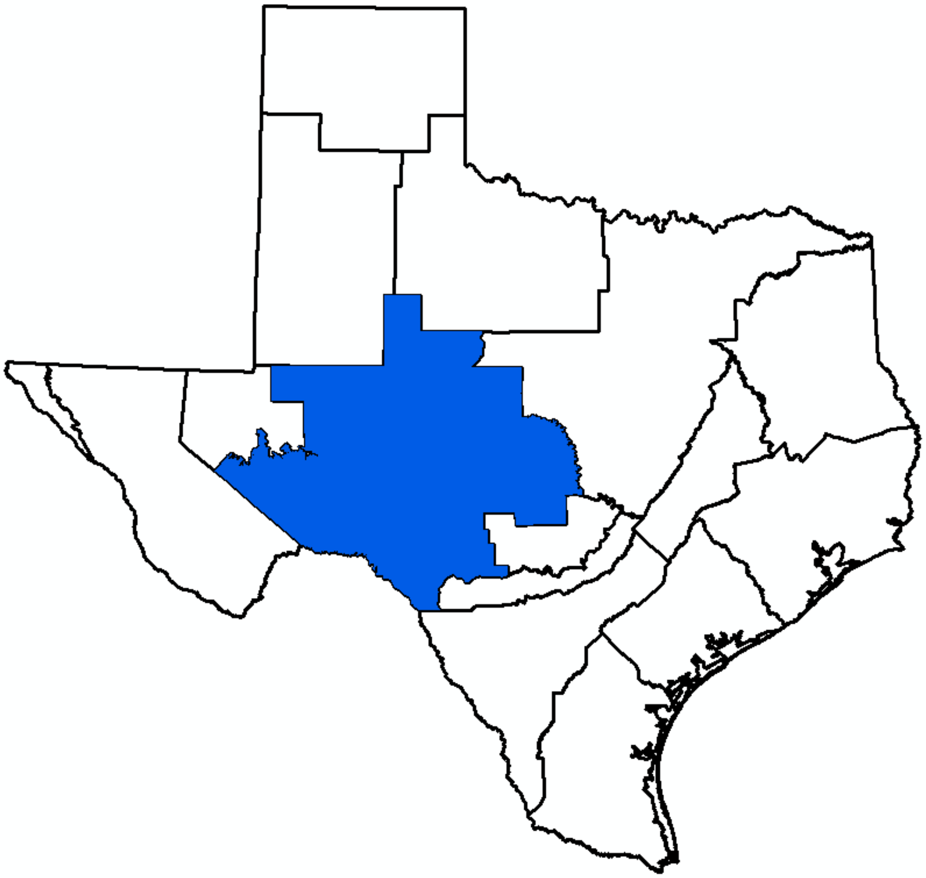
GMA 7 Explanatory Report – Draft 1

Edward-Trinity (Plateau), Pecos Valley and Trinity Aquifers



Prepared for:

Groundwater Management Area 7

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1.0 Groundwater Management Area 7

Groundwater Management Area 7 is one of sixteen groundwater management areas in Texas and covers that portion of west Texas that is underlain by the Edwards-Trinity (Plateau) Aquifer (Figure 1).

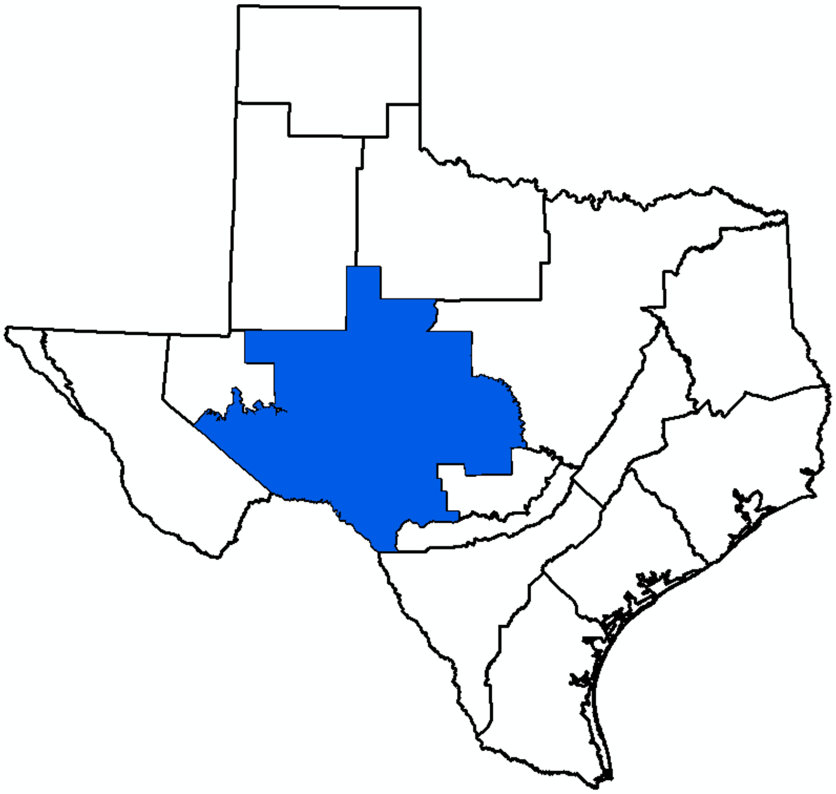


Figure 1. Groundwater Management Area 7

Groundwater Management Area 7 covers all or part of the following counties: Coke, Coleman, Concho, Crockett, Ector, Edwards, Gillespie, Glasscock, Irion, Kimble, Kinney, Llano, Mason, McCulloch, Menard, Midland, Mitchell, Nolan, Pecos, Reagan, Real, Runnels, San Saba, Schleicher, Scurry, Sterling, Sutton, Taylor, Terrell, Tom Green, Upton, and Uvalde (Figure 2).

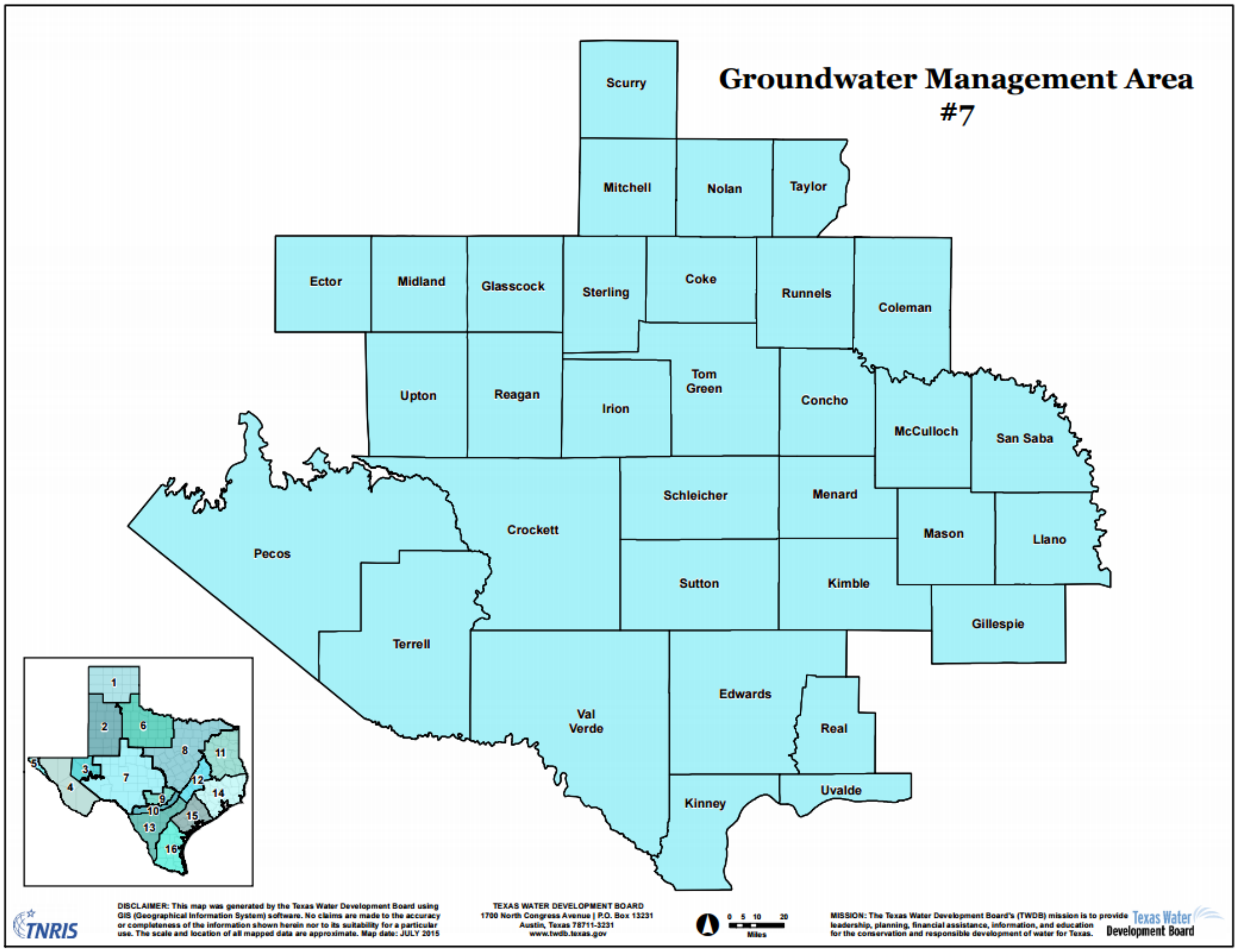


Figure 2. GMA 7 Counties (from TWDB)

There are 20 groundwater conservation districts in Groundwater Management Area 7: Coke County Underground Water Conservation District, Crockett County Groundwater Conservation District, Glasscock Groundwater Conservation District, Hickory Underground Water Conservation District No. 1, Hill County Underground Water Conservation District, Irion County Water Conservation District, Kimble County Groundwater Conservation District, Kinney County Groundwater Conservation District, Lipan-Kickapoo Water Conservation District, Lone Wolf Groundwater Conservation District, Menard County Underground Water District, Middle Pecos Groundwater Conservation District, Plateau Underground Water Conservation and Supply District, Real-Edwards Conservation and Reclamation District, Santa Rita Underground Water Conservation District, Sterling County Underground Water Conservation District, Sutton County Underground Water Conservation District, Terrell County Groundwater Conservation District, Uvalde County Underground Water Conservation District, and Wes-Tex Groundwater Conservation District (Figure 3).

The Edwards Aquifer Authority is also partially inside of the boundaries of GMA 7, but are exempt from participation in the joint planning process.

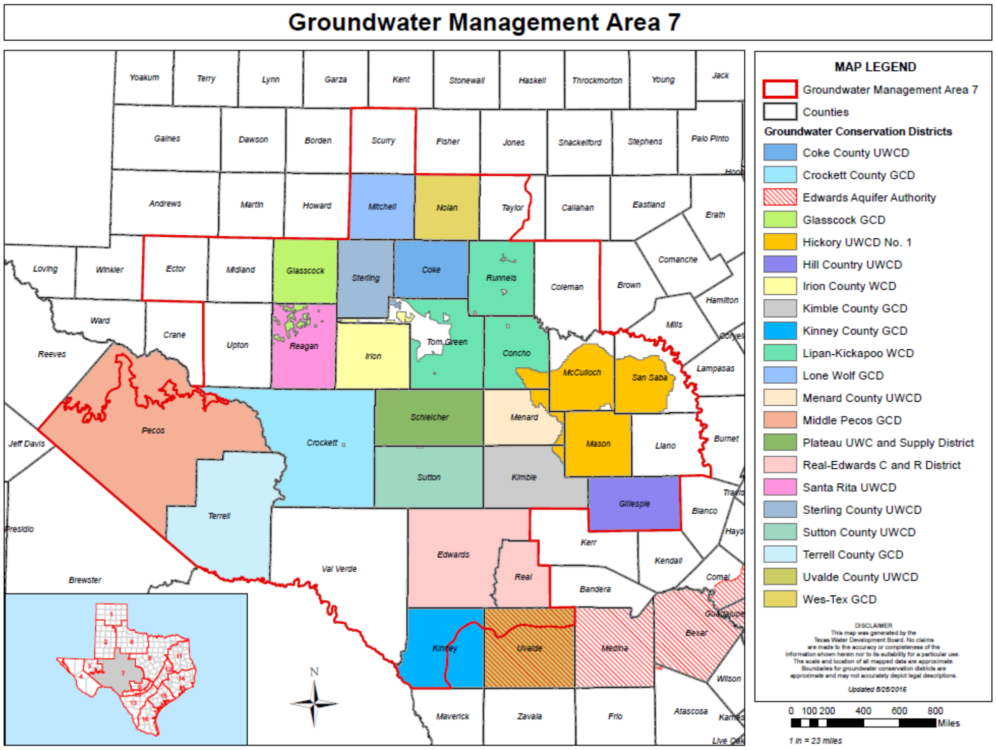


Figure 3. Groundwater Conservation Districts in GMA 7 (from TWDB)

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

> ***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.

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 Trinity Aquifer*, a major aquifer, extends across much of the central and northeastern part of the state. It is composed of several smaller aquifers contained within the Trinity Group. Although referred to differently in different parts of the state, they include the Antlers, Glen Rose, Paluxy, Twin Mountains, Travis Peak, Hensell, and Hosston aquifers. These aquifers consist of limestones, sands, clays, gravels, and conglomerates. Their combined freshwater saturated thickness averages about 600 feet in North Texas and about 1,900 feet in Central Texas. In general, groundwater is fresh but very hard in the outcrop of the aquifer. Total dissolved solids increase from less than 1,000 milligrams per liter in the east and southeast to between 1,000 and 5,000 milligrams per liter, or slightly to moderately saline, as the depth to the aquifer increases. Sulfate and chloride concentrations also tend to increase with depth. The Trinity Aquifer discharges to a large number of springs, with most discharging less than 10 cubic feet per second. The aquifer is one of the most extensive and highly used groundwater resources in Texas. Although its primary use is for municipalities, it is also used for irrigation, livestock, and other domestic purposes. Some of the state's largest water level declines, ranging from 350 to more than 1,000 feet, have occurred in counties along the IH-35 corridor from McLennan County to Grayson County. These declines are primarily attributed to municipal pumping, but they have slowed over the past decade as a result of increasing reliance on surface water. The regional water planning groups, in their 2006 Regional Water Plans, recommended numerous*

> *water management strategies for the Trinity Aquifer, including developing new wells and well fields, pumping more water from existing wells, overdrafting, reallocating supplies, and using surface water and groundwater conjunctively.*

2.0 Desired Future Condition

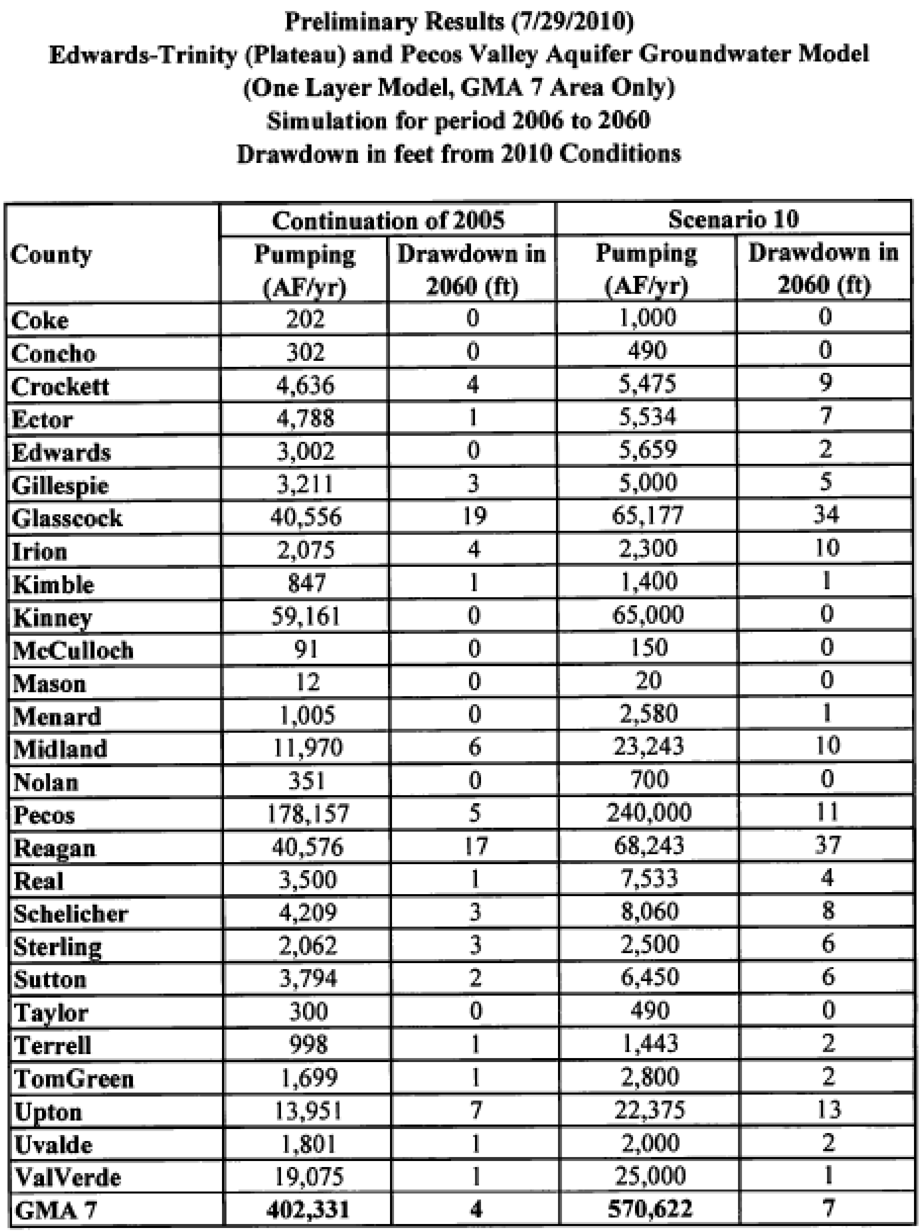
2.1 2010 Desired Future Conditions

During development of the DFC in 2010, GMA 7 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). GMA 7 based their 2010 DFC on Scenario 10 of Hutchison (2010). Drawdowns calculated in Hutchison (2010) were for predictive simulations through the year 2060.

On July 29, 2010, the groundwater conservation districts in Groundwater Management Area 7 adopted desired future conditions for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers after evaluating ten simulations with the groundwater availability model. The desired future conditions through the year 2060 were expressed as follows:

1. An average drawdown of 7 feet for the Edwards-Trinity (Plateau) aquifer, except for Kinney County GCD, based on Scenario 10 of the TWDB GAM Run 09-35 which is incorporated in its entirety into this resolution; and
2. In Kinney County, that drawdown which is consistent with maintaining, at Las Moras Springs, an annual average flow of 23.9 cfs, and a median flow of 24.4 cfs, based on Scenario 3 of the Texas Water Development Boards' flow model presented on July 27, 2010; and
3. The Edwards-Trinity aquifer for joint planning purposes within the boundaries of the Lipan-Kickapoo WCD, the Lone Wolf GCD, and the Hickory Underground Water Conservation District No. 1; and
4. The Trinity (Hill Country) portion of the aquifer is not relevant for joint planning purposes within the boundaries of the Uvalde UWCD in GMA 7.

The table of county drawdowns that was included in the resolution is presented below:



Preliminary Results (7/29/2010)
Edwards-Trinity (Plateau) and Pecos Valley Aquifer Groundwater Model
(One Layer Model, GMA 7 Area Only)
Simulation for period 2006 to 2060
Drawdown in feet from 2010 Conditions

County	Continuation of 2005		Scenario 10	
	Pumping (AF/yr)	Drawdown in 2060 (ft)	Pumping (AF/yr)	Drawdown in 2060 (ft)
Coke	202	0	1,000	0
Concho	302	0	490	0
Crockett	4,636	4	5,475	9
Ector	4,788	1	5,534	7
Edwards	3,002	0	5,659	2
Gillespie	3,211	3	5,000	5
Glasscock	40,556	19	65,177	34
Irion	2,075	4	2,300	10
Kimble	847	1	1,400	1
Kinney	59,161	0	65,000	0
McCulloch	91	0	150	0
Mason	12	0	20	0
Menard	1,005	0	2,580	1
Midland	11,970	6	23,243	10
Nolan	351	0	700	0
Pecos	178,157	5	240,000	11
Reagan	40,576	17	68,243	37
Real	3,500	1	7,533	4
Schelicher	4,209	3	8,060	8
Sterling	2,062	3	2,500	6
Sutton	3,794	2	6,450	6
Taylor	300	0	490	0
Terrell	998	1	1,443	2
TomGreen	1,699	1	2,800	2
Upton	13,951	7	22,375	13
Uvalde	1,801	1	2,000	2
ValVerde	19,075	1	25,000	1
GMA 7	**402,331**	**4**	**570,622**	**7**

2.2 2016 Desired Future Conditions

The desired future conditions that were proposed in 2016 and finally adopted in 2017 (and revised in 2018) were expressed through the year 2070 in accordance with the requirements of the Texas Water Development Board.

The desired future condition for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers in GMA 7 was based on Scenario 2 as described in GMA 7 Technical Memorandum 15-06 (updated in Technical Memorandum 18-01). During review of the materials for administrative completeness for GMA 3, 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 were attributed to 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 of the grid file had been 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 and GMA 7 instead of the most recent grid file developed by TWDB in 2015.

Because the GMA 3 files had used the same model files and post-processors as GMA 7, it was concluded that the same issues were present in GMA 7, and submittal of the materials to the Texas Water Development Board was delayed until GMA 7 met on March 22, 2018 to adopt updated desired future conditions based on the analyses presented in GMA 7 Technical Memorandum 18-01 that recalculated the average drawdowns from the GAM simulation using the 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 five counties.

The resolution that documents the adoption of the desired future condition on March 22, 2018 for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers. The desired future conditions were adopted as follows:

Average drawdown in the following GMA 7 counties not to exceed drawdowns from 2010 to 2070, as set forth in Table 5 of GMA 7 Technical Memo 18-01 (based on the Alternative GAM):

County	**Corrected Desired Future Conditions: Average Drawdowns from 2010 to 2070 (ft)**
Coke	0
Crockett	10
Ector	4
Edwards	2
Gillespie	5
Glasscock	42
Irion	10
Kimble	1
Menard	1
Midland	12
Pecos	14
Reagan	42
Real	4
Schelicher	8
Sterling	7
Sutton	6
Taylor	0
Terrell	2
Upton	20
Uvalde	2

The desired future conditions adopted on March 23, 2017 for Kinney and Val Verde counties were reaffirmed in the March 22, 2018 resolution as follows:

a) Total net drawdown in Kinney County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an annual average flow of 23.9 cfs and an annual median flow of 23.9 cfs at Las Moras Springs (Reference: Groundwater Flow Model of the Kinney County Area by W.R. Hutchison, Ph.D., P.E., P.G., Jerry Shi, Ph.D. and Marius Jigmond, TWDB, dated August 26, 2011).
b) Total net drawdown in Val Verde County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an average annual flow of 73-75 mgd at San Felipe Springs

Finally, the March 22, 2018 resolution reaffirmed the previous finding of March 23, 2017 that the Edwards-Trinity (Plateau) aquifer is not relevant for purposes of joint planning within the boundaries of the Hickory UWCD No. 1, the Lipan-Kickapoo WCD, Lone Wolf GCD, and Wes-Tex GCD, this finding is reaffirmed in this resolution.

The desired future conditions were developed after considering the simulations from three different models. For most of the area, the alternative one-layer model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers was used. For Kinney County, existing model runs using the alternative model for Kinney County was used. Finally, for Val Verde County, model runs from a model developed for Val Verde County and the City of Del Rio were used. These models are described in the next three sections of this report.

2.2.1 Use of Alternative GAM of the Edwards-Trinity (Plateau) and Pecos Valley Aquifers

GMA 7 Technical Memorandum 15-06 described two new simulations that built upon Scenario 10 of Hutchison (2010). Scenario 1 used the same pumping amounts but extended the simulation to the year 2070. The results were reviewed with GMA 7 at the April 23, 2015 GMA 7 meeting. After discussion and review of the results, adjustments to pumping were made in Irion County, and the model was run again and designated as Scenario 2. These results were discussed at the January 14, 2016 and March 17, 2016 meetings of GMA 7.

The desired future conditions that were adopted were based on Scenario 2 of GMA 7 Technical Memorandum 15-06 and based on the calculation of average drawdown in GMA 7 Technical Memorandum 18-01 that are based on the 2015 grid file.

2.2.2 Use of Alternative Model for Kinney County

In 2010, the adopted desired future condition for Kinney County was based on simulations with an alternative GAM developed by TWDB (Hutchison and others, 2011). The desired future condition was based on average spring flow in Las Moras Springs. GMA 7 (and the Kinney County GCD) has voted to keep the same DFC based on the 2010 analyses despite issues that have been identified with the model.

The simulations were documented in Draft GAM Task 10-027 (revised), referenced as Hutchison (2011). The adopted desired future condition is based on Scenario 3.

In 2014, the Kinney County GCD began an intensive effort to monitor groundwater elevations and spring flow in Kinney County. This effort began with instrumenting 13 wells with transducers in 2014, and now includes 33 wells with KCGCD transducers, one stream monitoring point with a KCGCD transducer, a well instrumented by TWDB, and Las Moras Spring (monitored by the USGS).

The wet year of 2015 resulted in a pause in model development because the recovery of groundwater elevations was significant and resulted in additional analyses to better understand the differential response among the various wells.

The DFC for Kinney County was based on maintaining an average spring flow that is independent of the model used to calculate the MAG (modeled available groundwater). Although TWDB will ultimately calculate the MAG using the tool it deems most suitable, it is reasonable to expect that the alternative GAM previously used in 2010 and 2011 will be selected, the issues with the model could result in a significantly different MAG if a different method is chosen. It is possible that the resulting MAG would be lower if a different method is used. It is also reasonable to assume that that TWDB will move forward with preparing a MAG report before the new model is completed. Once the model is completed, it will be forwarded to TWDB for consideration in updating the MAG.

2.2.3 Use of Val Verde County Model

The DFC for Val Verde County was based on maintaining an average spring flow that was based on simulations with a groundwater model that was developed for Val Verde County and the City of Del Rio as part of a hydrogeologic study completed by EcoKai Environmental, Inc. (EcoKai, 2014). The overall objective of the study was to determine the correlation and potential impacts of groundwater pumping on local spring flows, lake elevations, and groundwater levels. An understanding of these correlations is necessary to evaluate the potential effects that additional groundwater pumping for export would have on the overall groundwater system.

The groundwater model developed as part of this study was based on the alternative model for Kinney County referenced above (Hutchison and Shi, 2011). Specifically, the half-mile grid spacing, the geologic framework, and many of the boundary conditions of the Kinney County model were used as the foundation of this new model. The Kinney County model was developed using annual stress period. The new model was developed using monthly stress periods from 1968 to 2013.

Model calibration was completed using 3,605 groundwater elevations from 498 wells in Val Verde County from 1968 to 2013, and using spring flows from three springs (Cantu, McKee and San Felipe). Calibration of the model was considered sufficient to advance the objectives of the study with regard to providing technical information that could be used in developing groundwater management guidelines (e.g. identification and delineation of the boundaries of groundwater management areas, conservation triggers, exportation cessation triggers, and generally characterizing groundwater conditions based on groundwater elevations and spring flows).

Specific applications of the calibrated model included: 1) a simulation to estimate the effect of Lake Amistad on groundwater elevations in the area, 2) a series of runs that were designed to provide information useful for management zone delineation, and 3) a series of simulations to evaluate the effects of large-scale pumping in three different areas to develop a better understanding of the nature and character of potential impacts of groundwater pumping on spring flow, river baseflow, aquifer drawdown, and other changes to the groundwater flow system.

The simulations that considered pumping increases considered 6 different pumping scenarios and 3 well-field location scenarios. The adopted desired future condition was based on the pumping scenarios designated 50K (50,000 AF/yr of pumping). The listed range in average spring flow in the desired future condition reflects the range of average spring flow associated with different locations of pumping. The summary table and graph are that were used by GMA 7 at the April 21, 2016 meeting to propose the desired future condition are located on page 61of the EcoKai report (Table 23 and Figure 39).

2.3 Third Round Desired Future Condition

After review and discussion, the groundwater conservation districts in Groundwater Management Area 7 found that the desired future conditions first proposed in 2016 and finally approved in 2018 would remain unchanged. For completeness, they are repeated below.

> Average drawdown in the following GMA 7 counties not to exceed drawdowns from 2010 to 2070, as set forth in Table 5 of GMA 7 Technical Memo 18-01 (based on the Alternative GAM):

County	Corrected Desired Future Conditions: Average Drawdowns from 2010 to 2070 (ft)
Coke	0
Crockett	10
Ector	4
Edwards	2
Gillespie	5
Glasscock	42
Irion	10
Kimble	1
Menard	1
Midland	12
Pecos	14
Reagan	42
Real	4
Schelicher	8
Sterling	7
Sutton	6
Taylor	0
Terrell	2
Upton	20
Uvalde	2

The desired future conditions adopted on March 23, 2017 for Kinney and Val Verde counties were reaffirmed in the March 22, 2018 resolution as follows:

a) Total net drawdown in Kinney County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an annual average flow of 23.9 cfs and an annual median flow of 23.9 cfs at Las Moras Springs (Reference: Groundwater Flow Model of the Kinney County Area by W.R. Hutchison, Ph.D., P.E., P.G., Jerry Shi, Ph.D. and Marius Jigmond, TWDB, dated August 26, 2011).

b) Total net drawdown in Val Verde County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an average annual flow of 73-75 mgd at San Felipe Springs

Add specific info on voting dates for proposed and final DFCs and Resolution in Appendix A.

3.0 Policy Justification

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

1. Aquifer uses and conditions within Groundwater Management Area 7
2. Water supply needs and water management strategies included in the 2012 State Water Plan
3. Hydrologic conditions within Groundwater Management Area 7 including total estimated recoverable storage, average annual recharge, inflows, and discharge
4. Other environmental impacts, including 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 landowners and their lessees and assigns in Groundwater Management Area 7 in groundwater as recognized under Texas Water Code Section 36.002
8. The feasibility of achieving the desired future condition
9. 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 7.

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.

During the initial development of desired future conditions in 2010, there was no specific statutory guidance related to factor consideration or balancing. However, GMA 7 took a proactive approach in defining qualitative goals that were evaluated with the groundwater availability model at the time. The effort was rooted as a policy consideration but tested and verified as a technical consideration. Details are discussed in the next section. This approach was extended to the process of updating the desired future conditions that were adopted in 2018, and are incorporated into the decision to “readopt” the DFCs in the third round of joint planning.

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 statutory factors listed in the previous section. For the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers, the initial 10 simulations completed in 2010 were evaluated as well as two new simulations. In Kinney County, the DFCs were based on an evaluation of 7 scenarios. In Val Verde County, the DFCs were based on an evaluation of 18 scenarios.

Some critics of the process asserted that the districts were "reverse-engineering" 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 fairly 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 viewed as a means 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.

GMA 7 articulated a qualitative vision for desired future conditions in 2010: minimize drawdown in the eastern portion of GMA 7 (where baseflow to rivers is important) and provide for irrigation demands in the western portion of GMA 7 (where there would be significant drawdown). The key issue of the model simulations was to assess the compatibility of these qualitative goals. Given that groundwater models require pumping as inputs and calculate drawdowns as one of the outputs, this led to a series of simulations that evaluated increases in pumping on drawdown in various portions of GMA 7. Initially, six scenarios were run: a base case using 2005 pumping, and 5 scenarios where pumping was increased. The base case, or continuation of 2005 pumping was designated as Scenario 0. Scenario 1 was developed by polling each district to identify their expected pumping. Scenario 2 pumping was 110 percent of Scenario 1 pumping. Scenario 3 pumping was 120 percent of Scenario 1 pumping. Scenario 3 pumping was 120 percent of Scenario 1 pumping. Scenario 4 pumping was 130 percent of Scenario 1 pumping. Scenario 5 pumping was 140 percent of Scenario 1 pumping. These results were reviewed with GMA 7 at their meeting of July 28, 2010.

At the July 28, 2010 meeting, GMA 7 representatives then identified modifications to the pumping inputs and the model was re-run at the meeting, and the results were reviewed. These runs were labeled Scenarios 6 to 10. GMA 7 adopted DFCs based on Scenario 10. Based on the review, the GCD representatives found that Scenario 10 met the predefined qualitative vision of minimizing drawdown in the east while providing for irrigation demands in the west.

The evaluation of the eastern portion is exemplified by an analysis of San Saba River flow in Menard County. Figure 4 presents the flow of the San Saba River at Menard.

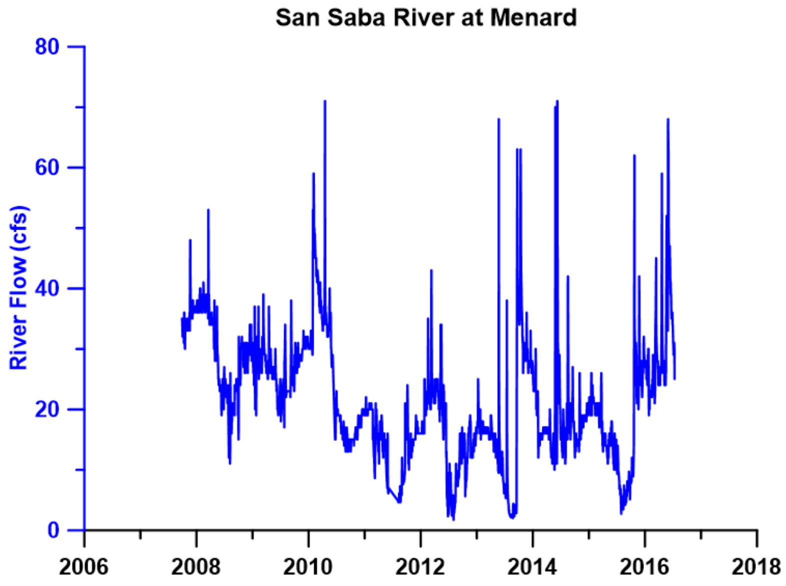


Figure 4. San Saba River at Menard

Please note that from about 2007 to 2010, minimum or base flow is about 30 cfs. From 2011 to 2014, minimum or base flow is about 10 cfs (during drought conditions), and after 2015, minimum or base flow return to about 30 cfs.

Figure 5 is a repeat of the river hydrograph and adds the hydrograph of a well completed in the Edwards-Trinity (Plateau) Aquifer several miles to the south of the stream gage.

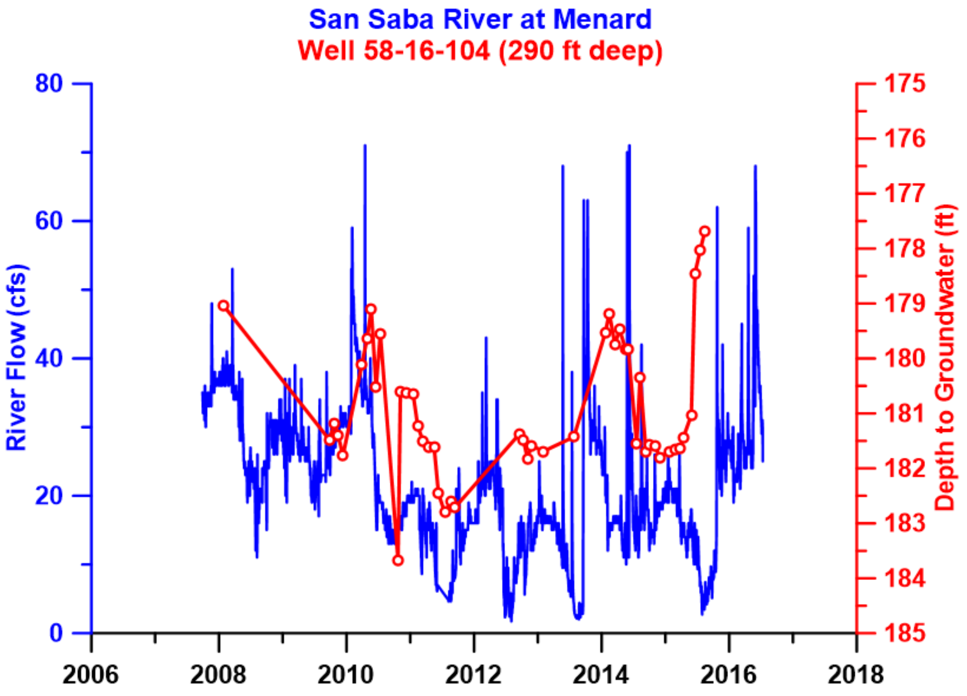


Figure 5. San Saba River at Menard and Well 58-16-104

Please note that the changes in the groundwater elevation in the well mimic the changes in river flow. The groundwater elevation from 1962 to 2016 in this well ranges from about 1,983 to 2,045 ft MSL. The stream gage elevation is 1,863 ft MSL, so it appears that this is a gaining reach of the river.

In general, the depth to water in the well is about 179 feet when river flow is high (i.e. during wet years), and the depth to water is about 182 feet when the river flow is low (i.e. during dry years). Thus, it was assumed that if, in wet periods, groundwater pumping resulted in a groundwater level decline of 3 feet, the river flow would be reduced. Thus, the pumping inputs into the GAM simulations were evaluated in the context of average drawdown that would be less than 3 feet to maintain base flow. In fact, the drawdown in Menard County under the desired future condition simulation was one foot suggested that impacts to baseflow would be minimal.

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 from 2000 to 2012 in the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers are presented in Appendix B. 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. In the Pecos Valley Aquifer, the modeled available groundwater in Crockett County is 31 AF/yr, is 113 AF/yr in Ector County, is 1,448 in Pecos County, and is 2 AF/yr in Upton County. In the Trinity Aquifer, the modeled available groundwater in Gillespie County is 2,482 AF/yr, and is 52 AF/yr in Real County.

Hydrographs that compare the historic pumping and the modeled available groundwater values are presented in Appendix C.

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

Total = 473,169 AF/yr

County	Modeled Available Groundwater (2020 to 2070) (Acre-feet/yr)	County	Modeled Available Groundwater (2010 to 2070) (Acre-feet/yr)
Coke	997	Pecos	117,039
Crockett	5,447	Reagan	68,205
Ector	5,542	Real	7,523
Edwards	5,676	Schleicher	8,034
Gillespie	4,979	Sterling	2,495
Glasscock	65,186	Sutton	6,410
Irion	3,289	Taylor	489
Kimble	1,282	Terrell	1,420
Kinney	70,341	Upton	22,369
Menard	2,217	Uvalde	1,993
Midland	23,233	Val Verde	50,000

These data were discussed at the GMA 7 meeting of January 21, 2021 in Sonora, Texas.

5.2 Groundwater Supply Needs and Strategies

The 2021 Region F Initially Prepared Plan (IPP)summarizes a variety of metrics on a county or sub-county level: modeled available groundwater, future demand, permit authorizations, highest recent historic production. The IPP also summarizes current supplies by Water Supply Group that does not correspond well to the tabular summarizes of modeled available groundwater provided by the TWDB. In general, there appears to be no serious disconnect between the available groundwater (as defined by the modeled available groundwater) and the future demands. Thus, there was no need to reconsider the desired future condition with respect to this factor.

5.3 Hydrologic Conditions, including Total Estimated Recoverable Storage

The groundwater budget as presented by Hutchison and others (2011) for the Edwards-Trinity (Plateau) Aquifer, Pecos Valley, and Trinity aquifers 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 5 presents storage for the Trinity.

5.4 Other Environmental Impacts, including Impacts on Spring Flow and Surface Water

Table 2 (referenced above) includes the entire groundwater budget for the Edwards-Trinity (Plateau) Aquifer, Pecos Valley, and Trinity aquifers.

The primary consideration for the desired future conditions in Val Verde and Kinney counties was the preservation of spring flow. The primary consideration in the northeastern portion of GMA 7 was the maintenance of groundwater levels to maintain baseflow to the tributaries of the Colorado River.

5.5 Subsidence

Subsidence is not an issue in the Edwards-Trinity (Plateau) Aquifer, Pecos Valley, and Trinity aquifers in GMA 7.

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

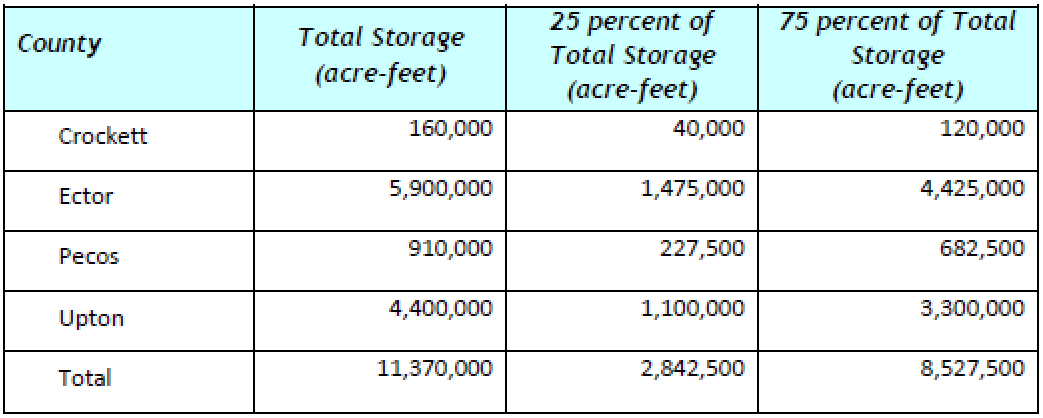
	Water Budget 1930-1939 (acre-feet per year)	Water Budget 1940-1949 (acre-feet per year)	Water Budget 1950-1959 (acre-feet per year)	Water Budget 1960-1969 (acre-feet per year)	Water Budget 1970-1979 (acre-feet per year)	Water Budget 1980-1989 (acre-feet per year)	Water Budget 1990-1999 (acre-feet per 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)*
Coke	120,000	30,000	90,000
Concho	79,000	19,750	59,250
Crockett	1,500,000	375,000	1,125,000
Ector	220,000	55,000	165,000
Edwards	5,000,000	1,250,000	3,750,000
Gillespie	430,000	107,500	322,500
Glasscock	270,000	67,500	202,500
Irion	420,000	105,000	315,000
Kimble	1,100,000	275,000	825,000
Kinney[20]	4,400,000	1,100,000	3,300,000
Mason	51,000	12,750	38,250
McCulloch	93,000	23,250	69,750
Menard	250,000	62,500	187,500
Midland	240,000	60,000	180,000
Nolan	170,000	42,500	127,500
Pecos	3,100,000	775,000	2,325,000
Reagan	560,000	140,000	420,000
Real	1,600,000	400,000	1,200,000
Schleicher	890,000	222,500	667,500
Sterling	150,000	37,500	112,500
Sutton	1,800,000	450,000	1,350,000
Taylor	78,000	19,500	58,500
Terrell	4,500,000	1,125,000	3,375,000
Tom Green	250,000	62,500	187,500
Upton	550,000	137,500	412,500
Uvalde	1,000,000	250,000	750,000
Val Verde	10,000,000	2,500,000	7,500,000
Total	38,821,000	9,705,250	29,115,750

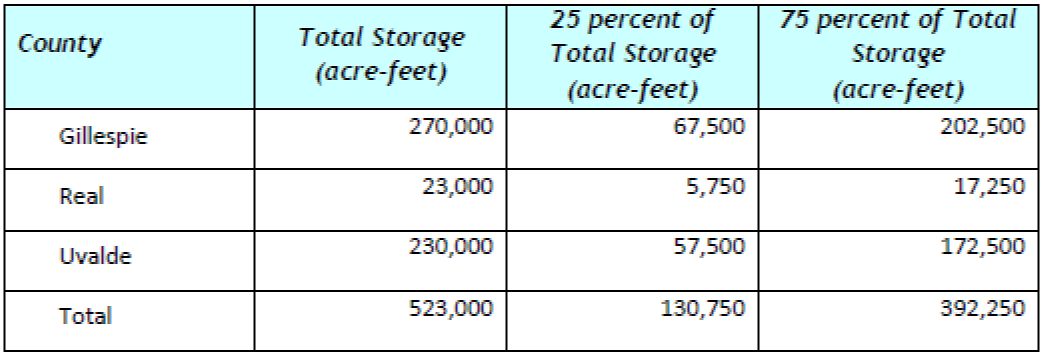
[20] Total storage values for Kinney County are based on the alternative model by Hutchison and others (2011), the other total storage values were based on the groundwater availability model by Anaya and Jones (2009).

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)*
Crockett	160,000	40,000	120,000
Ector	5,900,000	1,475,000	4,425,000
Pecos	910,000	227,500	682,500
Upton	4,400,000	1,100,000	3,300,000
Total	11,370,000	2,842,500	8,527,500

Table 5. Total Estimated Recoverable Storage - Trinity Aquifer



County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Gillespie	270,000	67,500	202,500
Real	23,000	5,750	17,250
Uvalde	230,000	57,500	172,500
Total	523,000	130,750	392,250

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 2021 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 7 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 7 in groundwater is recognized under Texas Water Code Section 36.002.

The desired future conditions adopted by GMA 7 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 2021 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 7 considered these impacts and balanced them with the increasing demand of water in the GMA 7 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 7. 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 (Devils River)

GMA 7 received two letters in support of developing an explicit desired future condition in the Devils River area of Val Verde County. The joint letter from The Nature Conservancy of Texas and the Devils River Conservancy is presented in Appendix E. The letter from the Devils River Conservancy is presented in Appendix F.

Both letters recognize that there is no groundwater conservation district in Val Verde County, so there is no administrative mechanism to manage groundwater nor regulate pumping. Both letters also correctly state that the current desired future condition in Val Verde County is based on maintaining flows from San Felipe Springs, and that a certain distribution in pumping was assumed in the groundwater model simulations that were used to develop the desired future conditions. If future pumping were to be developed in a different pattern than that assumed in the model simulation upon which the desired future condition was based, there may be impacts to other areas of the county, and this may result in impacts to a sensitive environment like the Devils River area. Because there is no groundwater conservation district, the only "decision-maker" in the planning, development, and pumping of groundwater in Val Verde County is the landowner.

Both letters acknowledge that groundwater models need to be refined before the next round of joint planning to allow explicit consideration of Devils River (and Pecos River) flow, spring flow in the Devils River area. Fortunately, the Texas Water Development Board is currently in the process of refining and updating the Groundwater Availability Model for the Edwards-Trinity (Plateau), and, according to the current schedule, the updated model should be available for use in the next round of joint planning.

The groundwater conservation districts in Groundwater Management Area 7 plan to work closely with the TWDB in the update of the groundwater availability model. Once TWDB delivers the model in final form, the utility of the model will be assessed relative to the development of desired future condition in sub areas of Val Verde County on a technical level. Once there the technical assessment is completed, recommendations regarding the model's utility and limitations will be presented at a Groundwater Management Area 7 meeting. During the fourth round of joint planning, the groundwater conservation districts in Groundwater Management Area 7 commit to revisiting this topic.

6.0 Discussion of Other Desired Future Conditions Considered

As discussed earlier in this explanatory report, desired future conditions were adopted after considering the nine statutory factors and after reviewing and discussing numerous model simulations. The simulations provided a foundation for the discussions and decisions. The Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifer simulation model was used in 12 simulations. The Kinney County simulation model was used in 7 simulations. The Val Verde County simulation model was used in 18 simulations.

7.0 Discussion of Other Recommendations

Public comments were invited, and each district held a public hearing on the proposed desired future conditions for aquifers within their boundaries as follows:

District	Date of Public Meeting	Comments Received During Public Comment Period
Coke County UWCD	To be added	To be added
Crockett County GCD	To be added	To be added
Glasscock County GCD	To be added	To be added
Hill Country GCD	To be added	To be added
Irion County WCD	To be added	To be added
Kimble County GCD	To be added	To be added
Kinney County GCD	To be added	To be added
Menard County UWD	To be added	To be added
Middle Pecos GCD	To be added	To be added
Plateau UWC & SD	To be added	To be added
Real-Edwards C & RD	To be added	To be added
Santa Rita UWCD	To be added	To be added
Sterling County UWCD	To be added	To be added
Sutton County UWCD	To be added	To be added
Terrell County GCD	To be added	To be added
Uvalde County WCD	To be added	To be added

Add summary of any comments received during public hearings and public comment period

8.0 References

George, P.G., Mace, R.E., and Petrossian, R., 2011. Aquifers of Texas. Texas Water Development Board Report 380, July 2011, 182p.

EcoKai Environmental, Inc. and Hutchison, William R., 2014. Hydrogeological Study for Val Verde County and City of Del Rio, Texas. Final Report, November 2014. 168p.

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

Hutchison, W.R., 2017. Simulations with USGS Groundwater Model of Pecos County Region. GMA 7 Technical Memorandum 17-01, Draft 2. February 13, 2017, 17p.

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.

Hutchison, W.R., Shi, J., and Jigmond, M., 2011. Groundwater Flow Model of the Kinney County Area. TWDB Report, August 26, 2011. 219p.

Jones, I.C., Bradley, R., Boghici, R., Kohlrenken, W., Shi, J., 2013. GAM Task 13-030: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 7. Texas Water Development Board, Groundwater Resources Division, October 2, 2013, 53 p.

Appendix A

Desired Future Conditions Resolution

To be Added

Appendix B

Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2000	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	50	10	90
2001	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	50	12	92
2002	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	61	10	101
2003	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	26	6	62
2004	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	29	0	0	0	47	7	83
2005	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	32	0	0	0	47	61	140
2006	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	26	0	0	0	59	68	153
2007	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	21	0	0	0	38	62	121
2008	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	24	0	0	0	43	92	159
2009	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	25	0	0	0	25	88	138
2010	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	26	0	0	0	54	80	160
2011	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	51	0	0	0	56	82	189
2012	COKE	EDWARDS-TRINITY-PLATEAU AQUIFER	58	0	0	0	33	73	164
2000	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	144	145
2001	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	141	141
2002	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	144	144
2003	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	116	116
2004	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	303	303
2005	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	195	195
2006	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	17	0	0	0	0	241	258
2007	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	14	0	0	0	0	292	306
2008	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	15	0	0	0	0	204	219
2009	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	16	0	0	0	0	204	220
2010	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	16	0	0	0	0	187	203
2011	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	17	0	0	0	0	184	201
2012	CONCHO	EDWARDS-TRINITY-PLATEAU AQUIFER	13	0	0	0	0	163	176
2000	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,561	0	31	0	123	608	2,323
2001	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,240	0	22	0	165	572	1,999
2002	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,317	0	42	0	150	515	2,024

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2003	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,215	0	50	0	289	435	1,989
2004	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,209	0	50	0	242	487	1,988
2005	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,312	0	49	0	328	607	2,296
2006	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,366	0	40	0	373	641	2,420
2007	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,309	0	25	0	293	631	2,258
2008	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,331	0	30	0	279	612	2,252
2009	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,409	0	20	0	0	605	2,034
2010	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,426	0	20	0	115	557	2,118
2011	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,760	0	60	0	221	549	2,590
2012	CROCKETT	EDWARDS-TRINITY-PLATEAU AQUIFER	1,509	0	120	0	162	493	2,284
2000	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,809	2,479	99	0	304	151	4,842
2001	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	2,008	1,826	98	0	418	92	4,442
2002	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	2,079	2,278	98	0	392	78	4,925
2003	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,684	2,228	99	0	116	55	4,182
2004	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,662	3,510	98	0	717	62	6,049
2005	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,787	767	98	0	918	224	3,794
2006	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	2,781	1,965	98	0	17	210	5,071
2007	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,738	906	13	0	170	224	3,051
2008	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	1,959	938	13	0	0	202	3,112
2009	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	2,948	586	13	0	0	224	3,771
2010	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	4,420	584	12	0	748	211	5,975
2011	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	4,862	590	12	0	351	213	6,028
2012	ECTOR	EDWARDS-TRINITY-PLATEAU AQUIFER	4,455	587	12	0	100	185	5,339
2000	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	371	0	0	0	160	448	979
2001	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	383	0	0	0	130	143	656
2002	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	343	0	0	0	202	126	671
2003	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	294	0	0	0	137	122	553
2004	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	312	0	0	0	315	121	748
2005	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	355	0	0	0	347	416	1,118

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2006	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	345	0	0	0	359	352	1,056
2007	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	286	0	0	0	104	280	670
2008	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	349	0	0	0	57	465	871
2009	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	327	0	0	0	0	463	790
2010	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	261	0	0	0	33	432	726
2011	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	387	0	0	0	257	425	1,069
2012	EDWARDS	EDWARDS-TRINITY-PLATEAU AQUIFER	329	0	0	0	97	372	798
2000	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	102	275	382
2001	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	116	261	379
2002	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	116	258	377
2003	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	116	242	361
2004	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	123	245	375
2005	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	14	0	0	0	100	374	488
2006	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	319	0	0	0	109	372	800
2007	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	257	0	0	0	9	388	654
2008	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	294	0	0	0	102	426	822
2009	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	289	0	0	0	99	398	786
2010	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	281	0	0	0	66	691	1,038
2011	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	311	0	0	0	163	711	1,185
2012	GILLESPIE	EDWARDS-TRINITY-PLATEAU AQUIFER	297	0	0	0	100	335	732
2000	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	156	0	0	0	30,528	135	30,819
2001	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	157	0	0	0	22,176	133	22,466
2002	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	148	0	0	0	22,729	122	22,999
2003	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	146	0	0	0	38,824	95	39,065
2004	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	124	0	0	0	38,147	86	38,357
2005	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	145	0	0	0	38,083	109	38,337
2006	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	134	0	0	0	40,105	119	40,358
2007	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	108	1	0	0	32,560	163	32,832
2008	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	122	0	0	0	36,919	84	37,125

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2009	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	124	3	0	0	39,479	89	39,695
2010	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	126	3	0	0	49,218	107	49,454
2011	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	143	3	0	0	45,848	118	46,112
2012	GLASSCOCK	EDWARDS-TRINITY-PLATEAU AQUIFER	167	3	0	0	38,915	84	39,169
2000	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	179	0	0	0	808	248	1,235
2001	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	170	0	0	0	640	226	1,036
2002	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	206	0	0	0	640	218	1,064
2003	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	188	0	0	0	288	150	626
2004	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	185	0	0	0	104	148	437
2005	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	190	0	0	0	180	158	528
2006	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	185	0	0	0	573	169	927
2007	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	164	0	0	0	341	168	673
2008	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	168	0	0	0	542	202	912
2009	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	175	0	0	0	225	197	597
2010	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	186	0	0	0	43	208	437
2011	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	193	0	0	0	258	218	669
2012	IRION	EDWARDS-TRINITY-PLATEAU AQUIFER	212	0	0	0	47	158	417
2000	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	209	2	0	0	10	359	580
2001	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	211	2	0	0	11	347	571
2002	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	212	2	0	0	11	314	539
2003	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	210	2	0	0	11	278	501
2004	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	203	2	0	0	19	288	512
2005	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	221	2	0	0	35	259	517
2006	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	205	2	0	0	5	249	461
2007	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	171	2	0	0	98	268	539
2008	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	188	2	0	0	40	223	453
2009	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	195	2	0	0	165	222	584
2010	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	203	2	0	0	115	302	622
2011	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	229	2	0	0	66	306	603

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2012	KIMBLE	EDWARDS-TRINITY-PLATEAU AQUIFER	221	2	0	0	84	172	479
2000	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	10,454	236	10,697
2001	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	4,435	115	4,557
2002	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	4,357	106	4,470
2003	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	7,337	78	7,422
2004	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	3,355	36	3,398
2005	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	7	0	0	0	2,959	74	3,040
2006	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	14	0	0	0	3,551	67	3,632
2007	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	12	0	0	0	1,220	61	1,293
2008	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	13	0	0	0	1,519	87	1,619
2009	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	665	100	795
2010	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	536	0	0	0	640	50	1,226
2011	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	670	0	0	0	3,425	51	4,146
2012	KINNEY	EDWARDS-TRINITY-PLATEAU AQUIFER	621	0	0	0	1,663	46	2,330
2000	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	6	6
2001	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	7	7
2002	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	6	6
2003	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	9	9
2004	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	10	10
2005	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	14	14
2006	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	17	18
2007	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	14	15
2008	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	14	15
2009	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	12	13
2010	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	0	8	10
2011	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	0	12	14
2012	MASON	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	0	11	13
2000	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	17	17
2001	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	12	12

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2002	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	15	15
2003	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	11	11
2004	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2005	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	4	4
2006	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	3	4
2007	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	3	4
2008	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	1	0	0	0	0	3	4
2009	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	0	4	7
2010	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	0	6	11
2011	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	6	0	0	0	0	3	9
2012	MCCULLOCH	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	72	0	0	3	80
2000	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	358	0	0	0	111	307	776
2001	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	338	0	0	0	126	306	770
2002	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	329	0	0	0	126	273	728
2003	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	315	0	0	0	56	292	663
2004	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	256	0	0	0	42	297	595
2005	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	261	0	0	0	65	304	630
2006	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	289	0	0	0	468	318	1,075
2007	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	255	0	0	0	318	326	899
2008	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	306	0	0	0	0	276	582
2009	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	339	0	0	0	244	314	897
2010	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	73	0	0	0	256	256	585
2011	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	81	0	0	0	100	245	426
2012	MENARD	EDWARDS-TRINITY-PLATEAU AQUIFER	79	0	0	0	301	211	591
2000	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,308	0	1	0	9,262	226	10,797
2001	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,717	0	1	0	8,382	223	10,323
2002	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,861	0	1	0	7,921	191	9,974
2003	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,257	0	1	0	5,828	102	7,188
2004	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,261	0	1	0	8,389	94	9,745

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2005	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,324	0	1	0	8,982	181	10,488
2006	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,643	0	1	0	9,851	216	11,711
2007	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,376	0	1	0	7,403	243	9,023
2008	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	1,636	0	0	0	9,584	157	11,377
2009	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	2,191	0	0	0	9,997	211	12,399
2010	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	2,112	0	0	0	7,128	158	9,398
2011	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	3,229	0	0	0	10,087	165	13,481
2012	MIDLAND	EDWARDS-TRINITY-PLATEAU AQUIFER	3,114	0	0	0	9,715	140	12,969
2000	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	669	70	0	0	39	22	800
2001	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,559	76	0	0	23	10	2,668
2002	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,908	79	0	0	23	10	3,020
2003	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	3,390	79	0	0	25	7	3,501
2004	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,454	79	0	0	33	11	2,577
2005	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,210	105	0	0	43	143	2,501
2006	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	3,108	105	0	0	42	165	3,420
2007	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,905	136	0	0	47	156	3,244
2008	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,945	132	0	0	81	150	3,308
2009	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,283	86	0	0	90	143	2,602
2010	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	1,927	11	0	0	65	131	2,134
2011	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,307	15	0	0	98	133	2,553
2012	NOLAN	EDWARDS-TRINITY-PLATEAU AQUIFER	2,046	19	0	0	100	117	2,282
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
2007	PECOS	EDWARDS-TRINITY-PLATEAU AQUIFER	4,831	129	0	0	32,579	581	38,120

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
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
2000	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	148	0	0	0	15,735	167	16,050
2001	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	848	0	0	0	11,624	132	12,604
2002	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	849	0	0	0	14,746	132	15,727
2003	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	848	0	0	0	9,911	73	10,832
2004	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	845	0	0	0	10,300	79	11,224
2005	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	750	0	0	0	12,164	150	13,064
2006	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	879	0	0	0	18,599	120	19,598
2007	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	796	0	0	0	16,863	127	17,786
2008	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	751	0	0	0	19,305	223	20,279
2009	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	762	0	0	0	16,577	224	17,563
2010	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	603	0	0	0	19,238	189	20,030
2011	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	767	0	0	0	26,164	188	27,119
2012	REAGAN	EDWARDS-TRINITY-PLATEAU AQUIFER	717	0	0	0	19,681	167	20,565
2000	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	103	0	0	0	21	131	255
2001	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	89	0	0	0	22	85	196
2002	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	95	0	0	0	22	86	203
2003	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	105	0	0	0	17	76	198
2004	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	224	0	0	0	72	74	370
2005	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	251	0	0	0	92	118	461
2006	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	263	0	0	0	284	93	640
2007	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	214	0	0	0	0	105	319
2008	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	254	0	0	0	50	93	397
2009	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	269	0	0	0	0	98	367
2010	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	471	0	0	0	88	187	746

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2011	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	511	0	0	0	188	194	893
2012	REAL	EDWARDS-TRINITY-PLATEAU AQUIFER	442	0	0	0	99	79	620
2000	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	4	4
2001	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	4	4
2002	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	4	4
2003	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2004	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	3	3
2005	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	0	0	0	0	0	15	15
2006	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	0	16	19
2007	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	2	0	0	0	0	15	17
2008	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	0	17	20
2009	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	3	0	0	0	0	16	19
2010	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	4	0	0	0	0	17	21
2011	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	4	0	0	0	0	18	22
2012	RUNNELS	EDWARDS-TRINITY-PLATEAU AQUIFER	4	0	0	0	0	11	15
2000	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	657	0	18	0	2,150	438	3,263
2001	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	552	0	18	0	1,294	273	2,137
2002	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	591	0	17	0	1,300	243	2,151
2003	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	461	0	18	0	964	222	1,665
2004	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	485	0	18	0	734	247	1,484
2005	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	473	0	18	0	762	477	1,730
2006	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	480	0	18	0	1,005	506	2,009
2007	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	484	0	17	0	500	508	1,509
2008	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	610	0	0	0	1,095	467	2,172
2009	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	613	0	0	0	1,432	463	2,508
2010	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	616	0	0	0	1,442	422	2,480
2011	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	806	0	0	0	1,941	414	3,161
2012	SCHLEICHER	EDWARDS-TRINITY-PLATEAU AQUIFER	652	0	0	0	2,020	364	3,036
2000	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	4	0	0	0	235	214	453

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2001	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	251	270	526
2002	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	264	236	505
2003	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	226	145	376
2004	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	183	164	352
2005	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	5	0	0	0	166	208	379
2006	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	20	0	0	0	221	217	458
2007	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	16	0	0	0	176	236	428
2008	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	19	0	0	0	272	196	487
2009	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	19	0	0	0	378	208	605
2010	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	20	0	0	0	253	183	456
2011	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	20	0	0	0	360	176	556
2012	STERLING	EDWARDS-TRINITY-PLATEAU AQUIFER	19	0	0	0	313	157	489
2000	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,389	0	0	0	1,234	440	3,063
2001	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,338	0	0	0	1,114	208	2,660
2002	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,339	0	0	0	1,114	188	2,641
2003	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,243	0	0	0	292	150	1,685
2004	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,108	0	0	0	292	141	1,541
2005	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,142	0	0	0	1,249	396	2,787
2006	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,247	0	0	0	1,407	363	3,017
2007	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,024	0	0	0	1,542	395	2,961
2008	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,141	0	0	0	342	469	1,952
2009	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	891	0	0	0	567	458	1,916
2010	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	928	0	0	0	958	477	2,363
2011	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,285	0	0	0	1,256	495	3,036
2012	SUTTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,267	0	0	0	859	360	2,486
2000	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	88	0	0	0	3	25	116
2001	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	88	0	0	0	8	10	106
2002	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	88	0	0	0	6	7	101
2003	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	87	0	0	0	1	6	94

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2004	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	85	0	0	0	1	11	97
2005	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	91	0	0	0	28	32	151
2006	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	123	0	0	0	26	42	191
2007	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	102	0	0	0	14	36	152
2008	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	113	0	0	0	0	90	203
2009	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	219	0	0	0	7	82	308
2010	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	328	0	0	0	21	44	393
2011	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	279	0	0	0	52	47	378
2012	TAYLOR	EDWARDS-TRINITY-PLATEAU AQUIFER	293	0	0	0	19	37	349
2000	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	217	0	5	0	0	292	514
2001	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	200	0	5	0	0	280	485
2002	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	178	0	5	0	0	234	417
2003	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	175	0	5	0	0	189	369
2004	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	147	0	5	0	0	207	359
2005	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	181	0	4	0	0	233	418
2006	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	196	0	5	0	0	211	412
2007	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	192	0	4	0	255	170	621
2008	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	178	0	4	0	0	193	375
2009	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	196	0	4	0	154	206	560
2010	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	202	0	4	0	173	182	561
2011	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	218	0	9	0	398	179	804
2012	TERRELL	EDWARDS-TRINITY-PLATEAU AQUIFER	186	0	9	0	41	163	399
2000	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	123	0	0	0	131	137	391
2001	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	75	0	0	0	171	125	371
2002	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	94	0	0	0	183	143	420
2003	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	95	0	0	0	166	122	383
2004	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	92	0	0	0	538	98	728
2005	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	97	0	0	0	615	841	1,553
2006	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	129	0	0	0	731	921	1,781

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2007	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	109	0	0	0	1,520	615	2,244
2008	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	199	0	0	0	1,896	844	2,939
2009	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	448	0	0	0	1,474	764	2,686
2010	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	613	0	0	0	836	786	2,235
2011	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	825	0	0	0	174	864	1,863
2012	TOM GREEN	EDWARDS-TRINITY-PLATEAU AQUIFER	672	0	0	0	1,166	747	2,585
2000	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,006	0	0	0	12,236	131	13,373
2001	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	1,051	0	0	0	8,553	60	9,664
2002	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	683	0	0	0	7,962	53	8,698
2003	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	779	0	0	0	7,792	35	8,606
2004	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	369	0	0	0	7,000	40	7,409
2005	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	759	0	0	0	6,584	98	7,441
2006	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	663	0	0	0	7,195	98	7,956
2007	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	297	0	0	0	6,253	94	6,644
2008	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	305	0	0	0	8,984	113	9,402
2009	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	411	0	0	0	7,873	111	8,395
2010	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	430	0	0	0	9,395	90	9,915
2011	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	450	0	0	0	13,651	87	14,188
2012	UPTON	EDWARDS-TRINITY-PLATEAU AQUIFER	286	0	0	0	10,033	75	10,394
2000	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	30	0	0	0	0	381	411
2001	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	39	0	0	0	0	351	390
2002	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	41	0	0	0	0	343	384
2003	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	42	0	0	0	0	374	416
2004	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	41	0	0	0	0	40	81
2005	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	44	0	0	0	0	61	105
2006	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	25	0	0	0	0	59	84
2007	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	21	0	0	0	0	60	81
2008	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	23	0	0	0	0	53	76
2009	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	95	0	0	0	0	45	140

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2010	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	466	0	0	0	0	47	513
2011	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	417	0	0	0	0	49	466
2012	UVALDE	EDWARDS-TRINITY-PLATEAU AQUIFER	440	0	0	0	0	42	482
2000	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,766	0	0	0	245	604	16,615
2001	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,769	0	0	0	287	607	16,663
2002	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,783	0	0	0	293	541	16,617
2003	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,778	0	0	0	209	464	16,451
2004	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,746	0	0	0	97	419	16,262
2005	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	15,828	0	0	0	133	482	16,443
2006	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	11,297	0	0	0	136	464	11,897
2007	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	834	0	0	0	31	408	1,273
2008	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	903	0	0	0	16	497	1,416
2009	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	1,755	0	0	0	0	488	2,243
2010	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	11,292	0	0	0	251	458	12,001
2011	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	13,053	0	0	0	130	459	13,642
2012	VAL VERDE	EDWARDS-TRINITY-PLATEAU AQUIFER	12,677	0	0	0	61	407	13,145
2000	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2001	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2002	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2003	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2004	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2005	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2006	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2007	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2008	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2009	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2010	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2011	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2012	CROCKETT	PECOS AQUIFER	0	0	0	0	0	0	0
2000	ECTOR	PECOS AQUIFER	158	0	24	0	0	19	201

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2001	ECTOR	PECOS AQUIFER	209	0	24	0	0	6	239
2002	ECTOR	PECOS AQUIFER	213	0	13	0	0	5	231
2003	ECTOR	PECOS AQUIFER	214	0	13	0	0	4	231
2004	ECTOR	PECOS AQUIFER	207	0	13	0	0	0	220
2005	ECTOR	PECOS AQUIFER	222	0	13	0	0	0	235
2006	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2007	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2008	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2009	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2010	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2011	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
2012	ECTOR	PECOS AQUIFER	0	0	13	0	0	0	13
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
2007	PECOS	PECOS AQUIFER	351	0	5	0	14,917	53	15,326
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
2000	UPTON	PECOS AQUIFER	0	0	0	0	0	1	1
2001	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2002	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2003	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2004	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2005	UPTON	PECOS AQUIFER	0	0	0	0	0	1	1
2006	UPTON	PECOS AQUIFER	0	0	0	0	0	1	1

Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

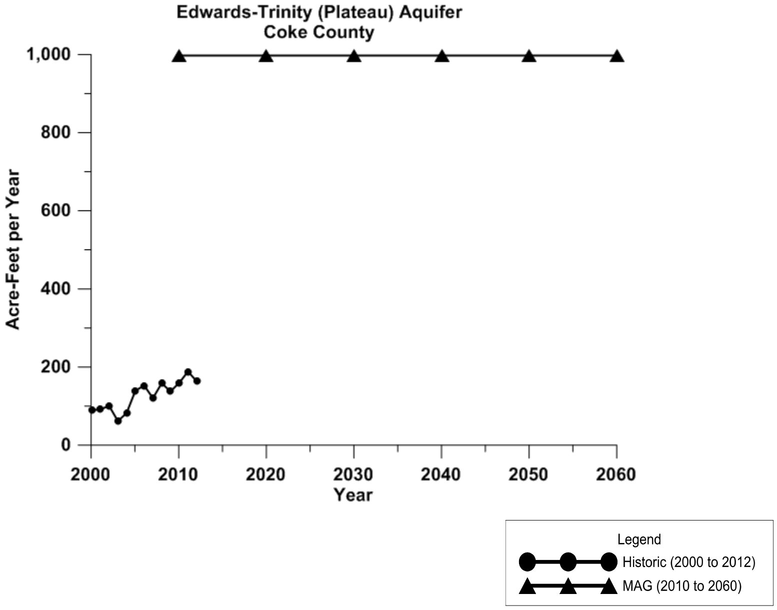
Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2007	UPTON	PECOS AQUIFER	0	0	0	0	0	1	1
2008	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2009	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2010	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2011	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2012	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2000	GILLESPIE	TRINITY AQUIFER	542	0	0	0	982	148	1,672
2001	GILLESPIE	TRINITY AQUIFER	517	0	0	0	1,123	128	1,768
2002	GILLESPIE	TRINITY AQUIFER	553	0	0	0	1,123	127	1,803
2003	GILLESPIE	TRINITY AQUIFER	629	0	0	0	1,123	119	1,871
2004	GILLESPIE	TRINITY AQUIFER	610	0	0	0	1,189	73	1,872
2005	GILLESPIE	TRINITY AQUIFER	666	0	0	0	968	111	1,745
2006	GILLESPIE	TRINITY AQUIFER	719	0	0	0	1,059	110	1,888
2007	GILLESPIE	TRINITY AQUIFER	616	0	0	0	90	115	821
2008	GILLESPIE	TRINITY AQUIFER	681	0	0	0	985	127	1,793
2009	GILLESPIE	TRINITY AQUIFER	653	0	0	0	958	118	1,729
2010	GILLESPIE	TRINITY AQUIFER	706	0	0	0	638	245	1,589
2011	GILLESPIE	TRINITY AQUIFER	774	0	0	0	1,577	252	2,603
2012	GILLESPIE	TRINITY AQUIFER	748	0	0	0	971	119	1,838
2000	REAL	TRINITY AQUIFER	0	0	0	0	2	9	11
2001	REAL	TRINITY AQUIFER	0	0	0	0	2	7	9
2002	REAL	TRINITY AQUIFER	0	0	0	0	2	7	9
2003	REAL	TRINITY AQUIFER	0	0	0	0	1	6	7
2004	REAL	TRINITY AQUIFER	0	0	0	0	6	6	12
2005	REAL	TRINITY AQUIFER	0	0	0	0	8	10	18
2006	REAL	TRINITY AQUIFER	0	0	0	0	24	8	32
2007	REAL	TRINITY AQUIFER	0	0	0	0	0	9	9
2008	REAL	TRINITY AQUIFER	0	0	0	0	4	8	12
2009	REAL	TRINITY AQUIFER	0	0	0	0	0	8	8
2010	REAL	TRINITY AQUIFER	0	0	0	0	7	15	22
2011	REAL	TRINITY AQUIFER	31	0	0	0	15	15	61
2012	REAL	TRINITY AQUIFER	2	0	0	0	8	6	16

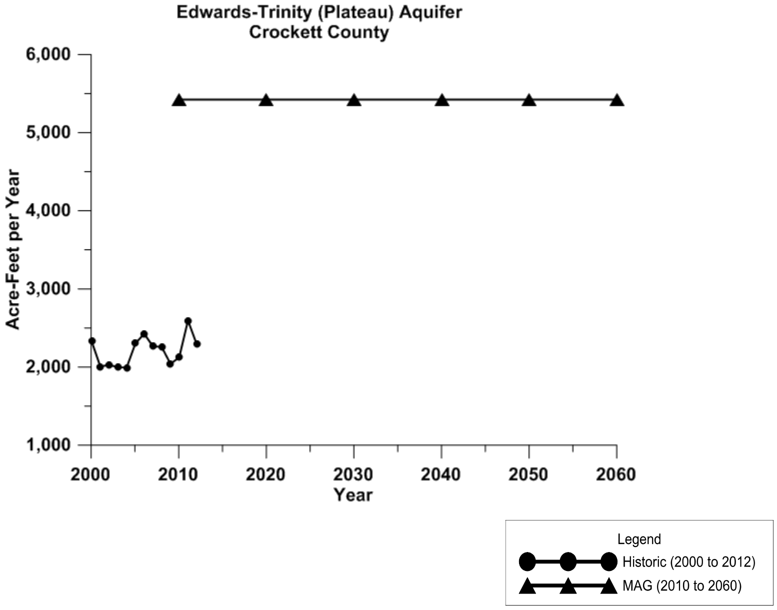
Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

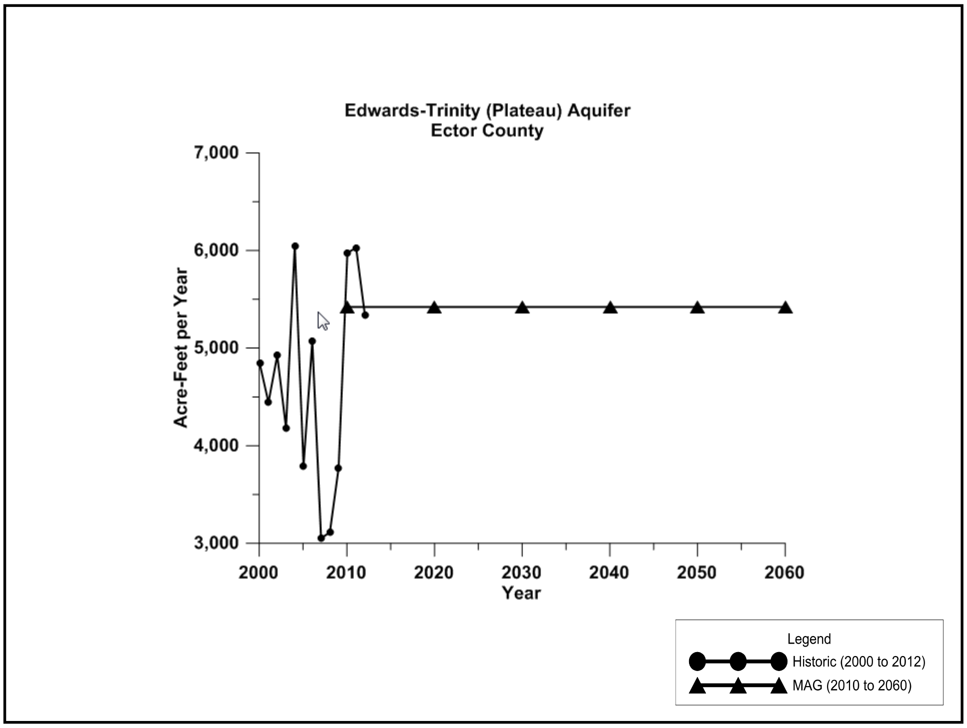
Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2000	UVALDE	TRINITY AQUIFER	0	0	0	0	0	49	49
2001	UVALDE	TRINITY AQUIFER	0	0	0	0	0	46	46
2002	UVALDE	TRINITY AQUIFER	0	0	0	0	0	45	45
2003	UVALDE	TRINITY AQUIFER	0	0	0	0	0	43	43
2004	UVALDE	TRINITY AQUIFER	0	0	0	0	0	40	40
2005	UVALDE	TRINITY AQUIFER	0	0	0	0	0	61	61
2006	UVALDE	TRINITY AQUIFER	37	0	0	0	0	59	96
2007	UVALDE	TRINITY AQUIFER	31	0	0	0	0	60	91
2008	UVALDE	TRINITY AQUIFER	117	0	0	0	0	53	170
2009	UVALDE	TRINITY AQUIFER	118	0	0	0	0	45	163
2010	UVALDE	TRINITY AQUIFER	199	0	0	0	0	47	246
2011	UVALDE	TRINITY AQUIFER	208	0	0	0	0	49	257
2012	UVALDE	TRINITY AQUIFER	153	0	0	0	0	42	195

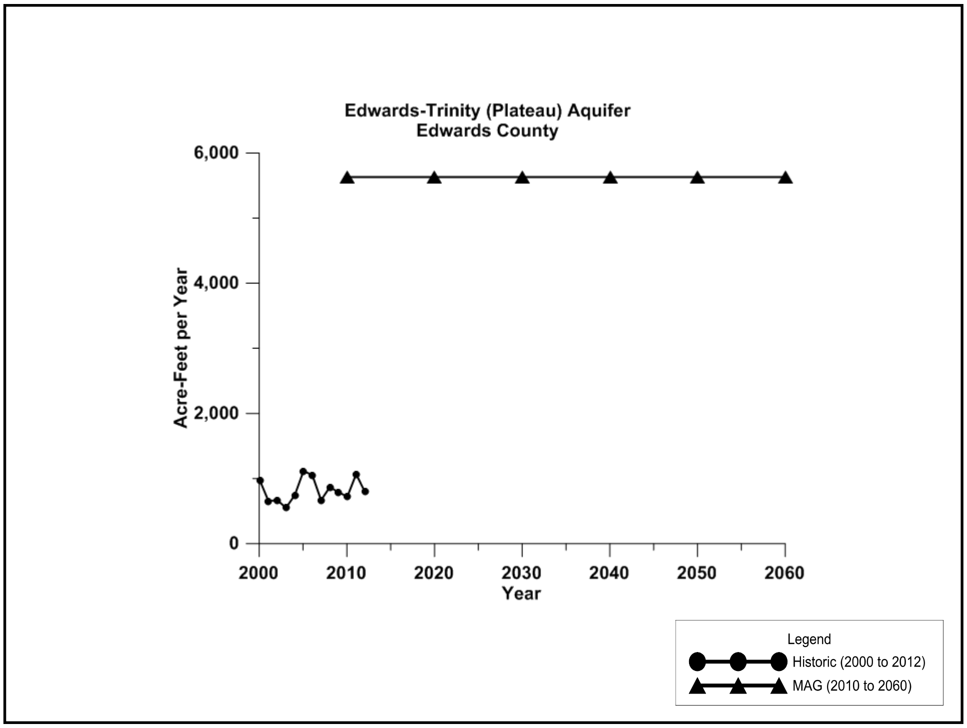
Appendix C

Hydrographs Comparing Historic Pumping and Modeled Available Groundwater from the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers


Edwards-Trinity (Plateau) Aquifer
Coke County
Acre-Feet per Year
1,000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Edwards-Trinity (Plateau) Aquifer
Crockett County
Acre-Feet per Year
6,000
5,000
4,000
3,000
2,000
1,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Edwards-Trinity (Plateau) Aquifer
Ector County
7,000
6,000
5,000
4,000
3,000
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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Edwards County
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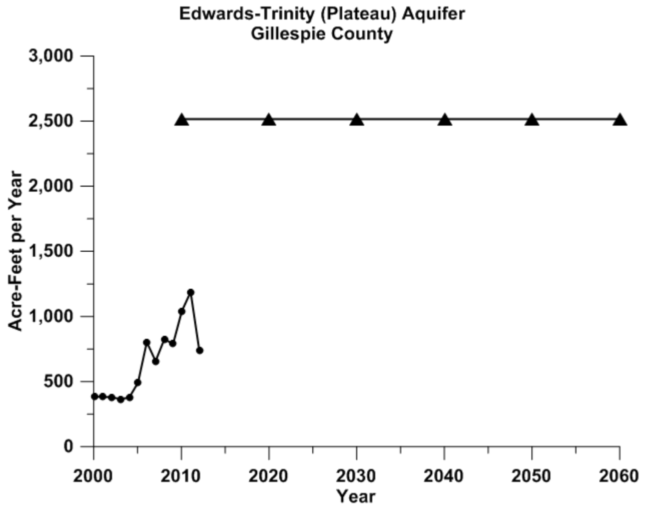
4,000
2,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Edwards-Trinity (Plateau) Aquifer
Gillespie County
Acre-Feet per Year
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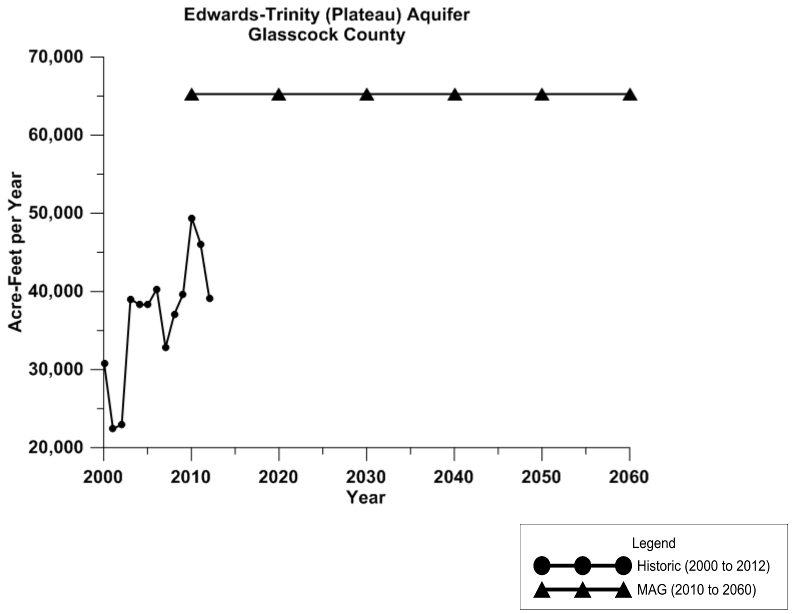
2,000
1,500
1,000
500
0
2000
2010
2020
2030
2040
2050
2060
Year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Glasscock County
Acre-Feet per Year
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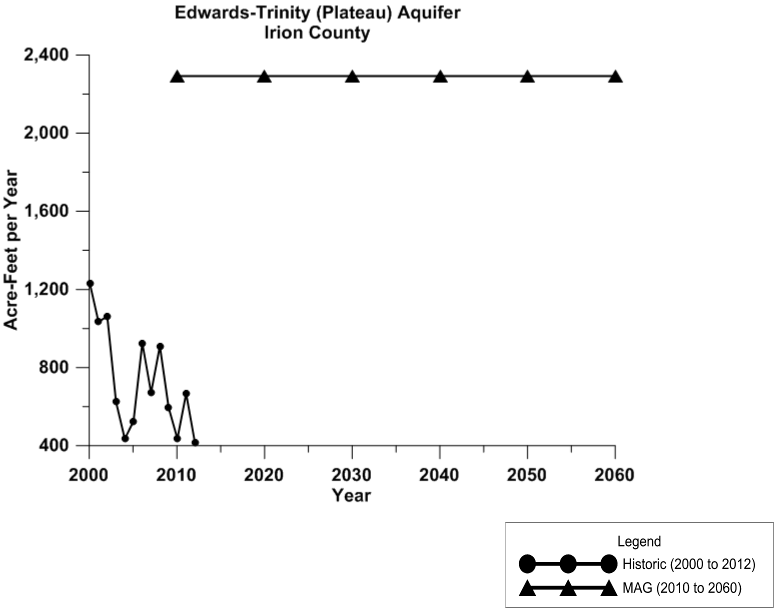
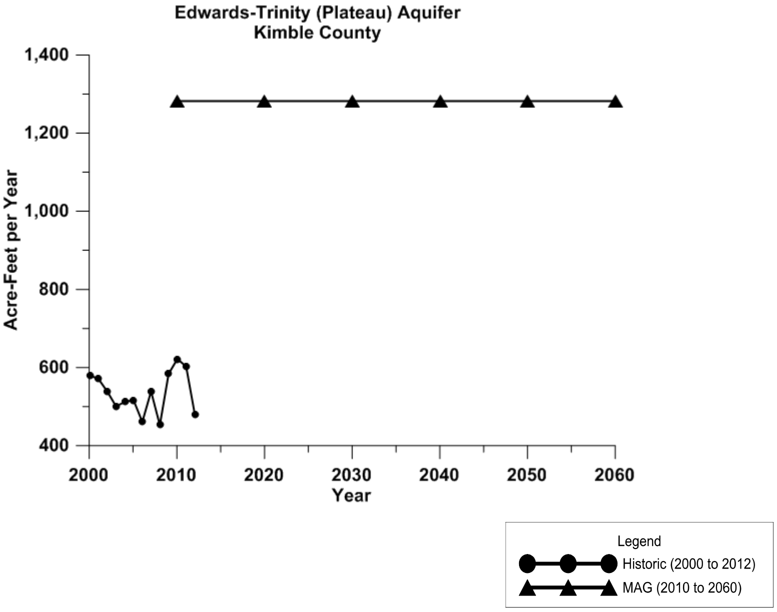
60,000
50,000
40,000
30,000
20,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)



Edwards-Trinity (Plateau) Aquifer
Irion County
2,400
2,000
1,600
1,200
800
400
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)



Edwards-Trinity (Plateau) Aquifer
Kimble County
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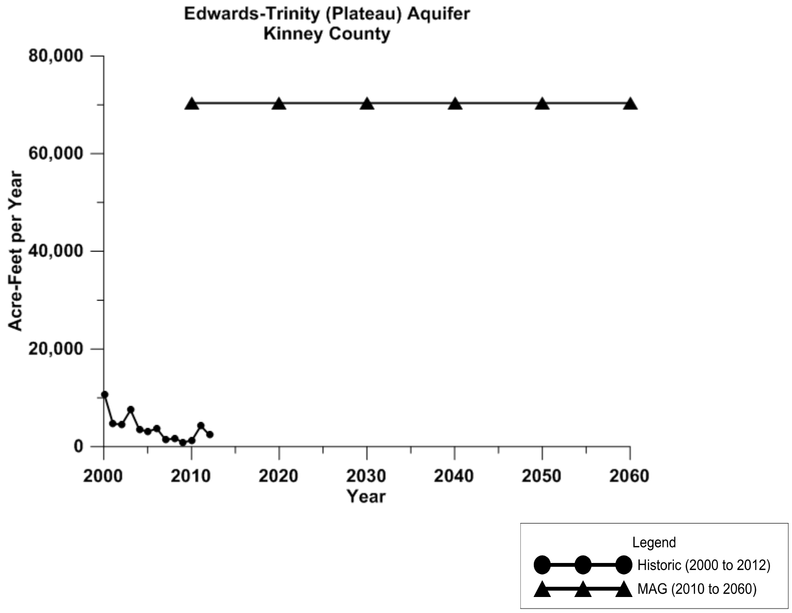
1,200
1,000
800
600
400
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)



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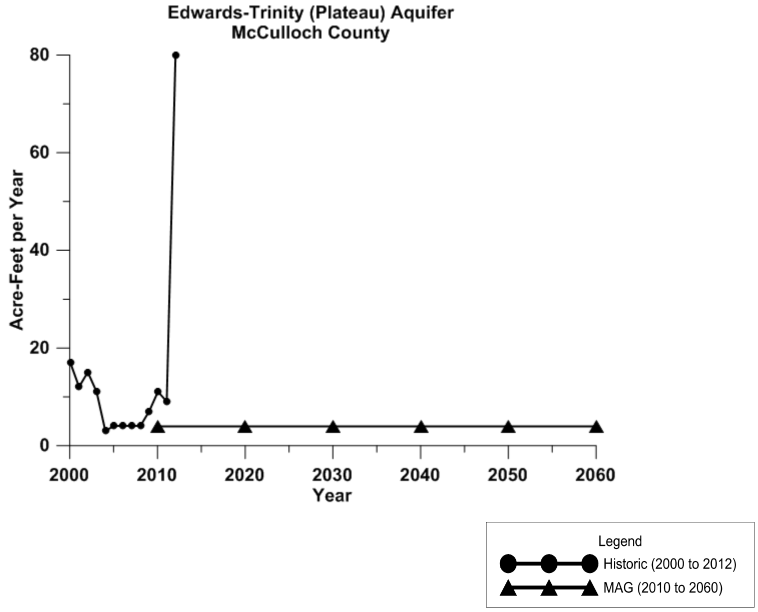
Kinney County



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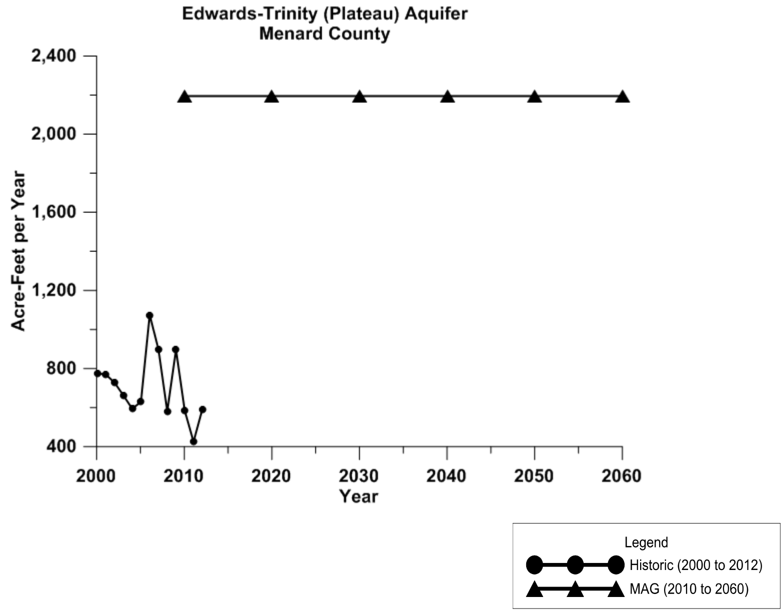
McCulloch County



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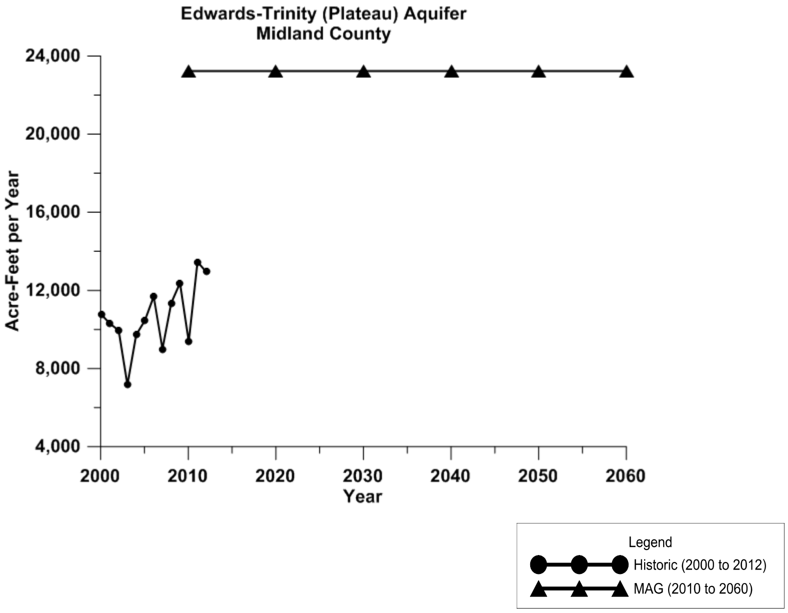

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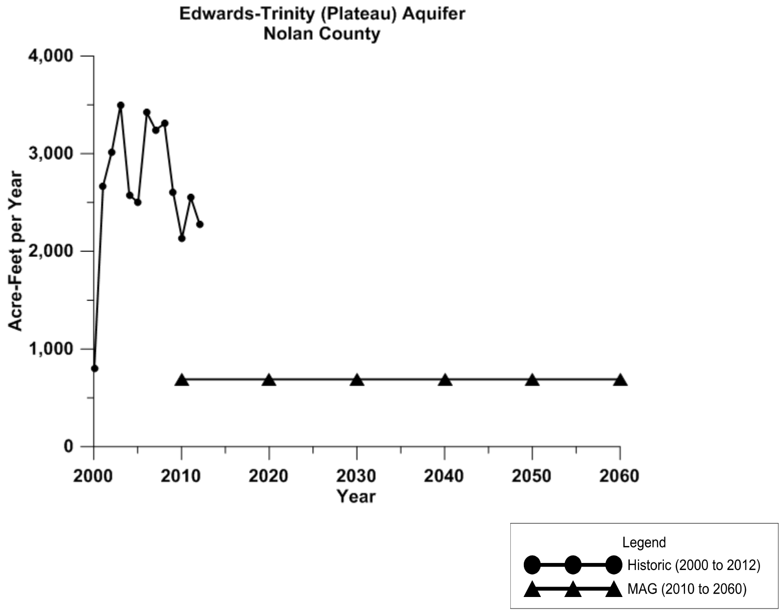
Midland County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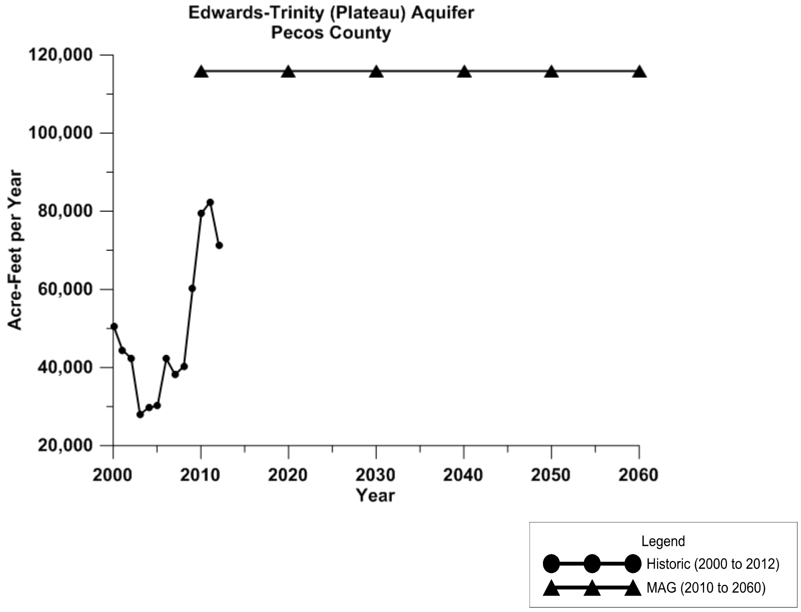
Nolan County
Acre-Feet per Year
4,000
3,000
2,000
1,000
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Edwards-Trinity (Plateau) Aquifer
Pecos County
Acre-Feet per Year
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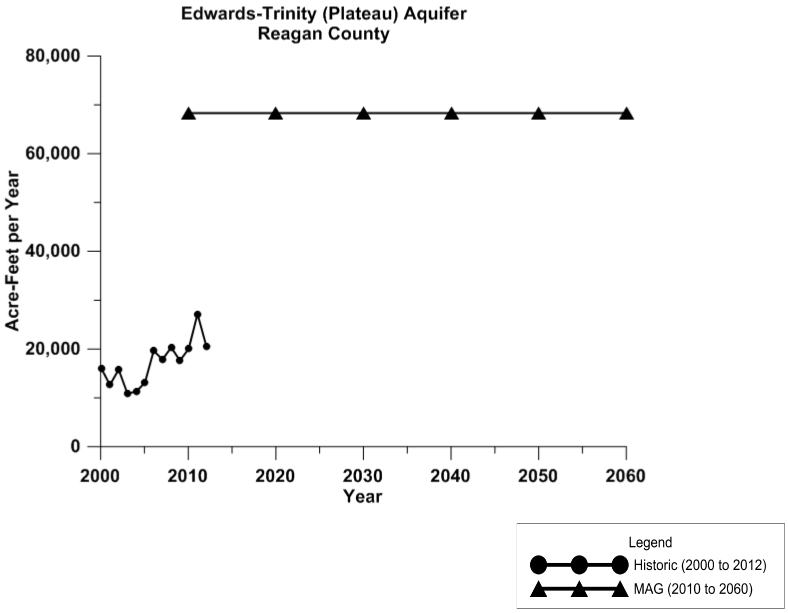
100,000
80,000
60,000
40,000
20,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)



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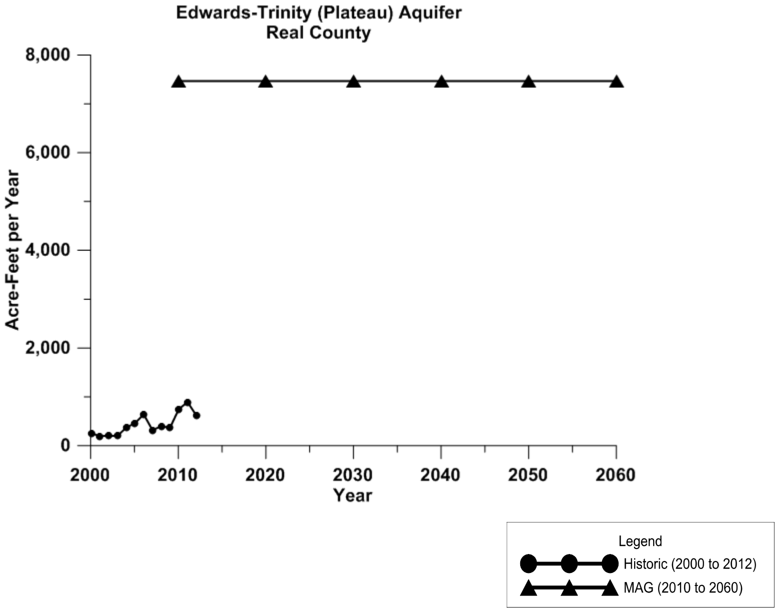
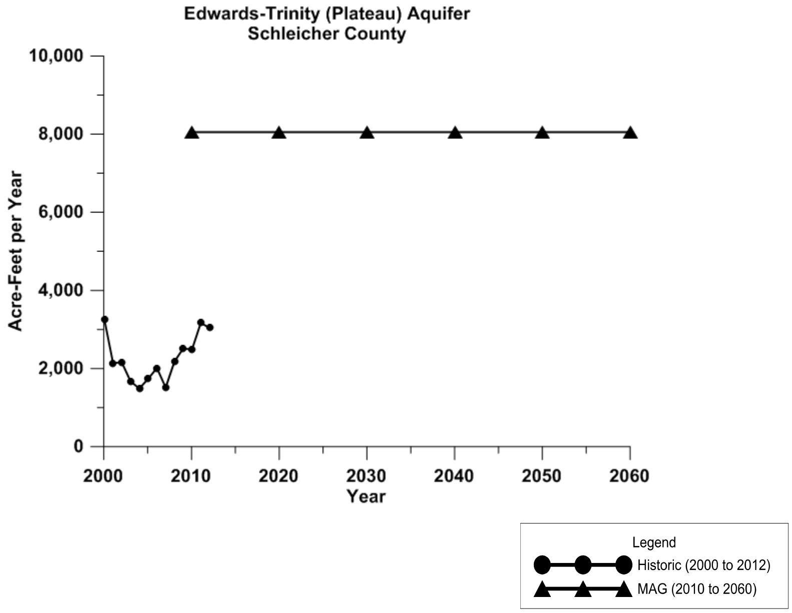
Reagan County



Edwards-Trinity (Plateau) Aquifer
Real County


Edwards-Trinity (Plateau) Aquifer
Schleicher County
10,000
8,000
6,000
4,000
2,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
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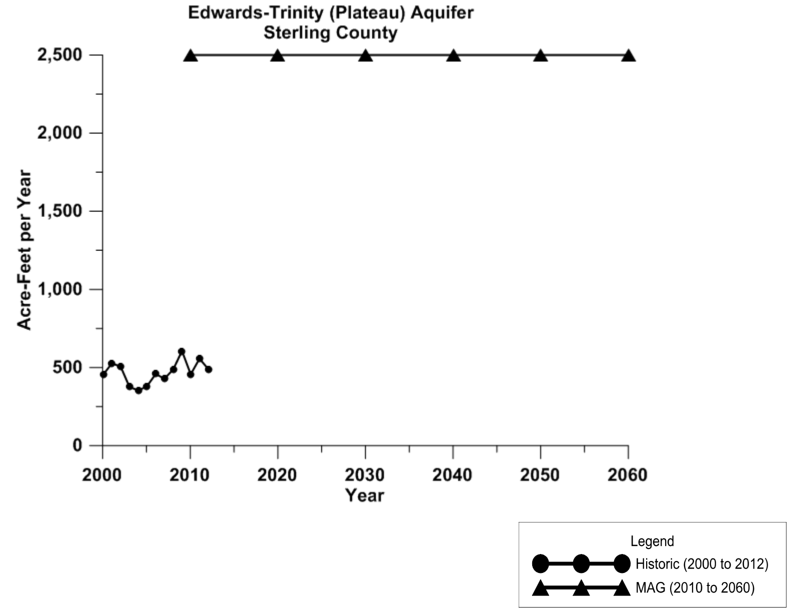
Historic (2000 to 2012)
MAG (2010 to 2060)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Sterling County
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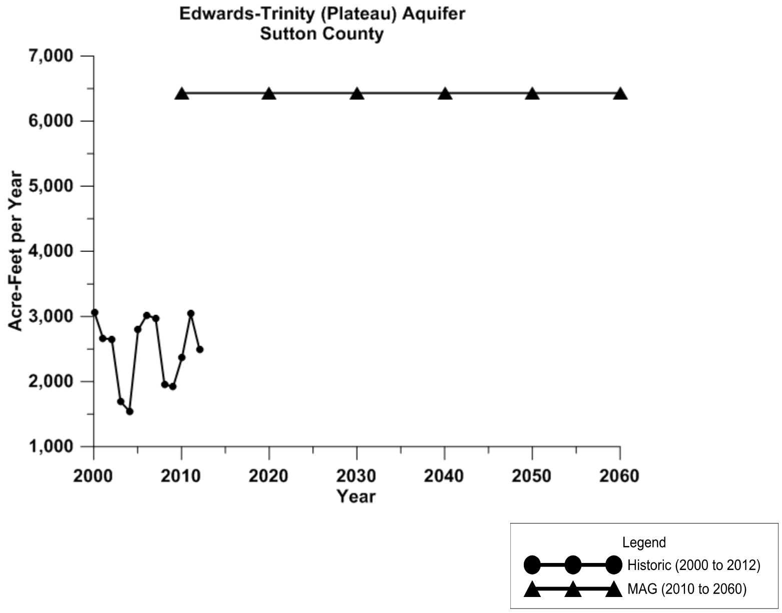
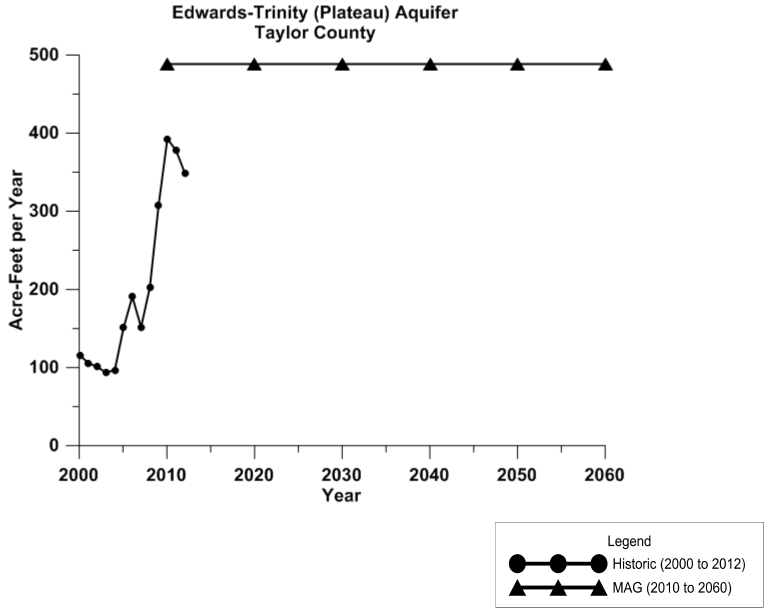
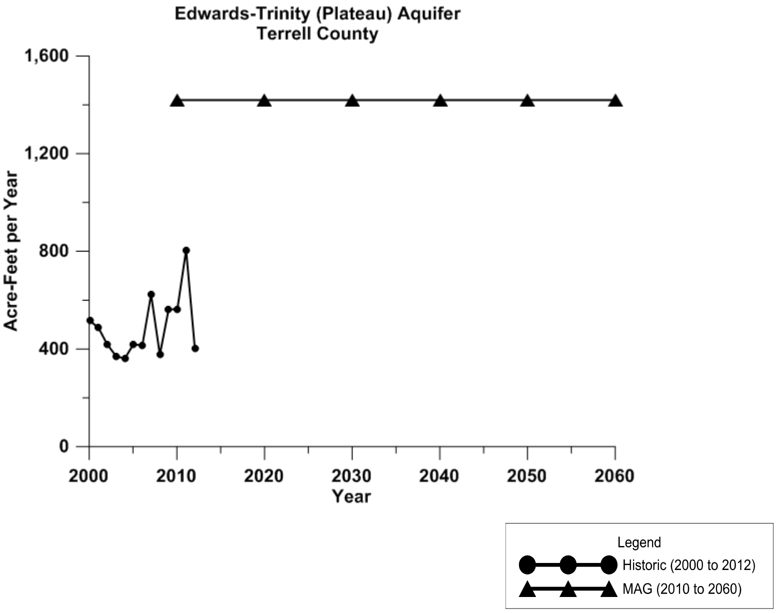
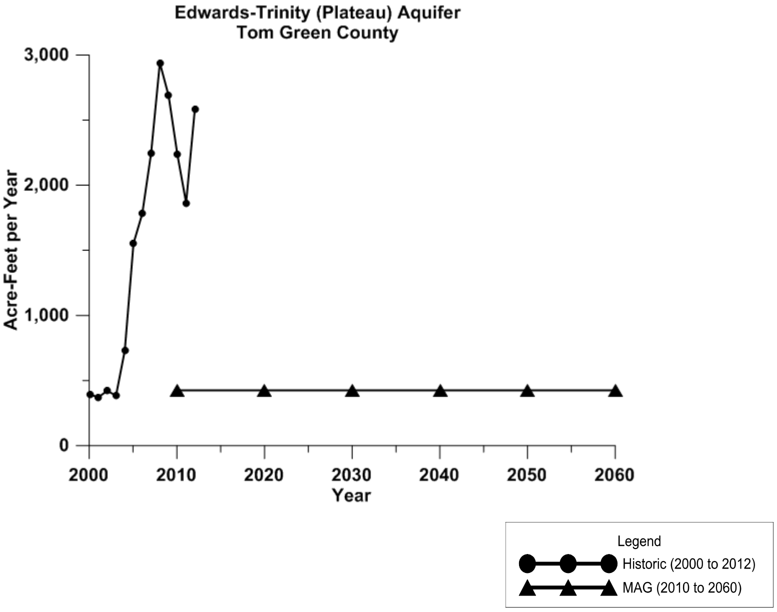
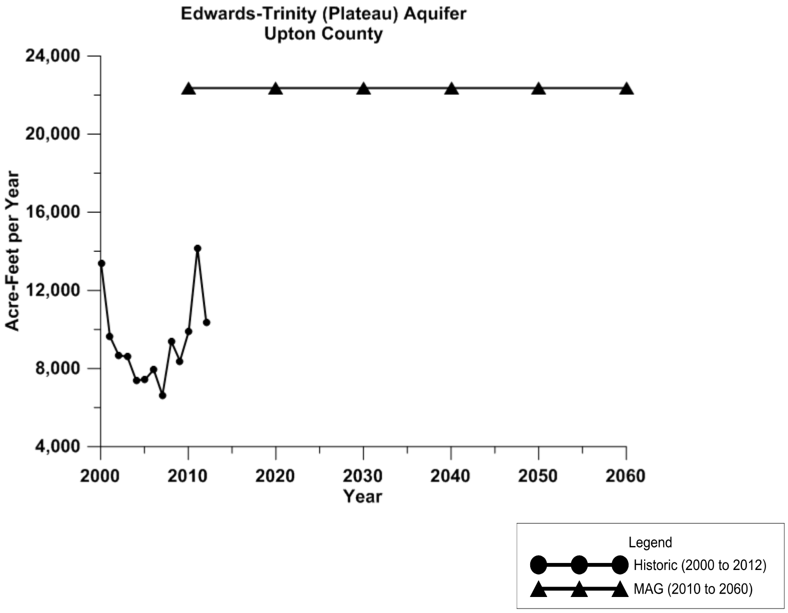
2,000
1,500
1,000
500
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

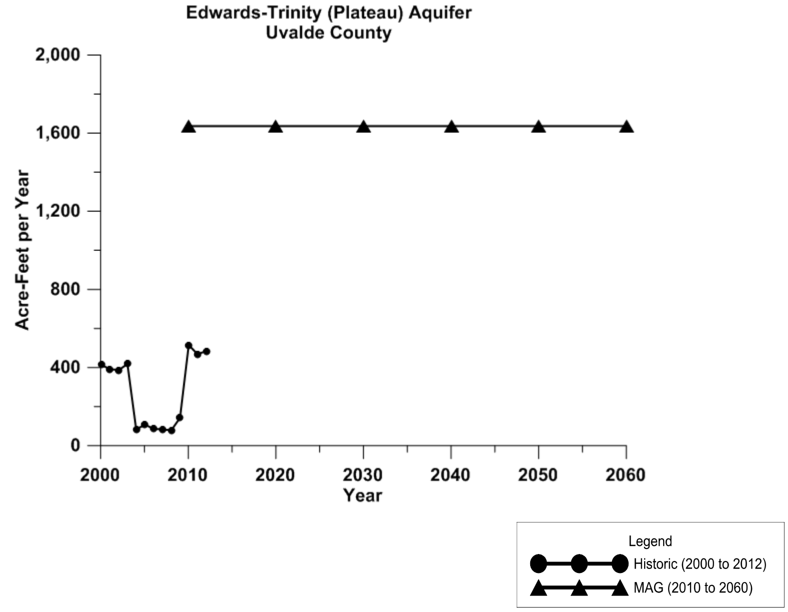

Edwards-Trinity (Plateau) Aquifer
Sutton County
Acre-Feet per Year
7,000
6,000
5,000
4,000
3,000
2,000
1,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

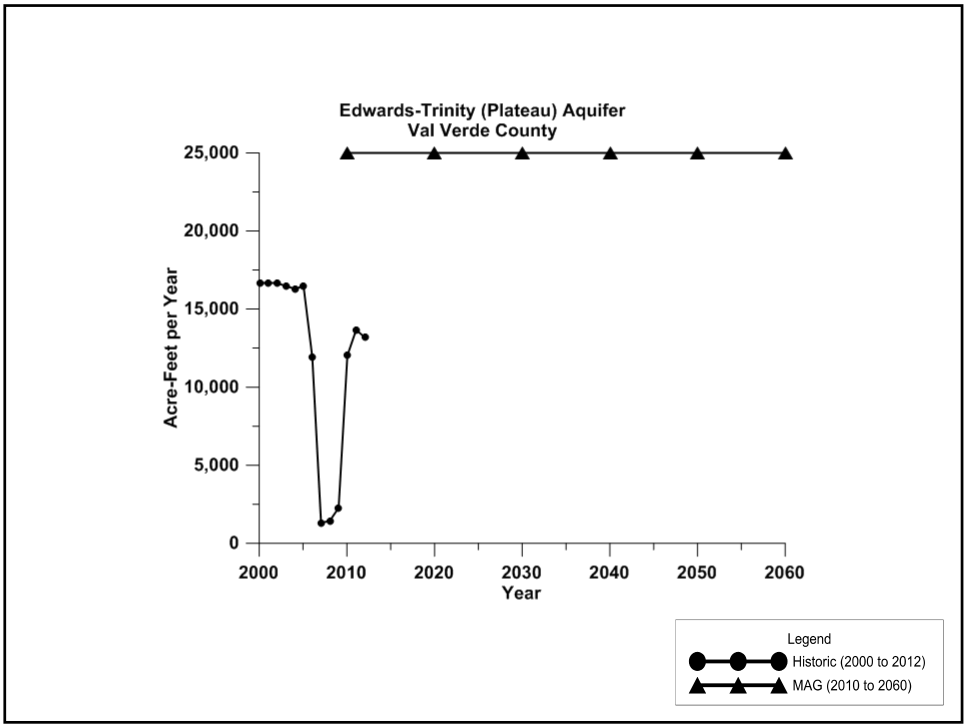

Edwards-Trinity (Plateau) Aquifer
Taylor County
Acre-Feet per Year
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

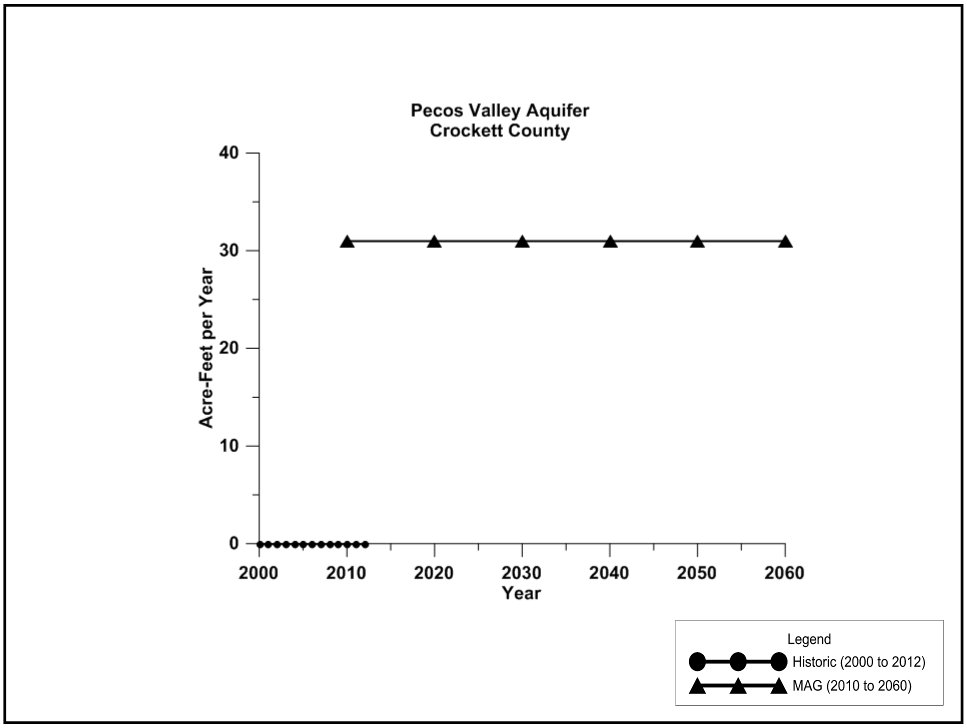

Edwards-Trinity (Plateau) Aquifer
Terrell County
Acre-Feet per Year
1,600
1,200
800
400
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

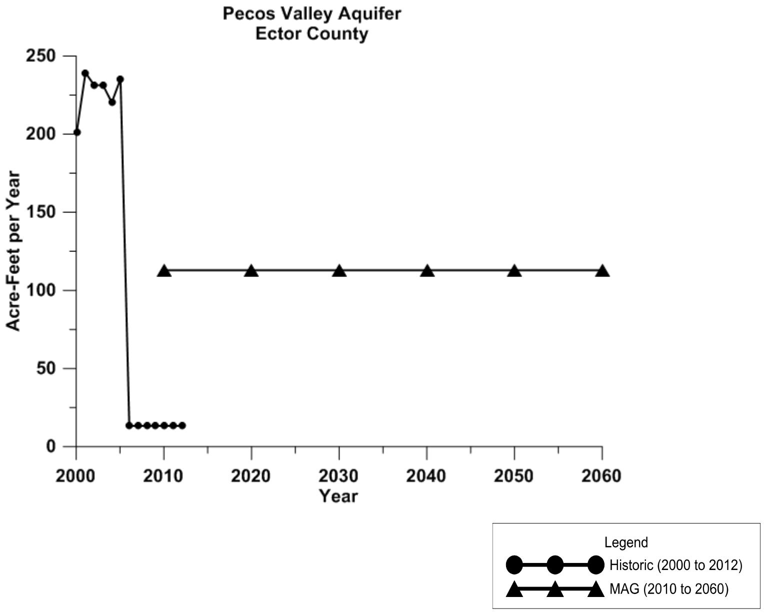

Edwards-Trinity (Plateau) Aquifer
Tom Green County
Acre-Feet per Year
3,000
2,000
1,000
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

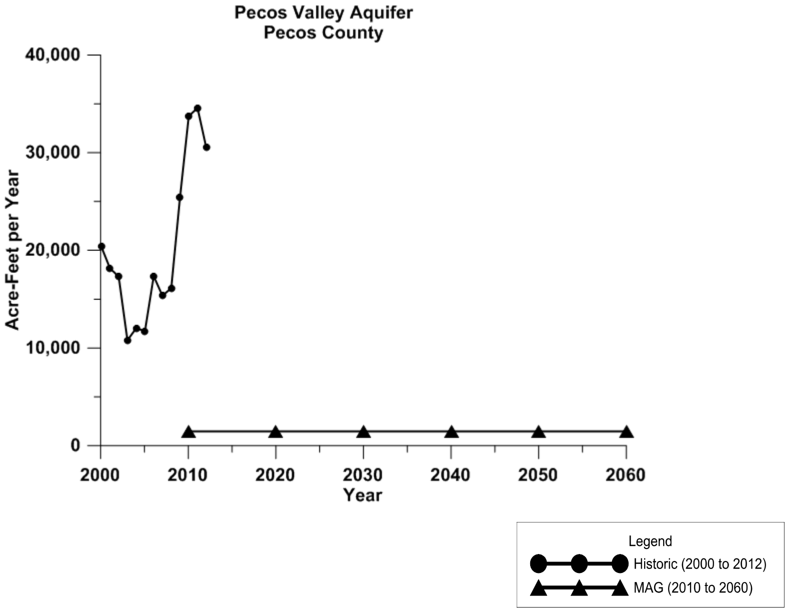

Edwards-Trinity (Plateau) Aquifer
Upton County
Acre-Feet per Year
24,000
20,000
16,000
12,000
8,000
4,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

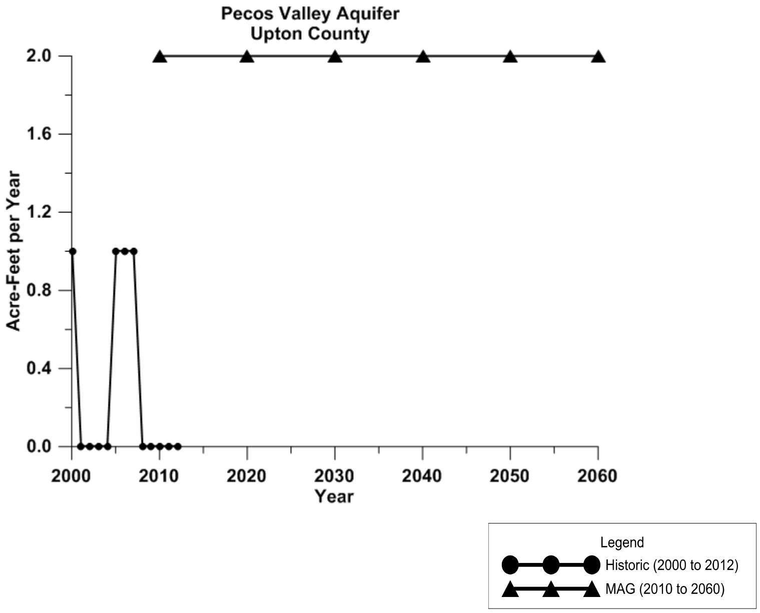

Edwards-Trinity (Plateau) Aquifer
Uvalde County
Acre-Feet per Year
2,000
1,600
1,200
800
400
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

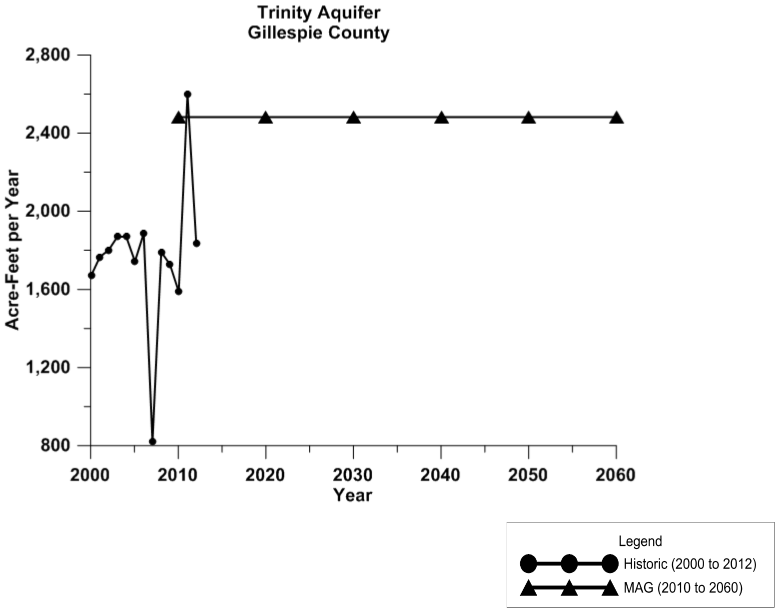

Edwards-Trinity (Plateau) Aquifer
Val Verde County
25,000
20,000
15,000
10,000
5,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

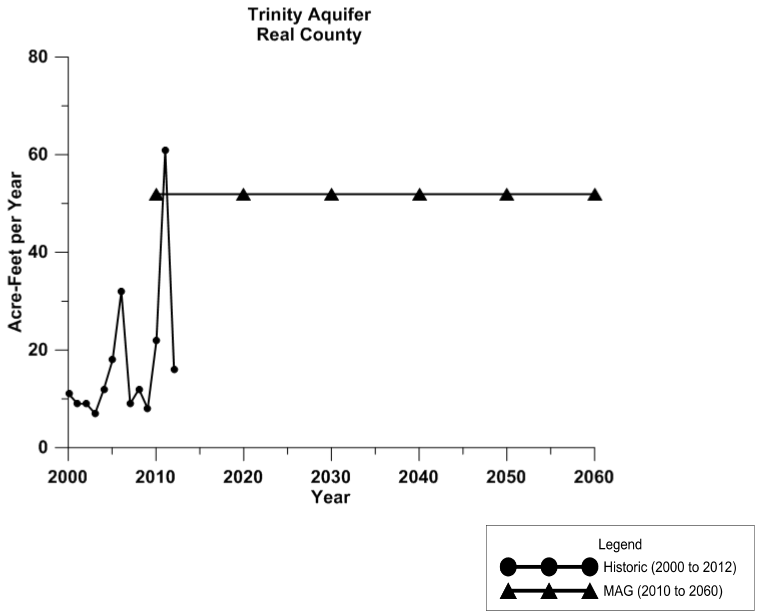

Pecos Valley Aquifer
Crockett County
40
30
20
10
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Pecos Valley Aquifer
Ector County
Acre-Feet per Year
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Pecos Valley Aquifer
Pecos County
Acre-Feet per Year
40,000
30,000
20,000
10,000
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Pecos Valley Aquifer
Upton County
Acre-Feet per Year
2.0
1.6
1.2
0.8
0.4
0.0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Trinity Aquifer
Gillespie County
Acre-Feet per Year
2,800
2,400
2,000
1,600
1,200
800
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


Trinity Aquifer
Real County
Acre-Feet per Year
80
60
40
20
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

Appendix D

Region F Socioeconomic Impact Reports from TWDB

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

Prepared in Support of the 2021 Region F Regional Water Plan

Dr. John R. Ellis
Water Use, Projections, & Planning Division
Texas Water Development Board

November 2021

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Executive Summary

Evaluating the social and economic impacts of not meeting identified water needs is a required analysis in the regional water planning process. The Texas Water Development Board (TWDB) estimates these impacts for regional water planning groups (RWPGs) and summarizes the impacts in the state water plan. The analysis presented is for the Region F Regional Water Planning Group (Region F).

Based on projected water demands and existing water supplies, Region F identified water needs (potential shortages) that could occur within its region under a repeat of the drought of record for six water use categories (irrigation, livestock, manufacturing, mining, municipal and steam-electric power). The TWDB then estimated the annual socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

This analysis was performed using an economic impact modeling software package, IMPLAN (Impact for Planning Analysis), as well as other economic analysis techniques, and represents a snapshot of socioeconomic impacts that may occur during a single year repeat of the drought of record with the further caveat that no mitigation strategies are implemented. Decade specific impact estimates assume that growth occurs, and future shocks are imposed on an economy at 10-year intervals. The estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

For regional economic impacts, income losses and job losses are estimated within each planning decade (2020 through 2070). The income losses represent an approximation of gross domestic product (GDP) that would be foregone if water needs are not met.

The analysis also provides estimates of financial transfer impacts, which include tax losses (state, local, and utility tax collections); water trucking costs; and utility revenue losses. In addition, social impacts are estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

IMPLAN data reported that Region F generated more than $50 billion in gross domestic product (GDP) (2018 dollars) and supported more than 424,000 jobs in 2016. The Region F estimated total population was approximately 686,000 in 2016.

It is estimated that not meeting the identified water needs in Region F would result in an annually combined lost income impact of approximately $19.6 billion in 2020 and $6.4 billion in 2070 (Table ES-1). It is also estimated that the region would lose approximately 98,000 jobs in 2020 and 39,000 in 2070.

All impact estimates are in year 2018 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from TWDB annual water use estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and the Texas Municipal League.

Table ES-1 Region F socioeconomic impact summary

Regional Economic Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Income losses ($ millions)*	$19,624	$19,720	$17,058	$13,443	$7,750	$6,356
Job losses	98,208	100,186	88,685	71,444	43,995	38,833
Financial Transfer Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Tax losses on production and imports ($ millions)*	$2,644	$2,647	$2,266	$1,749	$937	$725
Water trucking costs ($ millions)*	$29	$29	$29	$30	$31	$32
Utility revenue losses ($ millions)*	$56	$82	$111	$139	$172	$207
Utility tax revenue losses ($ millions)*	$1	$1	$2	$3	$3	$4
Social Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Consumer surplus losses ($ millions)*	$87	$93	$149	$183	$227	$286
Population losses	18,031	18,394	16,283	13,117	8,078	7,130
School enrollment losses	3,449	3,518	3,115	2,509	1,545	1,364

* Year 2018 dollars, rounded**.** Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

1 Introduction

Water shortages during a repeat of the drought of record would likely curtail or eliminate certain economic activity in businesses and industries that rely heavily on water. Insufficient water supplies could not only have an immediate and real impact on the regional economy in the short term, but they could also adversely and chronically affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages could disrupt activity in homes, schools and government, and could adversely affect public health and safety. For these reasons, it is important to evaluate and understand how water supply shortages during drought could impact communities throughout the state.

As part of the regional water planning process, RWPGs must evaluate the social and economic impacts of not meeting water needs (31 Texas Administrative Code §357.33 (c)). Due to the complexity of the analysis and limited resources of the planning groups, the TWDB has historically performed this analysis for the RWPGs upon their request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of Region F, and those efforts for this region as well as the other 15 regions allow consistency and a degree of comparability in the approach.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 provides a snapshot of the region's economy and summarizes the identified water needs in each water use category, which were calculated based on the RWPG's water supply and demand established during the regional water planning process. Section 2 defines each of ten impact assessment measures used in this analysis. Section 3 describes the methodology for the impact assessment and the approaches and assumptions specific to each water use category (i.e., irrigation, livestock, manufacturing, mining, municipal, and steam-electric power). Section 4 presents the impact estimates for each water use category with results summarized for the region as a whole. Appendix A presents a further breakdown of the socioeconomic impacts by county.

1.1 Regional Economic Summary

The Region F Regional Water Planning Area generated more than $50 billion in GDP (2018 dollars) and supported roughly 424,000 jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for 3 percent of the state's total GDP of 1.73 trillion dollars for the year based on IMPLAN. Table 1-1 lists all economic sectors ranked by the total value-added to the economy in Region F. The mining sector (including oil and gas extraction) generated close to 40 percent of the region's total value-added and was also a significant source of tax revenue. The top employers in the region were in the mining, public administration, and retail trade sectors. Region F's estimated total population was roughly 686,000 in 2016, approximately 2.5 percent of the state's total.

This represents a snapshot of the regional economy as a whole, and it is important to note that not all economic sectors were included in the TWDB socioeconomic impact analysis. Data considerations prompted use of only the more water-intensive sectors within the economy because damage estimates could only be calculated for those economic sectors which had both reliable income and water use estimates.

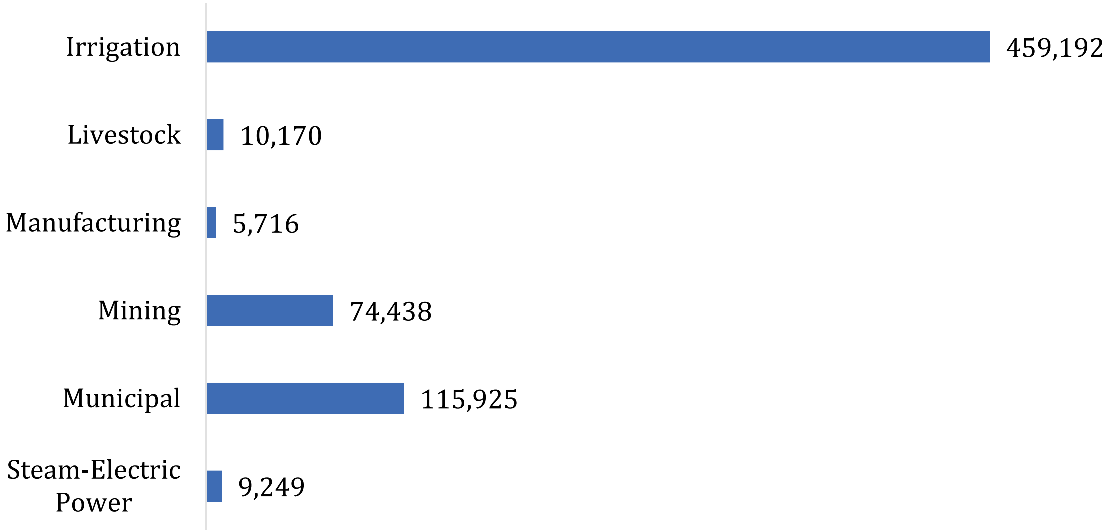
Table 1-1 Region F regional economy by economic sector*

Economic sector	Value-added ($ millions)	Tax ($ millions)	Jobs
Mining, Quarrying, and Oil and Gas Extraction	$19,711.6	$2,458.8	67,722
Public Administration	$4,274.8	$(23.0)	53,420
Real Estate and Rental and Leasing	$3,831.9	$556.6	14,285
Wholesale Trade	$3,199.8	$496.7	16,901
Manufacturing	$3,091.3	$95.4	18,614
Construction	$2,650.8	$33.3	30,015
Retail Trade	$2,203.5	$542.9	39,778
Health Care and Social Assistance	$1,743.9	$25.6	30,056
Finance and Insurance	$1,513.5	$66.2	16,366
Utilities	$1,350.0	$174.2	2,089
Accommodation and Food Services	$1,346.2	$196.9	32,131
Professional, Scientific, and Technical Services	$1,256.2	$37.8	18,165
Other Services (except Public Administration)	$1,229.4	$124.4	21,836
Transportation and Warehousing	$1,011.8	$97.2	15,793
Administrative and Support and Waste Management and Remediation Services	$719.3	$26.4	14,728
Information	$695.5	$208.0	3,546
Agriculture, Forestry, Fishing and Hunting	$412.7	$15.9	16,847
Management of Companies and Enterprises	$394.9	$9.5	3,372
Arts, Entertainment, and Recreation	$187.6	$33.8	5,317
Educational Services	$92.6	$5.4	3,175
Grand Total	**$50,917.2**	**$5,182.1**	**424,156**

*Source: 2016 IMPLAN for 536 sectors aggregated by 2-digit NAICS (North American Industry Classification System)

While the mining sector led the region in economic output, the majority (68 percent) of water use in 2016 occurred in irrigated agriculture. Notably, more than 44 percent of the state's mining water use occurred within Region F. Figure 1-1 illustrates Region F's breakdown of the 2016 water use estimates by TWDB water use category.

Figure 1-1 Region F 2016 water use estimates by water use category (in acre-feet)



Source: TWDB Annual Water Use Estimates (all values in acre-feet)

1.2 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for water user groups (WUG) in Region F with input from the planning group. WUG-level demand projections were established for utilities that provide more than 100 acre-feet of annual water supply, combined rural areas (designated as county-other), and county-wide water demand projections for five non-municipal categories (irrigation, livestock, manufacturing, mining and steam-electric power). The RWPG then compared demands to the existing water supplies of each WUG to determine potential shortages, or needs, by decade.

Table 1-2 summarizes the region's identified water needs in the event of a repeat of the drought of record. Demand management, such as conservation, or the development of new infrastructure to increase supplies, are water management strategies that may be recommended by the planning group to address those needs. This analysis assumes that no strategies are implemented, and that the identified needs correspond to future water shortages. Note that projected water needs generally increase over time, primarily due to anticipated population growth, economic growth, or declining supplies. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are also presented in aggregate in Table 1-2. Projected needs for individual water user groups within the aggregate can vary greatly and may reach 100% for a given WUG and water use category. A detailed summary of water needs by WUG and county appears in Chapter 4 of the 2021 Region F Regional Water Plan.

Table 1-2 Regional water needs summary by water use category

Water Use Category		2020	2030	2040	2050	2060	2070
Irrigation	water needs (acre-feet per year)	13,528	17,957	18,618	19,676	22,157	24,740
	% of the category's total water demand	3%	4%	4%	4%	5%	5%
Livestock	water needs (acre-feet per year)	9	17	25	39	50	60
	% of the category's total water demand	0%	0%	0%	0%	0%	1%
Manufacturing	water needs (acre-feet per year)	1,137	1,226	1,269	1,461	1,664	1,851
	% of the category's total water demand	10%	10%	10%	12%	13%	15%
Mining	water needs (acre-feet per year)	23,009	22,916	19,702	15,080	7,993	5,880
	% of the category's total water demand	21%	21%	22%	23%	17%	17%
Municipal*	water needs (acre-feet per year)	16,030	24,159	33,381	42,081	52,530	63,829
	% of the category's total water demand	12%	16%	21%	25%	29%	34%
Steam-electric power	water needs (acre-feet per year)	12,746	12,793	12,850	12,945	13,042	13,129
	% of the category's total water demand	70%	71%	71%	72%	72%	73%
Total water needs (acre-feet per year)		**66,459**	**79,068**	**85,845**	**91,282**	**97,436**	**109,489**

* Municipal category consists of residential and non-residential (commercial and institutional) subcategories.

2 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic and social impacts of potential water shortages during a repeat of the drought of record. Consistent with previous water plans, ten impact measures were estimated and are described in Table 2-1.

Table 2-1 Socioeconomic impact analysis measures

Regional economic impacts	**Description**
Income losses - value-added	The value of output less the value of intermediate consumption; it is a measure of the contribution to gross domestic product (GDP) made by an individual producer, industry, sector, or group of sectors within a year. Value-added measures used in this report have been adjusted to include the direct, indirect, and induced monetary impacts on the region.
Income losses - electrical power purchase costs	Proxy for income loss in the form of additional costs of power as a result of impacts of water shortages.
Job losses	Number of part-time and full-time jobs lost due to the shortage. These values have been adjusted to include the direct, indirect, and induced employment impacts on the region.
Financial transfer impacts	**Description**
Tax losses on production and imports	Sales and excise taxes not collected due to the shortage, in addition to customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies. These values have been adjusted to include the direct, indirect and induced tax impacts on the region.
Water trucking costs	Estimated cost of shipping potable water.
Utility revenue losses	Foregone utility income due to not selling as much water.
Utility tax revenue losses	Foregone miscellaneous gross receipts tax collections.
Social impacts	**Description**
Consumer surplus losses	A welfare measure of the lost value to consumers accompanying restricted water use.
Population losses	Population losses accompanying job losses.
School enrollment losses	School enrollment losses (K-12) accompanying job losses.

2.1 Regional Economic Impacts

The two key measures used to assess regional economic impacts are income losses and job losses. The income losses presented consist of the sum of value-added losses and the additional purchase costs of electrical power.

Income Losses - Value-added Losses

Value-added is the value of total output less the value of the intermediate inputs also used in the production of the final product. Value-added is similar to GDP, a familiar measure of the productivity of an economy. The loss of value-added due to water shortages is estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region. The indirect and induced effects are measures of reduced income as well as reduced employee spending for those input sectors which provide resources to the water shortage impacted production sectors.

Income Losses - Electric Power Purchase Costs

The electrical power grid and market within the state is a complex interconnected system. The industry response to water shortages, and the resulting impact on the region, are not easily modeled using traditional input/output impact analysis and the IMPLAN model. Adverse impacts on the region will occur and are represented in this analysis by estimated additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employs additional power purchase costs as a proxy for the value-added impacts for the steam-electric power water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it is assumed that power companies with insufficient water will be forced to purchase power on the electrical market at a projected higher rate of 5.60 cents per kilowatt hour. This rate is based upon the average day-ahead market purchase price of electricity in Texas that occurred during the recent drought period in 2011. This price is assumed to be comparable to those prices which would prevail in the event of another drought of record.

Job Losses

The number of jobs lost due to the economic impact is estimated using IMPLAN output associated with each TWDB water use category. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates are not calculated for the steam-electric power category.

2.2 Financial Transfer Impacts

Several impact measures evaluated in this analysis are presented to provide additional detail concerning potential impacts on a portion of the economy or government. These financial transfer impact measures include lost tax collections (on production and imports), trucking costs for imported water, declines in utility revenues, and declines in utility tax revenue collected by the state. These measures are not solely adverse, with some having both positive and negative impacts. For example, cities and residents would suffer if forced to pay large costs for trucking in potable water. Trucking firms, conversely, would benefit from the transaction. Additional detail for each of these measures follows.

Tax Losses on Production and Imports

Reduced production of goods and services accompanying water shortages adversely impacts the collection of taxes by state and local government. The regional IMPLAN model is used to estimate reduced tax collections associated with the reduced output in the economy. Impact estimates for this measure include the direct, indirect, and induced impacts for the affected sectors.

Water Trucking Costs

In instances where water shortages for a municipal water user group are estimated by RWPGs to exceed 80 percent of water demands, it is assumed that water would need to be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed, maximum of $35,000[1] per acre-foot of water applied as an economic cost. This water trucking cost was utilized for both the residential and non-residential portions of municipal water needs.

Utility Revenue Losses

Lost utility income is calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates are obtained from utility-specific pricing data provided by the Texas Municipal League, where available, for both water and wastewater. These water rates are applied to the potential water shortage to estimate forgone utility revenue as water providers sold less water during the drought due to restricted supplies.

Utility Tax Losses

Foregone utility tax losses include estimates of forgone miscellaneous gross receipts taxes. Reduced water sales reduce the amount of utility tax that would be collected by the State of Texas for water and wastewater service sales.

2.3 Social Impacts

Consumer Surplus Losses for Municipal Water Users

Consumer surplus loss is a measure of impact to the wellbeing of municipal water users when their water use is restricted. Consumer surplus is the difference between how much a consumer is willing and able to pay for a commodity (i.e., water) and how much they actually have to pay. The

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[1] Based on staff survey of water hauling firms and historical data concerning transport costs for potable water in the recent drought in California for this estimate. There are many factors and variables that would determine actual water trucking costs including distance to, cost of water, and length of that drought.

difference is a benefit to the consumer's wellbeing since they do not have to pay as much for the commodity as they would be willing to pay. Consumer surplus may also be viewed as an estimate of how much consumers would be willing to pay to keep the original quantity of water which they used prior to the drought. Lost consumer surplus estimates within this analysis only apply to the residential portion of municipal demand, with estimates being made for reduced outdoor and indoor residential use. Lost consumer surplus estimates varied widely by location and degree of water shortage.

Population and School Enrollment Losses

Population loss due to water shortages, as well as the associated decline in school enrollment, are based upon the job loss estimates discussed in Section 2.1. A simplified ratio of job and net population losses are calculated for the state as a whole based on a recent study of how job layoffs impact the labor market population.[2] For every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses are estimated as a proportion of the population lost based upon public school enrollment data from the Texas Education Agency concerning the age K-12 population within the state (approximately 19%).

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[2] Foote, Andrew, Grosz, Michel, Stevens, Ann. "Locate Your Nearest Exit: Mass Layoffs and Local Labor Market Response." University of California, Davis. April 2015, http://paa2015.princeton.edu/papers/150194. The study utilized Bureau of Labor Statistics data regarding layoffs between 1996 and 2013, as well as Internal Revenue Service data regarding migration, to model the change in the population as the result of a job layoff event. The study found that layoffs impact both out-migration and in-migration into a region, and that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county.

3 Socioeconomic Impact Assessment Methodology

This portion of the report provides a summary of the methodology used to estimate the potential economic impacts of future water shortages. The general approach employed in the analysis was to obtain estimates for income and job losses on the smallest geographic level that the available data would support, tie those values to their accompanying historic water use estimate, and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts are based on the overall composition of the economy divided into many underlying economic sectors. Sectors in this analysis refer to one or more of the 536 specific production sectors of the economy designated within IMPLAN, the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 330 of these sectors, with the focus on the more water-intensive production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple, related IMPLAN economic sectors.

3.1 Analysis Context

The context of this socioeconomic impact analysis involves situations where there are physical shortages of groundwater or surface water due to a recurrence of drought of record conditions. Anticipated shortages for specific water users may be nonexistent in earlier decades of the planning horizon, yet population growth or greater industrial, agricultural or other sector demands in later decades may result in greater overall demand, exceeding the existing supplies. Estimated socioeconomic impacts measure what would happen if water user groups experience water shortages for a period of one year. Actual socioeconomic impacts would likely become larger as drought of record conditions persist for periods greater than a single year.

3.2 IMPLAN Model and Data

Input-Output analysis using the IMPLAN software package was the primary means of estimating the value-added, jobs, and tax related impact measures. This analysis employed regional level models to determine key economic impacts. IMPLAN is an economic impact model, originally developed by the U.S. Forestry Service in the 1970's to model economic activity at varying geographic levels. The model is currently maintained by the Minnesota IMPLAN Group (MIG Inc.) which collects and sells county and state specific data and software. The year 2016 version of IMPLAN, employing data for all 254 Texas counties, was used to provide estimates of value-added, jobs, and taxes on production for the economic sectors associated with the water user groups examined in the study. IMPLAN uses 536 sector-specific Industry Codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories (irrigation, livestock, manufacturing, mining, and municipal). Estimates of value-added for a water use category were obtained by summing value-added estimates across the relevant IMPLAN sectors associated with that water use category. These calculations were also performed for job losses as well as tax losses on production and imports.

The adjusted value-added estimates used as an income measure in this analysis, as well as the job and tax estimates from IMPLAN, include three components:

- ***Direct effects*** representing the initial change in the industry analyzed;
- ***Indirect effects*** that are changes in inter-industry transactions as supplying industries respond to reduced demands from the directly affected industries; and,
- ***Induced effects*** that reflect changes in local spending that result from reduced household income among employees in the directly and indirectly affected industry sectors.

Input-output models such as IMPLAN only capture backward linkages and do not include forward linkages in the economy.

3.3 Elasticity of Economic Impacts

The economic impact of a water need is based on the size of the water need relative to the total water demand for each water user group. Smaller water shortages, for example, less than 5 percent, are generally anticipated to result in no initial negative economic impact because water users are assumed to have a certain amount of flexibility in dealing with small shortages. As a water shortage intensifies, however, such flexibility lessens and results in actual and increasing economic losses, eventually reaching a representative maximum impact estimate per unit volume of water. To account for these characteristics, an elasticity adjustment function is used to estimate impacts for the income, tax and job loss measures. Figure 3-1 illustrates this general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage reaches the lower bound 'b1' (5 percent in Figure 3-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound reaches the 'b2' level shortage (40 percent in Figure 3-1).

To illustrate this, if the total annual value-added for manufacturing in the region was $2 million and the reported annual volume of water used in that industry is 10,000 acre-feet, the estimated economic measure of the water shortage would be $200 per acre-foot. The economic impact of the shortage would then be estimated using this value-added amount as the maximum impact estimate ($200 per acre-foot) applied to the anticipated shortage volume and then adjusted by the elasticity function. Using the sample elasticity function shown in Figure 3-1, an approximately 22 percent shortage in the livestock category would indicate an economic impact estimate of 50% of the original $200 per acre-foot impact value (i.e., $100 per acre-foot).

Such adjustments are not required in estimating consumer surplus, utility revenue losses, or utility tax losses. Estimates of lost consumer surplus rely on utility-specific demand curves with the lost consumer surplus estimate calculated based on the relative percentage of the utility's water shortage. Estimated changes in population and school enrollment are indirectly related to the elasticity of job losses.

Assumed values for the lower and upper bounds 'b1' and 'b2' vary by water use category and are presented in Table 3-1.

Figure 3-1 Example economic impact elasticity function (as applied to a single water user's shortage)

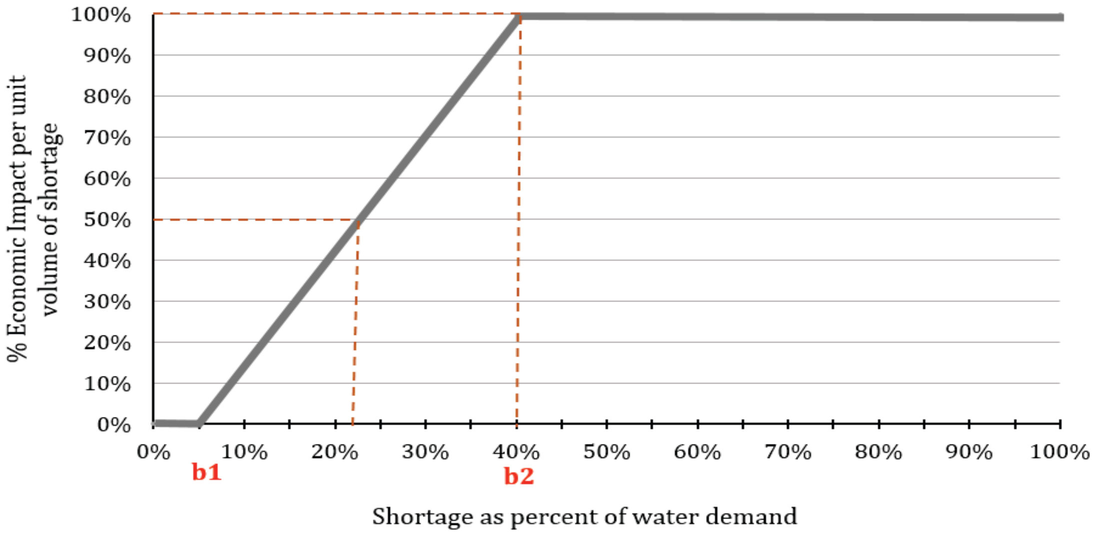


Table 3-1 Economic impact elasticity function lower and upper bounds

Water use category	Lower bound (b1)	Upper bound (b2)
Irrigation	**5%**	**40%**
Livestock	**5%**	**10%**
Manufacturing	**5%**	**40%**
Mining	**5%**	**40%**
Municipal (non-residential water intensive subcategory)	**5%**	**40%**
Steam-electric power	**N/A**	**N/A**

3.4 Analysis Assumptions and Limitations

The modeling of complex systems requires making many assumptions and acknowledging the model's uncertainty and limitations. This is particularly true when attempting to estimate a wide range of socioeconomic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of this methodology include:

1. The foundation for estimating the socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified by RWPGs as part of the

regional water planning process. These needs have some uncertainty associated with them but serve as a reasonable basis for evaluating the potential impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshots for years in which water needs were identified (i.e., 2020, 2030, 2040, 2050, 2060, and 2070). The estimates are independent and distinct "what if" scenarios for each particular year, and water shortages are assumed to be temporary events resulting from a single year recurrence of drought of record conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

3. Input-output models such as IMPLAN rely on a static profile of the structure of the economy as it appears today. This presumes that the relative contributions of all sectors of the economy would remain the same, regardless of changes in technology, availability of limited resources, and other structural changes to the economy that may occur in the future. Changes in water use efficiency will undoubtedly take place in the future as supplies become more stressed. Use of the static IMPLAN structure was a significant assumption and simplification considering the 50-year time period examined in this analysis. To presume an alternative future economic makeup, however, would entail positing many other major assumptions that would very likely generate as much or more error.

4. This is not a form of cost-benefit analysis. That approach to evaluating the economic feasibility of a specific policy or project employs discounting future benefits and costs to their present value dollars using some assumed discount rate. The methodology employed in this effort to estimate the economic impacts of future water shortages did not use any discounting methods to weigh future costs differently through time.

5. All monetary values originally based upon year 2016 IMPLAN and other sources are reported in constant year 2018 dollars to be consistent with the water management strategy requirements in the State Water Plan.

6. IMPLAN based loss estimates (income-value-added, jobs, and taxes on production and imports) are calculated only for those IMPLAN sectors for which the TWDB's Water Use Survey (WUS) data was available and deemed reliable. Every effort is made in the annual WUS effort to capture all relevant firms who are significant water users. Lack of response to the WUS, or omission of relevant firms, impacts the loss estimates.

7. Impacts are annual estimates. The socioeconomic analysis does not reflect the full extent of impacts that might occur as a result of persistent water shortages occurring over an extended duration. The drought of record in most regions of Texas lasted several years.

8. Value-added estimates are the primary estimate of the economic impacts within this report. One may be tempted to add consumer surplus impacts to obtain an estimate of total adverse economic impacts to the region, but the consumer surplus measure represents the change to the wellbeing of households (and other water users), not an actual change in the flow of dollars through the economy. The two measures (value-added and consumer surplus) are both valid impacts but ideally should not be summed.

9. The value-added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects to capture backward linkages in the economy described in Section 2.1. Population and school enrollment losses also indirectly include such effects as they are based on the associated losses in employment. The remaining measures (consumer surplus, utility revenue, utility taxes, additional electrical power purchase costs, and potable water trucking costs), however, do not include any induced or indirect effects.

10. The majority of impacts estimated in this analysis may be more conservative (i.e., smaller) than those that might actually occur under drought of record conditions due to not including impacts in the forward linkages in the economy. Input-output models such as IMPLAN only capture backward linkages on suppliers (including households that supply labor to directly affected industries). While this is a common limitation in this type of economic modeling effort, it is important to note that forward linkages on the industries that use the outputs of the directly affected industries can also be very important. A good example is impacts on livestock operators. Livestock producers tend to suffer substantially during droughts, not because there is not enough water for their stock, but because reductions in available pasture and higher prices for purchased hay have significant economic effects on their operations. Food processors could be in a similar situation if they cannot get the grains or other inputs that they need. These effects are not captured in IMPLAN, resulting in conservative impact estimates.

11. The model does not reflect dynamic economic responses to water shortages as they might occur, nor does the model reflect economic impacts associated with a recovery from a drought of record including:
    a. The likely significant economic rebound to some industries immediately following a drought, such as landscaping;
    b. The cost and time to rebuild liquidated livestock herds (a major capital investment in that industry);
    c. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
    d. Impacts of negative publicity on Texas' ability to attract population and business in the event that it was not able to provide adequate water supplies for the existing economy.

12. Estimates for job losses and the associated population and school enrollment changes may exceed what would actually occur. In practice, firms may be hesitant to lay off employees, even in difficult economic times. Estimates of population and school enrollment changes are based on regional evaluations and therefore do not necessarily reflect what might occur on a statewide basis.

13. **The results must be interpreted carefully. It is the general and relative magnitudes of impacts as well as the changes of these impacts over time that should be the focus rather than the absolute numbers.** Analyses of this type are much better at predicting relative percent differences brought about by a shock to a complex system (i.e., a water shortage) than the precise size of an impact. To illustrate, assuming that the estimated economic impacts of a drought of record on the manufacturing and mining water user categories are $2 and $1 million, respectively, one should be more confident that the economic impacts on manufacturing are twice as large as those on mining and that these impacts will likely be in the millions of dollars. But one should have less confidence that the actual total economic impact experienced would be $3 million.

14. The methodology does not capture "spillover" effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

15. The methodology that the TWDB has developed for estimating the economic impacts of unmet water needs, and the assumptions and models used in the analysis, are specifically designed to estimate potential economic effects at the regional and county levels. Although it may be tempting to add the regional impacts together in an effort to produce a statewide result, the TWDB cautions against that approach for a number of reasons. The IMPLAN modeling (and corresponding economic multipliers) are all derived from regional models – a statewide model of Texas would produce somewhat different multipliers. As noted in point 14 within this section, the regional modeling used by TWDB does not capture spillover losses that could result in other regions from unmet needs in the region analyzed, or potential spillover gains if decreased production in one region leads to increases in production elsewhere. The assumed drought of record may also not occur in every region of Texas at the same time, or to the same degree.

4 Analysis Results

This section presents estimates of potential economic impacts that could reasonably be expected in the event of water shortages associated with a drought of record and if no recommended water management strategies were implemented. Projected economic impacts for the six water use categories (irrigation, livestock, manufacturing, mining, municipal, and steam-electric power) are reported by decade.

4.1 Impacts for Irrigation Water Shortages

Nine of the 32 counties in the region are projected to experience water shortages in the irrigated agriculture water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-1. Note that tax collection impacts were not estimated for this water use category. IMPLAN data indicates a negative tax impact (i.e., increased tax collections) for the associated production sectors, primarily due to past subsidies from the federal government. However, it was not considered realistic to report increasing tax revenues during a drought of record.

Table 4-1 Impacts of water shortages on irrigation in Region F

Impact measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$4	$6	$6	$7	$8	$8
Job losses	98	137	148	170	187	200

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.2 Impacts for Livestock Water Shortages

One of the 32 counties in the region are projected to experience water shortages in the livestock water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-2.

Table 4-2 Impacts of water shortages on livestock in Region F

Impact measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$-	$0	$1	$1	$1	$1
Jobs losses	-	11	26	41	52	63
Tax losses on production and imports ($ millions)*	$-	$0	$0	$0	$0	$0

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.3 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in seven of the 32 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 4-3.

Table 4-3 Impacts of water shortages on manufacturing in Region F

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$457	$535	$576	$684	$821	$982
Job losses	1,241	1,771	2,121	2,927	3,933	5,043
Tax losses on production and Imports ($ millions)*	$28	$33	$35	$42	$50	$60

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.4 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in seven of the 32 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use type appear in Table 4-4.

Table 4-4 Impacts of water shortages on mining in Region F

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$18,617	$18,533	$15,686	$11,894	$5,970	$4,291
Job losses	94,650	94,226	79,758	60,489	30,375	21,842
Tax losses on production and Imports ($ millions)*	$2,604	$2,592	$2,194	$1,663	$834	$599

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.5 Impacts for Municipal Water Shortages

Nineteen of the 32 counties in the region are projected to experience water shortages in the municipal water use category for one or more decades within the planning horizon.

Impact estimates were made for two sub-categories within municipal water use: residential and non-residential. Non-residential municipal water use includes commercial and institutional users, which are further divided into non-water-intensive and water-intensive subsectors including car wash, laundry, hospitality, health care, recreation, and education. Lost consumer surplus estimates were made only for needs in the residential portion of municipal water use. Available IMPLAN and TWDB Water Use Survey data for the non-residential, water-intensive portion of municipal demand allowed these sectors to be included in income, jobs, and tax loss impact estimate.

Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed, maximum cost of $35,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 4-5.

Table 4-5 Impacts of water shortages on municipal water users in Region F

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses[1] ($ millions)*	$121	$220	$362	$426	$515	$637
Job losses[1]	2,219	4,041	6,632	7,817	9,448	11,685
Tax losses on production and imports[1] ($ millions)*	$12	$23	$37	$44	$53	$65
Trucking costs ($ millions)*	$29	$29	$29	$30	$31	$32
Utility revenue losses ($ millions)*	$56	$82	$111	$139	$172	$207
Utility tax revenue losses ($ millions)*	$1	$1	$2	$3	$3	$4

[1] Estimates apply to the water-intensive portion of non-residential municipal water use.

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.6 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in four of the 32 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-6.

Note that estimated economic impacts to steam-electric water users:

- Are reflected as an income loss proxy in the form of estimated additional purchasing costs for power from the electrical grid to replace power that could not be generated due to a shortage;
- Do not include estimates of impacts on jobs. Because of the unique conditions of power generators during drought conditions and lack of relevant data, it was assumed that the industry would retain, perhaps relocating or repurposing, their existing staff in order to manage their ongoing operations through a severe drought.
- Do not presume a decline in tax collections. Associated tax collections, in fact, would likely increase under drought conditions since, historically, the demand for electricity increases during times of drought, thereby increasing taxes collected on the additional sales of power.

Table 4-6 Impacts of water shortages on steam-electric power in Region F

Impacts measure	2020	2030	2040	2050	2060	2070
Income Losses ($ millions)*	$424	$426	$428	$431	$434	$437

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

4.7 Regional Social Impacts

Projected changes in population, based upon several factors (household size, population, and job loss estimates), as well as the accompanying change in school enrollment, were also estimated and are summarized in Table 4-7.

Table 4-7 Region-wide social impacts of water shortages in Region F

Impacts measure	2020	2030	2040	2050	2060	2070
Consumer surplus losses ($ millions)*	$87	$93	$149	$183	$227	$286
Population losses	18,031	18,394	16,283	13,117	8,078	7,130
School enrollment losses	3,449	3,518	3,115	2,509	1,545	1,364

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

Appendix A - County Level Summary of Estimated Economic Impacts for Region F

County level summary of estimated economic impacts of not meeting identified water needs by water use category and decade (in 2018 dollars, rounded). Values are presented only for counties with projected economic impacts for at least one decade.

(* Entries denoted by a dash (-) indicate no estimated economic impact)

		Income losses (Million $)*						Job losses					
County	Water Use Category	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
ANDREWS	IRRIGATION	$0.07	$1.55	$1.98	$2.84	$3.51	$3.86	2	40	51	73	91	100
ANDREWS	LIVESTOCK	-	$0.24	$0.57	$0.88	$1.13	$1.36	-	11	26	41	52	63
ANDREWS	MANUFACTURING	$0.74	$18.63	$54.78	$155.00	$279.33	$417.54	5	117	343	970	1,748	2,613
ANDREWS	MINING	$2,415.23	$2,211.91	$1,774.79	$1,228.20	$754.04	$299.20	12,260	11,228	9,009	6,234	3,828	1,519
ANDREWS	MUNICIPAL	$0.00	$0.49	$1.84	$6.40	$13.72	$24.41	0	9	34	117	251	448
ANDREWS Total		**$2,416.05**	**$2,232.81**	**$1,833.97**	**$1,393.32**	**$1,051.73**	**$746.38**	**12,266**	**11,404**	**9,463**	**7,436**	**5,970**	**4,741**
BORDEN	IRRIGATION	-	-	$0.00	$0.01	$0.01	$0.02	-	-	0	0	0	0
BORDEN Total		**-**	**-**	**$0.00**	**$0.01**	**$0.01**	**$0.02**	**-**	**-**	**0**	**0**	**0**	**0**
BROWN	IRRIGATION	$1.14	$1.15	$1.14	$1.15	$1.14	$1.14	27	28	28	28	28	28
BROWN	MINING	$21.21	$21.98	$21.89	$22.23	$21.61	$21.54	142	147	146	149	144	144
BROWN	MUNICIPAL	$0.12	$0.12	$0.11	$0.11	$0.11	$0.11	2	2	2	2	2	2
BROWN Total		**$22.46**	**$23.24**	**$23.14**	**$23.48**	**$22.86**	**$22.79**	**171**	**177**	**176**	**178**	**174**	**174**
COKE	MUNICIPAL	$2.68	$2.64	$2.62	$2.61	$2.61	$2.61	49	48	48	48	48	48
COKE Total		**$2.68**	**$2.64**	**$2.62**	**$2.61**	**$2.61**	**$2.61**	**49**	**48**	**48**	**48**	**48**	**48**
COLEMAN	IRRIGATION	$0.17	$0.17	$0.17	$0.17	$0.17	$0.17	5	5	5	5	5	5
COLEMAN	MANUFACTURING	$1.22	$1.22	$1.22	$1.22	$1.22	$1.22	10	10	10	10	10	10
COLEMAN	MUNICIPAL	$7.62	$7.53	$7.34	$7.29	$7.28	$7.28	140	138	135	134	133	133
COLEMAN Total		**$9.01**	**$8.91**	**$8.72**	**$8.67**	**$8.66**	**$8.66**	**155**	**153**	**149**	**148**	**148**	**148**
CONCHO	MUNICIPAL	$0.07	$0.07	$0.07	$0.08	$0.08	$0.08	1	1	1	1	1	1
CONCHO Total		**$0.07**	**$0.07**	**$0.07**	**$0.08**	**$0.08**	**$0.08**	**1**	**1**	**1**	**1**	**1**	**1**
ECTOR	MUNICIPAL	$1.42	$1.55	$2.77	$5.68	$22.92	$57.07	26	28	51	104	420	1,046
ECTOR	STEAM ELECTRIC POWER	$2.16	$3.83	$5.72	$8.75	$11.35	$13.61	-	-	-	-	-	-

		Income losses (Million $)*						Job losses					
County	**Water Use Category**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
ECTOR Total		**$3.58**	**$5.38**	**$8.50**	**$14.44**	**$34.27**	**$70.68**	**26**	**28**	**51**	**104**	**420**	**1,046**
HOWARD	MANUFACTURING	-	-	-	-	$4.53	$18.06	-	-	-	-	15	59
HOWARD	MUNICIPAL	$0.98	-	-	$1.07	$8.98	$22.90	18	-	-	20	165	420
HOWARD	STEAM ELECTRIC POWER	$0.10	-	-	$0.13	$0.77	$1.40	-	-	-	-	-	-
HOWARD Total		**$1.08**	**-**	**-**	**$1.21**	**$14.27**	**$42.36**	**18**	**-**	**-**	**20**	**179**	**479**
IRION	IRRIGATION	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	3	3	3	3	3	3
IRION	MINING	$1,381.50	$1,374.78	$94.20	-	-	-	7,023	6,988	479	-	-	-
IRION Total		**$1,381.59**	**$1,374.87**	**$94.29**	**$0.09**	**$0.09**	**$0.09**	**7,025**	**6,991**	**482**	**3**	**3**	**3**
KIMBLE	IRRIGATION	$0.26	$0.26	$0.26	$0.26	$0.26	$0.26	8	8	8	8	8	8
KIMBLE	MANUFACTURING	$104.49	$121.99	$121.99	$121.99	$121.99	$121.99	312	364	364	364	364	364
KIMBLE	MUNICIPAL	$4.77	$4.72	$4.64	$4.61	$4.60	$4.60	87	87	85	85	84	84
KIMBLE Total		**$109.52**	**$126.97**	**$126.89**	**$126.86**	**$126.85**	**$126.85**	**407**	**459**	**457**	**457**	**457**	**457**
LOVING	MINING	$3,202.78	$3,202.78	$2,463.99	$1,202.04	$427.69	$571.91	16,281	16,281	12,525	6,110	2,174	2,907
LOVING Total		**$3,202.78**	**$3,202.78**	**$2,463.99**	**$1,202.04**	**$427.69**	**$571.91**	**16,281**	**16,281**	**12,525**	**6,110**	**2,174**	**2,907**
MARTIN	IRRIGATION	-	-	-	-	-	$0.18	-	-	-	-	-	4
MARTIN	MUNICIPAL	$0.04	$0.08	$0.19	$0.57	$1.11	$1.75	1	1	3	10	20	32
MARTIN Total		**$0.04**	**$0.08**	**$0.19**	**$0.57**	**$1.11**	**$1.93**	**1**	**1**	**3**	**10**	**20**	**36**
MASON	MUNICIPAL	$7.47	$7.37	$7.28	$7.23	$7.22	$7.22	137	135	133	132	132	132
MASON Total		**$7.47**	**$7.37**	**$7.28**	**$7.23**	**$7.22**	**$7.22**	**137**	**135**	**133**	**132**	**132**	**132**
MCCULLOCH	MUNICIPAL	$13.32	$13.60	$13.43	$13.50	$13.52	$13.54	244	249	246	248	248	248
MCCULLOCH Total		**$13.32**	**$13.60**	**$13.43**	**$13.50**	**$13.52**	**$13.54**	**244**	**249**	**246**	**248**	**248**	**248**
MENARD	MUNICIPAL	$1.68	$1.62	$1.57	$1.56	$1.56	$1.56	31	30	29	29	29	29
MENARD Total		**$1.68**	**$1.62**	**$1.57**	**$1.56**	**$1.56**	**$1.56**	**31**	**30**	**29**	**29**	**29**	**29**
MIDLAND	MUNICIPAL	$0.03	$111.77	$233.17	$267.70	$302.87	$341.40	0	2,049	4,275	4,908	5,553	6,259
MIDLAND Total		**$0.03**	**$111.77**	**$233.17**	**$267.70**	**$302.87**	**$341.40**	**0**	**2,049**	**4,275**	**4,908**	**5,553**	**6,259**
MITCHELL	IRRIGATION	$0.10	$0.15	$0.13	$0.11	$0.10	$0.08	2	3	2	2	2	1
MITCHELL	MUNICIPAL	-	$0.49	$0.62	$0.76	$0.94	$1.16	-	9	11	14	17	21
MITCHELL	STEAM ELECTRIC POWER	$343.68	$343.68	$343.68	$343.68	$343.68	$343.68	-	-	-	-	-	-
MITCHELL Total		**$343.78**	**$344.32**	**$344.43**	**$344.55**	**$344.71**	**$344.92**	**2**	**12**	**14**	**16**	**19**	**23**

		Income losses (Million $)*						Job losses					
County	**Water Use Category**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
PECOS	MANUFACTURING	$156.91	$148.60	$148.60	$148.60	$148.60	$148.60	352	334	334	334	334	334
PECOS	MINING	$2,869.87	$2,869.87	$2,869.87	$2,869.87	-	-	14,588	14,588	14,588	14,588	-	-
PECOS Total		**$3,026.79**	**$3,018.47**	**$3,018.47**	**$3,018.47**	**$148.60**	**$148.60**	**14,940**	**14,922**	**14,922**	**14,922**	**334**	**334**
REEVES	MINING	$8,527.63	$8,527.63	$8,117.65	$6,313.72	$4,591.80	$3,279.86	43,348	43,348	41,264	32,094	23,341	16,672
REEVES	MUNICIPAL	$0.45	$0.50	$0.55	$0.58	$0.60	$0.62	8	9	10	11	11	11
REEVES Total		**$8,528.08**	**$8,528.13**	**$8,118.19**	**$6,314.30**	**$4,592.40**	**$3,280.48**	**43,356**	**43,357**	**41,274**	**32,105**	**23,352**	**16,684**
RUNNELS	MUNICIPAL	$4.00	$3.77	$3.59	$3.56	$3.59	$3.77	73	69	66	65	66	69
RUNNELS Total		**$4.00**	**$3.77**	**$3.59**	**$3.56**	**$3.59**	**$3.77**	**73**	**69**	**66**	**65**	**66**	**69**
SCURRY	IRRIGATION	$2.67	$2.68	$2.68	$2.68	$2.68	$2.68	51	51	51	51	51	51
SCURRY	MANUFACTURING	$187.78	$225.33	$225.33	$225.33	$225.33	$225.33	415	498	498	498	498	498
SCURRY	MINING	$198.43	$323.89	$343.57	$258.29	$174.65	$118.07	1,009	1,646	1,746	1,313	888	600
SCURRY	MUNICIPAL	$1.81	$1.60	$1.73	$2.36	$5.62	$11.66	33	29	32	43	103	214
SCURRY Total		**$390.68**	**$553.50**	**$573.31**	**$488.66**	**$408.28**	**$357.74**	**1,508**	**2,225**	**2,327**	**1,905**	**1,540**	**1,363**
TOM GREEN	MANUFACTURING	$6.18	$18.84	$24.06	$31.54	$40.49	$48.95	147	449	573	751	964	1,166
TOM GREEN	MUNICIPAL	$74.57	$62.49	$80.20	$100.73	$116.86	$134.43	1,367	1,146	1,470	1,847	2,142	2,465
TOM GREEN Total		**$80.75**	**$81.33**	**$104.26**	**$132.27**	**$157.35**	**$183.38**	**1,514**	**1,594**	**2,043**	**2,598**	**3,107**	**3,630**
WARD	MUNICIPAL	-	-	-	-	$1.19	$1.22	-	-	-	-	22	22
WARD	STEAM ELECTRIC POWER	$78.28	$78.28	$78.28	$78.28	$78.28	$78.28	-	-	-	-	-	-
WARD Total		**$78.28**	**$78.28**	**$78.28**	**$78.28**	**$79.47**	**$79.50**	**-**	**-**	**-**	**-**	**22**	**22**
REGION F Total		**$19,623.72**	**$19,719.90**	**$17,058.36**	**$13,443.46**	**$7,749.80**	**$6,356.45**	**98,208**	**100,186**	**88,685**	**71,444**	**43,995**	**38,833**

Appendix E

Letter from The Nature Conservancy of Texas and the Devils River Conservancy

December 21, 2020

Ms. Meredith E. Allen
Groundwater Management Area 7 Coordinator
General Manager
Sutton County Underground Water Conservation District
301 South Crockett Avenue Sonora, Texas 76950

Re: The Devils River and Val Verde County Desired Future Conditions

Dear Ms. Allen,

We appreciate the opportunity to submit comments to Groundwater Management Area 7 (GMA7) regarding the groundwater resources of Val Verde County and the important values the Edwards-Trinity Plateau Aquifer (ETP) provides to its citizens and stakeholders. Together we are (or represent) the stewards of significant land holdings in the Devils River watershed. Below we recommend important considerations for future development of Desired Future Conditions (DFCs) aimed to protect the ETP in Val Verde County.

We commend GMA7 for consideration of springflow in DFCs for both Val Verde County (based on San Felipe Springs) and Kinney County (Las Moras Springs) and for making it a general goal for DFCs in portions of the GMA where groundwater-surface water interactions are of critical importance to water resources. We also commend GMA7 for inclusion of a DFC for Val Verde County, even though there is currently no Groundwater Conservation District (GCD) in the county.

Recent recognition of the importance and complexity of water resources in Val Verde County, the Devils River in particular, warrant consideration in the joint planning process. In addition, recent groundwater development proposals for Val Verde County highlight the urgency of considering the impacts of additional water development on all the ground and surface water resources of the county. While there is not currently a GCD to implement DFCs in Val Verde County, the joint planning results inform the groundwater component of regional water planning and will advise the scope of any future created GCD or other water management entity in Val Verde County.

Value of the Devils River

The Devils River is a valuable resource and provides critical freshwater flows to downstream areas of the Rio Grande Basin, including the lower Rio Grande Valley. In a year of normal rainfall, the Devils River contributes 20% of the inflow to Amistad Reservoir which provides water supply to millions of downstream users, as well as additional recreational opportunities on the lake.

The river’s undeveloped, rural watershed is the most intact ecosystem in the state and protects the region’s water quality as well as provides unparalleled wilderness recreation opportunities and historical and cultural tourism attractions. Indeed, the Devils, and groundwater resources upon which it depends, has been the subject of a legislatively-requested study in 2018 and discussions of legislative interim committees in 2018 and 2020. The recognition of the importance of the Devils River has led to significant advances in understanding the river and its relationship to the aquifer, which we briefly outline below.

Recent Hydrogeological and Ecological Research in the Devils River

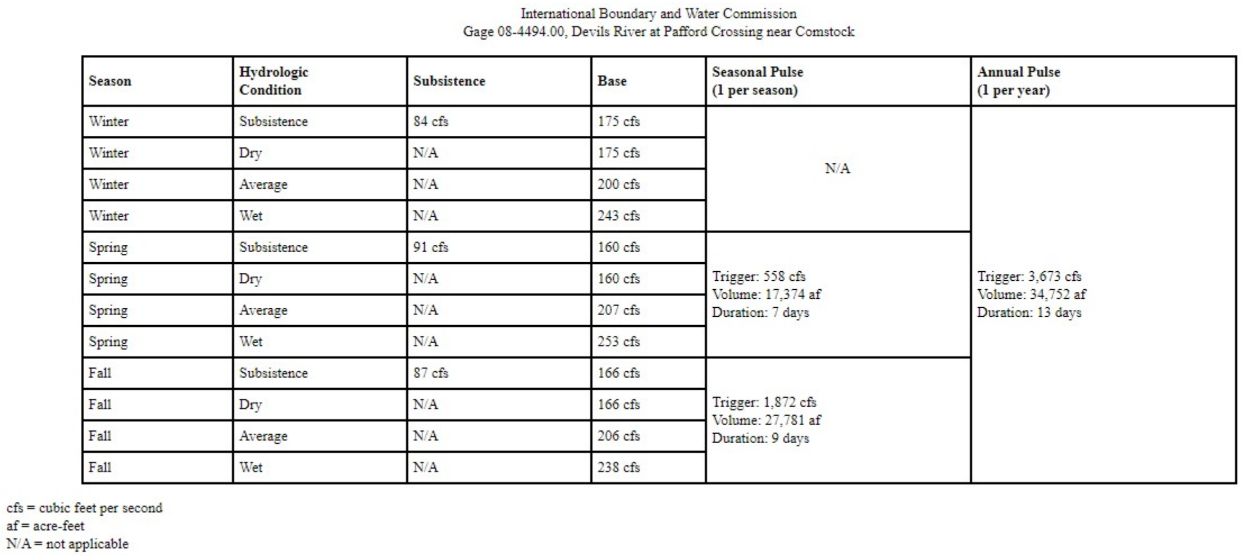
Much information has been developed over the last ten years on the Devils River. This work is the result of multi-partner collaborations and has brought more than $2 million in federal and private funding to research in the Devils River watershed. Key contributions have been made by stakeholders and research institutions such as Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, The Nature Conservancy, The Devils River Conservancy, University of Texas, Texas A&M University as well as philanthropic foundations and private donors.

In response to a legislative request, TWDB completed a comprehensive report synthesizing available information on the groundwater resources of Val Verde County (TWDB 2018). This report recognizes that the Devils River and its springs may be useful benchmarks for groundwater management in Val Verde County. Other researchers have also advanced the understanding of groundwater flow paths and groundwater surface water interactions in Val Verde County (Green et al. 2014, Wolaver et al. 2018, and Caldwell et al. 2020). This work supported the development of numerical groundwater models to simulate the groundwater system (Ecokai and Hutchison 2014, Green et al. 2016, Toll et al. 2017) that have been used to evaluate future water management scenarios, including additional pumping in the lower portions of the watershed (Ecokai and Hutchison 2014, Toll et al. 2017) and the headwater regions (Fratesi et al. 2019).

There has also been ongoing research and monitoring to understand the flow needs of the Devils River ecosystem and how it would repond to groundwater alteration. Instream habitat modeling studies (URG BBEST 2012, Hardy 2014) have estimated how available habitat changes with reductions in river flow, and these studies are currently being expanded to other areas of the river and updated with additional information on temperature. TPWD has also established a biological monitoring program that has informed research efforts and established a baseline for monitoring changes to ecosystem health that may result from water management, climate change or other impacts. Recent work has also increased the understanding of the flow needs of the two aquatic species in Val Verde County listed under the Endangered Species Act, the Devils River minnow (threatened) and Texas hornshell (endangered) (Randklev et al. 2018).

Devils River Flow Targets

In aggregate, these studies have resulted in scientifically-defensible information to determine levels of river flows necessary to maintain the values provided by the Devils River and could form the basis for future DFCs to protect the flow of the Devils. Some examples of potential flow targets have been based on percentages of historical flows (Smith 2007) or groundwater levels (Green 2016), similar to the approach used in the Edwards Aquifer to maintain flows at Comal and San Marcos Springs. An important advance in development of flow targets occurred during the process set forth by Senate Bill 3 (SB3) in 2007 to define environmental flow standards for Texas rivers and bays to maintain a sound ecological environment. In the Upper Rio Grande Basin, science-based recommendations were made for two locations on the Devils River which resulted in the eventual adoption of flow standards by the Texas Commission on Environmental Quality for the Devils River at Pafford's Crossing (TCEQ 2014)(Figure 1). The base flow portions of the flow standards represent seasonal flows necessary to maintain habitats and recreational opportunities, while the subsistence flow portion represents minimum flows needed to sustain the river, and rare species found there, during drought (URGB BBEST 2012).



International Boundary and Water Commission
Gage 08-4494.00, Devils River at Pafford Crossing near Comstock

Season	Hydrologic Condition	Subsistence	Base	Seasonal Pulse (1 per season)	Annual Pulse (1 per year)
Winter	Subsistence	84 cfs	175 cfs	N/A	Trigger: 3,673 cfs Volume: 34,752 af Duration: 13 days
Winter	Dry	N/A	175 cfs		
Winter	Average	N/A	200 cfs		
Winter	Wet	N/A	243 cfs		
Spring	Subsistence	91 cfs	160 cfs	Trigger: 558 cfs Volume: 17,374 af Duration: 7 days	
Spring	Dry	N/A	160 cfs		
Spring	Average	N/A	207 cfs		
Spring	Wet	N/A	253 cfs		
Fall	Subsistence	87 cfs	166 cfs	Trigger: 1,872 cfs Volume: 27,781 af Duration: 9 days	
Fall	Dry	N/A	166 cfs		
Fall	Average	N/A	206 cfs		
Fall	Wet	N/A	238 cfs		

cfs = cubic feet per second
af = acre-feet
N/A = not applicable

Figure 1. Adopted environmental flow standards for the Devils River at Pafford's Crossing.

Consideration of the Devils River in Groundwater Management and Planning

The Devils River should be specifically considered when creating and implementing DFCs for Val Verde County, and maintenance of historic surface flows should be a primary basis for groundwater management in the county should a GCD or other regulatory entity be formed. GMA 7 has set a MAG of 50,000 acre-feet for the ETP in Val Verde County, which was primarily developed with a DFC based on maintaining flows from San Felipe Springs. This degree of pumping in some areas of the county could result in unintended impacts to the groundwater resources and surface water flows of the Devils River. Recent work by SWRI (Fratesi et al. 2019) suggests that as little as 3,000 - 5,000 acre-feet of pumping beyond what is pumped now could create significant reductions in river flows during periods of drought, which in turn could have significant ecological impacts. Maintaining the previously described flow standards for the Devils River at or near the historical frequency should be considered as minimum thresholds when developing DFCs and MAGs for Val Verde County to maintain surface flows for a sound ecological environment and the downstream municipal and agricultural users historically dependent on those flows.

Consequently, groundwater models should be further refined before the next round of DFCs to allow explicit consideration of changes to Devils River (and Pecos River) flow and springflow resulting from pumping throughout the county. This would enable consideration of other approaches to more effectively manage the totality of water resources of Val Verde Co (e.g., management zones), depending on interest from stakeholders.

In closing, we commend GMA7 for consideration of the importance of Val Verde County, even though there is no GCD. The water resources of Val Verde County are uniquely important to the people of Texas. We appreciate GMA7's consideration of the Devils River and the future creation DFCs to better manage the groundwater which feeds it.

Thank you. Should you have any questions or wish to discuss this matter in more detail, please do not hesitate to contact Ryan Smith at ryan_smith@tnc.org.

Sincerely,

Ryan Smith
The Nature Conservancy of Texas

Julie Lewey
Executive Director
Devils River Conservancy

Cc: Sarah Robertson, Texas Parks and Wildlife Department

Attachment:

Fratesi, S.B., R.T. Green, and N. Martin. 2019. Evaluation of the Devils River Watershed Surface-Water/Groundwater Model for Determination of Pumping Impacts near Finnegan and Dolan Springs Image Courtesy of The Nature Conservancy. Prepared for The Nature Conservancy of Texas. Available on request and attached to these comments.

References

Caldwell, T.G., B.D. Wolaver, T. Bongiovanni, J.P. Pierre, S. Robertson, C. Abolt, and B.R. Scanlon. 2020. Spring discharge and thermal regime of a groundwater dependent ecosystem in an arid karst environment. Journal of Hydrology 587 (2020): 124947.

Eco-Kai Environmental Inc. and Hutchison,W. R., 2014, Hydrogeological study for Val Verde County and City of Del Rio, Texas, report prepared for Val Verde County and City of Del Rio, 152 pp, at www.edwardsaquifer.net/pdf/Val_Verde_May_2014.pdf

Fratesi, S.B., R.T. Green, and N. Martin. 2019. Evaluation of the Devils River Watershed Surface-Water/Groundwater Model for Determination of Pumping Impacts near Finnegan and Dolan Springs Image Courtesy of The Nature Conservancy. Prepared for The Nature Conservancy of Texas. Available on request and attached to these comments.

Green, R.T., F.P. Bertetti, and M.S. Miller. 2014. Focused Groundwater Flow in a Carbonate Aquifer in a Semi-Arid Environment. Journal of Hydrology. 517:284–297. doi: 10.1016/j.jhydrol.2014.05.015

Green, R. T., 2016, Val Verde County Drought/Pumping Triggers, presentation to Devils River stakeholder group, October 27, 2016.

Green, R.T., N. Toll, and F.P. Bertetti. 2016. Develop a Groundwater Flow Model to Understand the Groundwater Resources of the Lower Pecos River Watershed. Contract Report for the City of Laredo. Final Report.

Hardy, T.B. 2014. Relationship Between Stream Discharge and Habitat Availability for the Devils River Minnow (Dionda diaboli) and Other Native Fishes in Portions of the Devils River and Dolan Creek, Val Verde County, Texas. Final Report to Texas Parks and Wildlfe Department under U.S. Fish and Wildlife Service award: TX E-115-R-1, Endangered Species Grant Program.

Randklev, C., T.D. Miller, M. Hart, J. Morton, N. Johnson, K. Skow, K. Inoue, E.T. Tsakiris, S. Rogers-Oetker, R.K. Smith, C.R. Robertson, and R. Lopez. 2018. A semi-arid river in distress: Contributing factors and recovery solutions for three imperiled freshwater mussels (Family Unionidae) endemic to the Rio Grande basin in North America. Science of The Total Environment 631-632:733-744.

Smith, R.K. 2007. Analysis of Devils and Pecos River Base Flow and Potential Groundwater Management Triggers for Val Verde County GCD. Report from The Nature Conservancy. Available on request.

Texas Commission on Environmental Quality (TCEQ). 2014. Chapter 298 - Environmental Flow Standards for Surface Water. SUBCHAPTER H: RIO GRANDE, RIO GRANDE ESTUARY, AND LOWER LAGUNA MADRE. https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/298h.pdf

Texas Water Development Board (TWDB). 2018. Overview of Groundwater Conditions in Val Verde County, Texas. Prepared by: Texas Water Development Board with cooperation of the Texas Commission on Environmental Quality and the Texas Parks and Wildlife Department.

Toll, N., Fratesi, S.B., Green, R.T., Bertetti, F.P., and Nunu, R., 2017, Water resource management of the Devils River watershed, final report: Southwest Research Institute report under contract to the Devils River Conservancy, at http://www.devilsriverconservancy.org/research/

Upper Rio Grande Basin and Bay Expert Science Team (URGB BBEST). 2012. Environmental flows recommendations report. Final submission to the Environmental Flows Advisory Group, Rio Grande Basin and Bay Area Stakeholders Committee and Texas Commission on Environmental Quality. Texas Commission on Environmental Quality, Austin, Texas.

Wolaver, B., T. Caldwell, T. Bongiovanni, and J.P. Pierre. 2018. Monitoring the effects of groundwater level on spring and stream discharge, stream temperature, and habitat for Dionda diaboli in the Devils River. Final Report to Texas Parks and Wildlfe Department under U.S. Fish and Wildlife Sservice award: TX E-173-R-1, F15AP00669.

Appendix F

Letter from Texas Parks & Wildlife

TEXAS
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December 17, 2020

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Executive Director

Ms. Meredith E. Allen
GMA Coordinator
General Manager
Sutton County Underground Water Conservation District
301 South Crockett Avenue
Sonora, Texas 76950

Dear Ms. Allen,

As the state agency charged with the primary responsibility for protecting the state's fish and wildlife resources (Texas Parks and Wildlife Code § 12.001), and as the steward of the Devils River State Natural Area, Texas Parks and Wildlife Department appreciates this opportunity to provide comments regarding the determination of desired future conditions (DFCs) for Groundwater Management Area 7 (GMA 7).

We commend GMA7 for consideration of springflow in DFCs for both Val Verde County (based on San Felipe Springs) and Kinney County (based on Las Moras Springs) and for making it a general goal for DFCs in portions of the GMA where groundwater-surface water interactions are of critical importance to water resources. We also commend GMA7 for inclusion of a DFC for Val Verde County, even though there is currently no Groundwater Conservation District (GCD) in the county.

Recent recognition of the importance and complexity of water resources in Val Verde County, the Devils River in particular, warrant consideration in the joint planning process. In addition, recent groundwater development proposals for Val Verde County highlight the urgency of considering the impacts of additional water development on all the ground and surface water resources of the county. While there is not currently a GCD to implement DFCs in Val Verde County, the results of the joint planning process inform the groundwater component of regional water planning and will advise the scope of any future created GCD or other water management entity in Val Verde County.

Value of the Devils River

The Devils River is a valuable resource and provides critical freshwater flows to downstream areas of the Rio Grande Basin, including the lower Rio Grande Valley. In a year of normal rainfall, the Devils River contributes 20% of the inflow to Amistad Reservoir which provides water supply to millions of downstream users, as well as additional recreational opportunities on the lake. The river's undeveloped, rural watershed is the most intact ecosystem in the state and protects the region's water quality as well as provides unparalleled wilderness recreation opportunities and historical and cultural tourism attractions. Indeed, the Devils River, and groundwater resources upon which it depends, has been the subject of a legislatively-requested study in 2018 and discussions of legislative interim committees in 2018 and 2020. The recognition of the importance of the Devils River has led to significant advances in understanding the river and its relationship to the aquifer, which we briefly outline below.

Recent Hydrogeological and Ecological Research in the Devils River

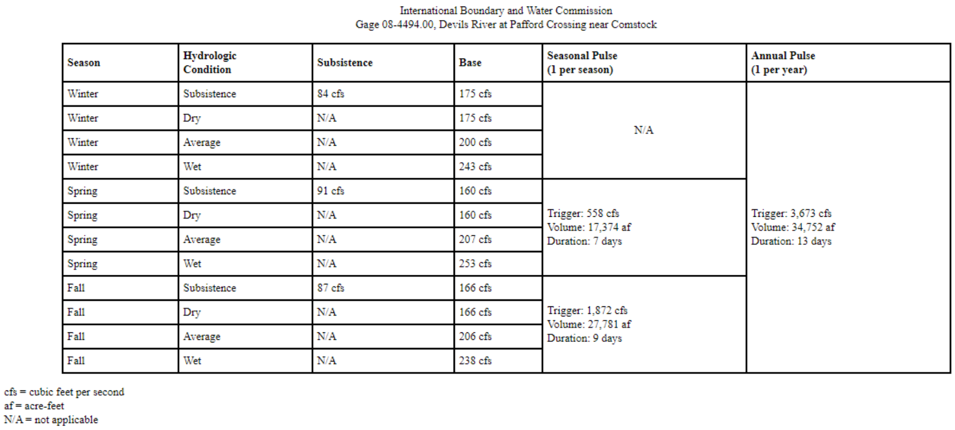
Much information has been developed over the last ten years on the Devils River. This work is the result of multi-partner collaborations and has brought more than $2 million in federal and private funding to research in the Devils River watershed. Key contributions have been made by stakeholders and research institutions such as Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, The Nature Conservancy, The Devils River Conservancy, University of Texas, Texas A&M University as well as philanthropic foundations and private donors.

In response to a legislative request, TWDB completed a comprehensive report synthesizing available information on the groundwater resources of Val Verde County (TWDB 2018). This report, which recognizes that the Devils River and its springs may be useful benchmarks for groundwater management in Val Verde County. Other researchers have also advanced the understanding of groundwater flow paths and groundwater surface water interactions in Val Verde County (Green et al. 2014, Wolaver et al. 2018, and Caldwell et al. 2020). This work supported the development of numerical groundwater models to simulate the groundwater system (Ecokai and Hutchison 2014, Green et al. 2016, Toll et al. 2017) that have been used to evaluate future water management scenarios, including additional pumping in the lower portions of the watershed (Ecokai and Hutchison 2014, Toll et al. 2017) and the headwater regions (Fratesi et al. 2019).

There has also been ongoing research and monitoring to understand the flow needs of the Devils River ecosystem and how it would respond to groundwater alteration. Instream habitat modeling studies (URG BBEST 2012, Hardy 2014) have estimated how available habitat changes with reductions in river flow, and these studies are currently being expanded to other areas of the river and updated with additional information on temperature. TPWD has also established a biological monitoring program that has informed research efforts and established a baseline for monitoring changes to ecosystem health that may result from water management, climate change or other impacts. Recent work has also increased the understanding of the flow needs of the two aquatic species in Val Verde County listed under the Endangered Species Act, the Devils River minnow and Texas hornshell (Randklev et al. 2018).

Devils River Flow Targets

In aggregate, these studies have resulted in scientifically-defensible information to define levels of river flows necessary to maintain the values provided by the Devils River and could form the basis for future DFCs to protect the flow of the Devils. Some examples of potential flow targets have been based on percentages of historical flows (Smith 2007) or groundwater levels (Green 2016), similar to the approach used in the Edwards Aquifer to maintain flows at Comal and San Marcos Springs. An important advance in development of flow targets occurred during the process set forth by Senate Bill 3 (SB3) in 2007 to define environmental flow standards for Texas rivers and bays to maintain a sound ecological environment. In the Upper Rio Grande Basin, science-based recommendations were made for two locations on the Devils River which resulted in the eventual adoption of flow standards by the Texas Commission on Environmental Quality for the Devils River at Pafford's Crossing (TCEQ 2014) (Figure 1). The base flow portions of the flow standards represent seasonal flows necessary to maintain habitats and recreational opportunities, while the subsistence flow portion represents minimum flows needed to sustain the river, and rare species found there, during drought (URGB BBEST 2012).



International Boundary and Water Commission
Gage 08-4494.00, Devils River at Pafford Crossing near Comstock

Season	**Hydrologic Condition**	**Subsistence**	**Base**	**Seasonal Pulse (1 per season)**	**Annual Pulse (1 per year)**
Winter	Subsistence	84 cfs	175 cfs	N/A	Trigger: 3,673 cfs Volume: 34,752 af Duration: 13 days
Winter	Dry	N/A	175 cfs		
Winter	Average	N/A	200 cfs		
Winter	Wet	N/A	243 cfs		
Spring	Subsistence	91 cfs	160 cfs	Trigger: 558 cfs Volume: 17,374 af Duration: 7 days	
Spring	Dry	N/A	160 cfs		
Spring	Average	N/A	207 cfs		
Spring	Wet	N/A	253 cfs		
Fall	Subsistence	87 cfs	166 cfs	Trigger: 1,872 cfs Volume: 27,781 af Duration: 9 days	
Fall	Dry	N/A	166 cfs		
Fall	Average	N/A	206 cfs		
Fall	Wet	N/A	238 cfs		

cfs = cubic feet per second
af = acre-feet
N/A = not applicable

Figure 1. Adopted environmental flow standards for the Devils River at Pafford's Crossing.

Consideration of the Devils River in Groundwater Management and Planning

The Devils River should be explicitly considered when creating and implementing DFCs for Val Verde County, and should be a primary basis for groundwater management in the county should a GCD or other regulatory entity be formed. GMA 7 has set the Modeled Available Groundwater (MAG) of 50,000 acre-feet for the ETP in Val Verde County, which was primarily developed with a DFC based on maintaining flows from San Felipe Springs. This degree of pumping in some areas of the county could result in unintended impacts to the groundwater resources and surface water flows of the Devils River. Recent work by SWRI (Fratesi et al. 2019) suggests that as little as 3,000 - 5,000 acre-feet of pumping beyond what is pumped now could create significant reductions in river flows during periods of drought, which in turn could have significant ecological impacts. Maintaining the previously described flow standards for the Devils River at or near the historical frequency should be considered as minimum thresholds when developing DFCs and MAGs for Val Verde County to maintain surface flows and a sound ecological environment.

Groundwater models should be further refined before the next round of DFCs to allow explicit consideration of changes to Devils River (and Pecos River) flow and springflow resulting from pumping throughout the county. This would also enable consideration of other approaches for representing the various water resources of Val Verde County (e.g., management zones), depending on interest from stakeholders.

In closing, we commend GMA7 for consideration of the importance of Val Verde County, even though there is no GCD. The water resources of Val Verde County are unique and important to the people of Texas. We appreciate GMA7's consideration of the Devils River and the future creation DFCs to better manage the groundwater which feeds it.

Thank you. Should you have any questions or wish to discuss this matter in more detail, please do not hesitate to contact Sarah Robertson at Sarah.Robertson@tpwd.texas.gov.

Sincerely,

Cindy Loeffler

Cindy Loeffler, Chief
Water Resources Branch

Cc: Ryan Smith, Texas Nature Conservancy
Julie Lewey, Devils River Conservancy

References

Caldwell, T.G., B.D. Wolaver, T. Bongiovanni, J.P. Pierre, S. Robertson, C. Abolt, and B.R. Scanlon. 2020. Spring discharge and thermal regime of a groundwater dependent ecosystem in an arid karst environment. Journal of Hydrology 587 (2020): 124947.

Eco-Kai Environmental Inc. and Hutchison,W. R., 2014, Hydrogeological study for Val Verde County and City of Del Rio, Texas, report prepared for Val Verde County and City of Del Rio, 152 pp, at www.edwardsaquifer.net/pdf/Val_Verde_May_2014.pdf

Fratesi, S.B., R.T. Green, and N. Martin. 2019. Evaluation of the Devils River Watershed Surface-Water/Groundwater Model for Determination of Pumping Impacts near Finnegan and Dolan Springs Image Courtesy of The Nature Conservancy. Prepared for The Nature Conservancy of Texas. Available on request and attached to these comments.

Green, R.T., F.P. Bertetti, and M.S. Miller. 2014. Focused Groundwater Flow in a Carbonate Aquifer in a Semi-Arid Environment. Journal of Hydrology. 517:284–297. doi: 10.1016/j.jhydrol.2014.05.015

Green, R. T., 2016, Val Verde County Drought/Pumping Triggers, presentation to Devils River stakeholder group, October 27, 2016.

Green, R.T., N. Toll, and F.P. Bertetti. 2016. Develop a Groundwater Flow Model to Understand the Groundwater Resources of the Lower Pecos River Watershed. Contract Report for the City of Laredo. Final Report.

Hardy, T.B. 2014. Relationship Between Stream Discharge and Habitat Availability for the Devils River Minnow (Dionda diaboli) and Other Native Fishes in Portions of the Devils River and Dolan Creek, Val Verde County, Texas. Final Report to Texas Parks and Wildlfe Department under U.S. Fish and Wildlife Service award: TX E-115-R-1, Endangered Species Grant Program.

Randklev, C., T.D. Miller, M. Hart, J. Morton, N. Johnson, K. Skow, K. Inoue, E.T. Tsakiris, S. Rogers-Oetker, R.K. Smith, C.R. Robertson, and R. Lopez. 2018. A semi-arid river in distress: Contributing factors and recovery solutions for three imperiled freshwater mussels (Family Unionidae) endemic to the Rio Grande basin in North America. Science of The Total Environment 631-632:733-744.

Smith, R.K. 2007. Analysis of Devils and Pecos River Base Flow and Potential Groundwater Management Triggers for Val Verde County GCD. Report from The Nature Conservancy. Available on request.

Texas Commission on Environmental Quality (TCEQ). 2014. Chapter 298 - Environmental Flow Standards for Surface Water. SUBCHAPTER H: RIO GRANDE, RIO GRANDE ESTUARY, AND LOWER LAGUNA MADRE. https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/298h.pdf

Texas Water Development Board (TWDB). 2018. Overview of Groundwater Conditions in Val Verde County, Texas. Prepared by: Texas Water Development Board with cooperation of the Texas Commission on Environmental Quality and the Texas Parks and Wildlife Department.

Toll, N., Fratesi, S.B., Green, R.T., Bertetti, F.P., and Nunu, R., 2017, Water resource management of the Devils River watershed, final report: Southwest Research Institute report under contract to the Devils River Conservancy, at http://www.devilsriverconservancy.org/research/

Upper Rio Grande Basin and Bay Expert Science Team (URGB BBEST). 2012. Environmental flows recommendations report. Final submission to the Environmental Flows Advisory Group, Rio Grande Basin and Bay Area Stakeholders Committee and Texas Commission on Environmental Quality. Texas Commission on Environmental Quality, Austin, Texas.

Wolaver, B., T. Caldwell, T. Bongiovanni, and J.P. Pierre. 2018. Monitoring the effects of groundwater level on spring and stream discharge, stream temperature, and habitat for Dionda diaboli in the Devils River. Final Report to Texas Parks and Wildlfe Department under U.S. Fish and Wildlife Sservice award: TX E-173-R-1, F15AP00669.