power generation and supply		$376.64	$105.96	$270.68	932	$261.54	$44.63
Based on year 2006 data from the Minnesota IMPLAN Group, Inc.								

Economic Data for Manufacturing Water User Groups ($millions)

Water Use Category	IMPLAN Sector	IMPLAN Code	Total Sales	Intermediate Sales	Final Sales	Jobs	Income	Business Taxes
Manufacturing	Petroleum refineries	142	$1,416.82	$526.63	$890.19	156	$154.70	$5.98
Manufacturing	New residential one-unit structures- all	33	$851.38	$0.00	$851.38	5,727	$282.36	$4.44
Manufacturing	Oil and gas field machinery and equipment	261	$523.73	$19.50	$504.22	1,465	$124.96	$2.54
Manufacturing	Other aluminum rolling and drawing	213	$482.71	$13.42	$469.30	642	$68.79	$2.74
Manufacturing	Commercial and institutional buildings	38	$479.41	$0.00	$479.41	4,993	$242.23	$2.98
Manufacturing	Air and gas compressor manufacturing	289	$392.54	$4.04	$388.51	911	$128.34	$2.41
Manufacturing	Vitreous china plumbing fixture manufacturing	182	$370.11	$19.16	$350.94	1,581	$194.11	$3.58
Manufacturing	Prefabricated metal buildings and components	232	$244.97	$12.30	$232.68	1,032	$50.43	$1.18
Manufacturing	Other new construction	41	$209.12	$0.00	$209.12	2,290	$112.29	$0.88
Manufacturing	Other miscellaneous chemical products	171	$149.55	$78.24	$71.31	333	$26.61	$0.65
Manufacturing	Synthetic rubber manufacturing	153	$148.58	$3.64	$144.94	199	$34.04	$0.82
Manufacturing	Asphalt paving mixture and blocks	143	$140.29	$125.83	$14.46	211	$27.81	$0.15
Manufacturing	Machine shops	243	$134.79	$32.53	$102.26	860	$70.03	$1.12
Manufacturing	Fabricated structural metal manufacturing	233	$121.00	$6.27	$114.74	482	$41.45	$0.67
Manufacturing	New residential additions and alterations-all	35	$120.95	$0.00	$120.95	682	$44.73	$0.63
Manufacturing	Cement manufacturing	191	$120.37	$0.32	$120.05	202	$53.57	$1.09
Manufacturing	Plastics pipe- fittings- and profile shapes	173	$116.14	$71.44	$44.70	310	$35.38	$0.80
Manufacturing	Plate work manufacturing	234	$110.15	$6.93	$103.21	446	$43.92	$0.57
Manufacturing	Iron- steel pipe and tubes	205	$107.02	$7.47	$99.55	209	$37.69	$0.96
Manufacturing	Motor vehicle parts manufacturing	350	$104.97	$8.44	$96.53	279	$26.82	$0.49
Manufacturing	Highway- street- bridge- and tunnel construct	39	$103.00	$0.00	$103.00	967	$51.86	$0.66
Manufacturing	Soft drink and ice manufacturing	85	$93.76	$5.24	$88.52	161	$7.92	$0.35
Manufacturing	New multifamily housing structures	34	$92.77	$0.00	$92.77	832	$43.47	$0.25
Manufacturing	Cut and sew apparel manufacturing	107	$76.34	$2.07	$74.27	541	$26.77	$0.43
Manufacturing	Water- sewer- and pipeline construction	40	$74.90	$0.00	$74.90	630	$33.22	$0.48
Manufacturing	Paperboard container manufacturing	126	$74.18	$0.79	$73.39	241	$18.19	$0.71
Manufacturing	Household vacuum cleaner manufacturing	328	$73.63	$2.78	$70.84	263	$24.46	$0.55
Manufacturing	All other manufacturing	various	$1,859.96	$439.61	$1,420.35	9,444	$607.80	$13.47
	Total manufacturing		**$8,793.15**	**$1,386.66**	**$7,406.49**	**36,089**	**$2,613.94**	**$51.57**

Based on year 2006 data from the Minnesota IMPLAN Group, Inc.

Economic Data for Municipal Water User Groups ($millions)								
Water Use Category	**IMPLAN Sector**	**IMPLAN Code**	**Total Sales**	**Intermediate Sales**	**Final Sales**	**Jobs**	**Income**	**Business Taxes**
Municipal	Wholesale trade	390	$2,098.95	$1,004.90	$1,094.05	12,934	$1,105.37	$310.12
Municipal	Owner-occupied dwellings	509	$1,892.34	$0.00	$1,892.34	0	$1,465.93	$223.76
Municipal	State & Local Education	503	$1,254.80	$0.00	$1,254.79	31,837	$1,254.80	$0.00
Municipal	Telecommunications	422	$965.38	$331.59	$633.79	3,360	$362.46	$60.38
Municipal	Food services and drinking places	481	$928.45	$118.56	$809.89	19,811	$373.53	$43.64
Municipal	Monetary authorities and depository credit in	430	$736.91	$242.70	$494.21	4,003	$517.47	$9.43
Municipal	State & Local Non-Education	504	$729.16	$0.00	$729.16	13,857	$729.16	$0.00
Municipal	Offices of physicians- dentists- and other he	465	$692.35	$0.00	$692.35	6,505	$486.53	$4.26
Municipal	Pipeline transportation	396	$617.24	$269.94	$347.30	801	$204.11	$43.20
Municipal	Truck transportation	394	$524.82	$284.17	$240.64	4,007	$240.77	$5.45
Municipal	Hospitals	467	$508.85	$0.00	$508.85	4,933	$252.98	$3.23
Municipal	Motor vehicle and parts dealers	401	$498.77	$54.24	$444.54	4,626	$257.34	$72.89
Municipal	Machinery and equipment rental and leasing	434	$433.59	$235.80	$197.78	1,401	$175.66	$6.14
Municipal	Real estate	431	$414.65	$164.14	$250.51	2,447	$240.10	$50.89
Municipal	Commercial machinery repair and maintenance	485	$413.71	$217.81	$195.90	2,466	$216.38	$15.81
Municipal	Architectural and engineering services	439	$402.20	$253.54	$148.67	3,640	$201.97	$1.68
Municipal	General merchandise stores	410	$375.62	$39.59	$336.03	7,016	$167.88	$53.50
Municipal	Other State and local government enterprises	499	$356.82	$116.19	$240.62	1,797	$121.61	$0.04
Municipal	Federal Military	505	$312.73	$0.00	$312.73	4,027	$312.73	$0.00
Municipal	Food and beverage stores	405	$283.68	$37.93	$245.75	5,296	$142.16	$31.15
Municipal	Federal Non-Military	506	$261.85	$0.00	$261.84	1,655	$261.84	$0.00
Municipal	Nursing and residential care facilities	468	$260.81	$0.00	$260.81	5,608	$161.88	$3.82
Municipal	Legal services	437	$258.66	$164.16	$94.50	2,162	$161.43	$5.06
Municipal	Management of companies and enterprises	451	$243.64	$229.12	$14.52	1,331	$136.89	$2.19
Municipal	Gasoline stations	407	$243.12	$36.92	$206.19	3,266	$131.09	$35.27
Municipal	All other municipal	various	$5,964.80	$2,337.40	$3,627.40	95,011	$2,952.30	$228.33
Municipal	Total municipal		$15,709.07	$3,801.30	$11,907.77	148,786	$9,682.07	$981.89
Based on year 2006 data from the Minnesota IMPLAN Group, Inc.								

Appendix 2: Impacts by Water User Group

Irrigation cont. ($millions)						
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Andrews County						
Reduced income from curtailed crop production	$2.6873	$2.6810	$2.6522	$2.3621	$2.3197	$2.2847
Reduced business taxes from curtailed crop production	$0.1093	$0.1090	$0.1079	$0.0961	$0.0943	$0.0929
Reduced jobs from curtailed crop production	33	33	33	29	29	28
Borden County						
Reduced income from curtailed crop production	$0.49	$0.49	$0.49	$0.49	$0.49	$0.49
Reduced business taxes from curtailed crop production	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Reduced jobs from curtailed crop production	6	6	6	6	6	6
Brown County						
Reduced income from curtailed crop production	$1.31	$1.31	$1.31	$1.30	$1.30	$1.30
Reduced business taxes from curtailed crop production	$0.06	$0.06	$0.06	$0.06	$0.06	$0.06
Reduced jobs from curtailed crop production	31	31	31	31	31	31
Coke County						
Reduced income from curtailed crop production	$0.03	$0.03	$0.03	$0.03	$0.03	$0.03
Reduced business taxes from curtailed crop production	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Reduced jobs from curtailed crop production	1	1	1	1	1	1
Coleman County						
Reduced income from curtailed crop production	$0.23	$0.23	$0.23	$0.23	$0.23	$0.23
Reduced business taxes from curtailed crop production	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Reduced jobs from curtailed crop production	6	6	6	6	6	6
Glasscock County						
Reduced income from curtailed crop production	$12.24	$12.06	$11.88	$11.69	$11.51	$11.33
Reduced business taxes from curtailed crop production	$0.60	$0.59	$0.58	$0.57	$0.56	$0.55
Reduced jobs from curtailed crop production	142	140	138	136	134	132

Irrigation cont. ($millions)						
	2010	2020	2030	2040	2050	2060
Irion County						
Reduced income from curtailed crop production	$0.13	$0.12	$0.12	$0.11	$0.11	$0.10
Reduced business taxes from curtailed crop production	$0.003	$0.003	$0.003	$0.003	$0.003	$0.003
Reduced jobs from curtailed crop production	2	2	2	1	1	1
Martin County						
Reduced income from curtailed crop production	$0.26	$0.19	$0.11	$0.00	$0.00	$0.00
Reduced business taxes from curtailed crop production	$0.01	$0.01	$0.00	$0.00	$0.00	$0.00
Reduced jobs from curtailed crop production	5	5	5	5	4	4
Menard County						
Reduced income from curtailed crop production	$0.46	$0.46	$0.45	$0.45	$0.44	$0.44
Reduced business taxes from curtailed crop production	$0.03	$0.03	$0.03	$0.02	$0.02	$0.02
Reduced jobs from curtailed crop production	10	10	10	10	10	10
Midland County						
Reduced income from curtailed crop production	$1.72	$1.73	$1.73	$1.72	$1.71	$1.69
Reduced business taxes from curtailed crop production	$0.09	$0.09	$0.09	$0.09	$0.08	$0.08
Reduced jobs from curtailed crop production	22	22	22	22	22	22
Reagan County						
Reduced income from curtailed crop production	$1.36	$1.31	$1.25	$1.18	$1.11	$1.04
Reduced business taxes from curtailed crop production	$0.07	$0.07	$0.06	$0.06	$0.06	$0.05
Reduced jobs from curtailed crop production	15	14	14	13	12	11
Runnels County						
Reduced income from curtailed crop production	$3.17	$3.09	$3.02	$2.94	$2.87	$2.79
Reduced business taxes from curtailed crop production	$0.16	$0.15	$0.15	$0.15	$0.14	$0.14
Reduced jobs from curtailed crop production	45	44	43	42	41	40
Tom Green County						
Reduced income from curtailed crop production	$0.20	$0.20	$0.20	$0.20	$0.19	$0.19
Reduced business taxes from curtailed crop production	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Reduced jobs from curtailed crop production	3	3	3	3	3	3
Upton County						
Reduced income from curtailed crop production	$5.99	$5.96	$5.93	$5.90	$5.86	$5.83
Reduced business taxes from curtailed crop production	$0.30	$0.30	$0.30	$0.29	$0.29	$0.29
Reduced jobs from curtailed crop production	79	78	78	77	77	77

Irrigation cont. ($millions)						
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Ward County						
Reduced income from curtailed crop production	$0.09	$0.08	$0.10	$0.11	$0.11	$0.11
Reduced business taxes from curtailed crop production	$0.004	$0.004	$0.005	$0.01	$0.01	$0.01
Reduced jobs from curtailed crop production	2	1	2	2	2	2

Manufacturing ($millions)						
	2010	2020	2030	2040	2050	2060
Coleman County						
Reduced income from reduced manufacturing output	$0.78	$0.78	$0.78	$0.78	$0.78	$0.78
Reduced business taxes from reduced manufacturing output	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
Reduced jobs from reduced manufacturing output	55	55	55	55	55	55
Ector County						
Reduced income from reduced manufacturing output	$14.56	$19.85	$4.30	$15.75	$15.36	$16.23
Reduced business taxes from reduced manufacturing output	$0.71	$0.97	$0.21	$0.77	$0.75	$0.80
Reduced jobs from reduced manufacturing output	147	201	43	159	155	164
Howard County						
Reduced income from reduced manufacturing output	$7.04	$11.97	$0.00	$2.82	$4.93	$8.75
Reduced business taxes from reduced manufacturing output	$0.35	$0.59	$0.00	$0.14	$0.24	$0.43
Reduced jobs from reduced manufacturing output	71	121	0	29	50	89
Kimble County						
Reduced income from reduced manufacturing output	$50.42	$55.11	$59.15	$63.27	$67.02	$72.07
Reduced business taxes from reduced manufacturing output	$2.69	$2.94	$3.16	$3.38	$3.58	$3.84
Reduced jobs from reduced manufacturing output	163	179	192	205	217	234
Runnels County						
Reduced income from reduced manufacturing output	$20.83	$23.14	$25.13	$27.11	$28.76	$31.08
Reduced business taxes from reduced manufacturing output	$1.60	$1.78	$1.93	$2.09	$2.21	$2.39
Reduced jobs from reduced manufacturing output	421	467	508	548	581	628
Tom Green County						
Reduced income from reduced manufacturing output	$735.98	$825.91	$904.93	$982.30	$1,049.74	$1,132.40
Reduced business taxes from reduced manufacturing output	$56.65	$63.58	$69.66	$75.61	$80.81	$87.17
Reduced jobs from reduced manufacturing output	14,865	16,682	18,278	19,840	21,203	22,872

Mining ($millions)						
	2010	2020	2030	2040	2050	2060
Coke County						
Reduced income from reduced mining activity	$2.12	$2.93	$0.05	$0.59	$1.06	$1.77
Reduced business taxes from reduced mining activity	$0.15	$0.20	$0.00	$0.04	$0.07	$0.12
Reduced jobs from reduced mining activity	13	18	0	4	6	11
Coleman County						
Reduced income from reduced mining activity	$1.91	$2.02	$2.02	$2.02	$2.02	$2.02
Reduced business taxes from reduced mining activity	$0.11	$0.12	$0.12	$0.12	$0.12	$0.12
Reduced jobs from reduced mining activity	11	12	12	12	12	12
Howard County						
Reduced income from reduced mining activity	$8.48	$11.09	$0.19	$2.14	$3.63	$6.04
Reduced business taxes from reduced mining activity	$0.68	$0.89	$0.02	$0.17	$0.29	$0.49
Reduced jobs from reduced mining activity	54	71	1	14	23	39

Steam-electric ($millions)						
	2010	2020	2030	2040	2050	2060
Coke County						
Reduced income from reduced electrical generation	$23.08	$18.39	$21.52	$25.24	$29.86	$35.52
Reduced business taxes from reduced electrical generation	$3.31	$2.64	$3.09	$3.62	$4.29	$5.10
Reduced jobs from reduced electrical generation	78	63	73	86	102	121
Ector County						
Reduced income from reduced electrical generation	$31.29	$203.76	$565.96	$759.10	$994.54	$1,281.52
Reduced business taxes from reduced electrical generation	$4.49	$29.25	$81.23	$108.96	$142.75	$183.94
Reduced jobs from reduced electrical generation	106	693	1,924	2,580	3,381	4,356
Mitchell County						
Reduced income from reduced electrical generation	$456.24	$440.25	$424.18	$408.10	$392.11	$376.04
Reduced business taxes from reduced electrical generation	$65.49	$63.19	$60.88	$58.58	$56.28	$53.97
Reduced jobs from reduced electrical generation	1,551	1,497	1,442	1,387	1,333	1,278
Tom Green County						
Reduced income from reduced electrical generation	$20.22	$28.93	$33.85	$39.80	$47.06	$55.92
Reduced business taxes from reduced electrical generation	$2.90	$4.15	$4.86	$5.71	$6.76	$8.03
Reduced jobs from reduced electrical generation	69	98	115	135	160	190
Ward County						
Reduced income from reduced electrical generation	$0.00	$0.00	$0.00	$0.00	$5.07	$14.74
Reduced business taxes from reduced electrical generation	$0.00	$0.00	$0.00	$0.00	$0.73	$2.12
Reduced jobs from reduced electrical generation	0	0	0	0	17	50

Municipal ($millions)						
	2010	2020	2030	2040	2050	2060
Andrews						
Monetary value of domestic water shortages	$0.00	$0.00	$0.00	$0.96	$0.98	$0.99
Lost utility revenues	$0.00	$0.00	$0.00	$1.49	$1.51	$1.53
Ballinger						
Monetary value of domestic water shortages	$7.38	$10.75	$7.67	$8.54	$23.75	$24.94
Lost income from reduced commercial business activity	$3.51	$4.15	$1.67	$1.95	$7.52	$7.90
Lost jobs due to reduced commercial business activity	132	156	63	74	284	298
Lost state and local taxes from reduced commercial business activity	$0.38	$0.45	$0.18	$0.21	$0.82	$0.86
Lost utility revenues	$1.31	$1.49	$1.35	$1.51	$2.33	$2.45
Brady						
Monetary value of domestic water shortages	$8.03	$8.13	$7.99	$7.84	$7.75	$7.75
Lost income from reduced commercial business activity	$1.06	$1.09	$1.05	$1.02	$1.00	$1.00
Lost jobs due to reduced commercial business activity	41	42	40	39	38	38
Lost state and local taxes from reduced commercial business activity	$0.12	$0.13	$0.12	$0.12	$0.12	$0.12
Lost utility revenues	$1.97	$2.00	$1.96	$1.92	$1.90	$1.90
Bronte Village						
Monetary value of domestic water shortages	$0.00	$0.02	$0.03	$0.05	$0.07	$0.09
Lost utility revenues	$0.00	$0.04	$0.06	$0.07	$0.09	$0.11
Coahoma						
Monetary value of domestic water shortages	$0.10	$0.12	$0.001	$0.01	$0.02	$0.04
Lost utility revenues	$0.10	$0.12	$0.002	$0.02	$0.04	$0.06
Coleman						
Monetary value of domestic water shortages	$25.91	$25.58	$25.24	$24.90	$24.66	$24.66
Lost income from reduced commercial business activity	$12.43	$12.28	$12.11	$11.95	$11.83	$11.83
Lost jobs due to reduced commercial business activity	348	344	339	335	332	332
Lost state and local taxes from reduced commercial business activity	$0.96	$0.95	$0.94	$0.92	$0.91	$0.91
Lost utility revenues	$2.54	$2.51	$2.48	$2.45	$2.42	$2.42

Municipal ($millions)						
	2010	2020	2030	2040	2050	2060
County-other (Coke)						
Monetary value of domestic water shortages	$0.04	$0.05	$0.00	$0.01	$0.01	$0.02
County-other (Coleman)						
Monetary value of domestic water shortages	$0.46	$0.43	$0.43	$0.43	$0.43	$0.46
County-other (Kimble)						
Monetary value of domestic water shortages	$0.01	$0.01	$0.003	$0.00	$0.00	$0.00
County-other (Menard)						
Monetary value of domestic water shortages	$0.03	$0.03	$0.03	$0.02	$0.02	$0.03
County-other (Runnels)						
Monetary value of domestic water shortages	$7.92	$6.38	$5.21	$3.96	$3.00	$1.85
County-other (Scurry)						
Monetary value of domestic water shortages	$0.07	$0.08	$0.00	$0.01	$0.03	$0.04
County-other (Tom Green)						
Monetary value of domestic water shortages	$0.04	$0.00	$0.00	$0.00	$0.00	$0.00
County-other (Ward)						
Monetary value of domestic water shortages	$0.00	$3.60	$3.60	$3.60	$3.60	$3.60
Junction						
Monetary value of domestic water shortages	$18.87	$18.85	$18.67	$18.49	$18.35	$18.35
Lost income from reduced commercial business activity	$9.58	$9.57	$9.48	$9.38	$9.31	$9.31
Lost jobs due to reduced commercial business activity	373	373	369	365	363	363
Lost state and local taxes from reduced commercial business activity	$1.22	$1.22	$1.21	$1.19	$1.19	$1.19
Lost utility revenues	$1.85	$1.85	$1.83	$1.82	$1.80	$1.80
Menard						
Monetary value of domestic water shortages	$0.07	$0.07	$0.05	$0.05	$0.04	$0.04
Lost utility revenues	$0.10	$0.10	$0.09	$0.07	$0.07	$0.07

Municipal ($millions)						
	2010	2020	2030	2040	2050	2060
Midland						
Monetary value of domestic water shortages	$1.06	$3.01	$95.81	$201.95	$244.36	$251.36
Lost income from reduced commercial business activity	$0.00	$0.00	$85.32	$311.55	$324.80	$339.87
Lost jobs due to reduced commercial business activity	0	0	2,125	7,760	8,090	8,466
Lost state and local taxes from reduced commercial business activity	$0.00	$0.00	$6.16	$22.49	$23.45	$24.54
Lost utility revenues	$2.29	$4.88	$30.91	$41.59	$42.80	$44.20
Miles						
Monetary value of domestic water shortages	$5.12	$5.60	$5.97	$3.50	$3.71	$3.91
Lost income from reduced commercial business activity	$1.54	$1.69	$1.80	$1.91	$2.03	$2.14
Lost jobs due to reduced commercial business activity	41	45	48	51	54	57
Lost state and local taxes from reduced commercial business activity	$0.19	$0.21	$0.23	$0.24	$0.26	$0.27
Lost utility revenues	$0.28	$0.30	$0.32	$0.34	$0.36	$0.38
Millersview-Doole WSC						
Monetary value of domestic water shortages	$0.02	$0.03	$0.00	$0.00	$1.66	$2.91
Lost utility revenues	$0.03	$0.05	$0.00	$0.00	$0.47	$0.57
Odessa						
Monetary value of domestic water shortages	$4.36	$61.75	$5.35	$6.24	$7.22	$10.05
Lost utility revenues	$7.35	$18.65	$7.94	$9.18	$10.61	$13.16
Robert Lee						
Monetary value of domestic water shortages	$0.16	$0.22	$0.00	$0.01	$0.03	$0.07
Lost utility revenues	$0.17	$0.21	$0.00	$0.03	$0.05	$0.10
San Angelo						
Monetary value of domestic water shortages	$64.65	$79.05	$83.30	$65.88	$76.44	$77.63
Lost income from reduced commercial business activity	$0.00	$0.00	$0.00	$21.05	$22.71	$24.02
Lost jobs due to reduced commercial business activity	0	0	0	519	559	592
Lost state and local taxes from reduced commercial business activity	$0.00	$0.00	$0.00	$1.46	$1.58	$1.67
Lost utility revenues	$0.17	$0.56	$0.30	$0.39	$0.46	$0.57

Municipal ($millions)						
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Snyder						
Monetary value of domestic water shortages	$0.66	$0.92	$0.01	$0.11	$0.20	$0.32
Lost utility revenues	$0.31	$0.39	$0.01	$0.07	$0.12	$0.19
Stanton						
Monetary value of domestic water shortages	$7.93	$8.54	$8.68	$8.70	$8.40	$7.95
Lost income from reduced commercial business activity	$4.90	$5.29	$5.38	$5.39	$5.20	$4.92
Lost jobs due to reduced commercial business activity	127	137	139	140	135	127
Lost state and local taxes from reduced commercial business activity	$0.40	$0.43	$0.44	$0.44	$0.42	$0.40
Lost utility revenues	$0.78	$0.84	$0.85	$0.85	$0.82	$0.78
Winters						
Monetary value of domestic water shortages	$8.90	$7.24	$7.30	$7.37	$7.42	$7.63
Lost income from reduced commercial business activity	$2.82	$2.29	$2.31	$2.33	$2.35	$2.41
Lost jobs due to reduced commercial business activity	102	83	84	85	85	88
Lost state and local taxes from reduced commercial business activity	$0.30	$0.24	$0.25	$0.25	$0.25	$0.26
Lost utility revenues	$1.09	$1.11	$1.12	$1.13	$1.14	$1.17