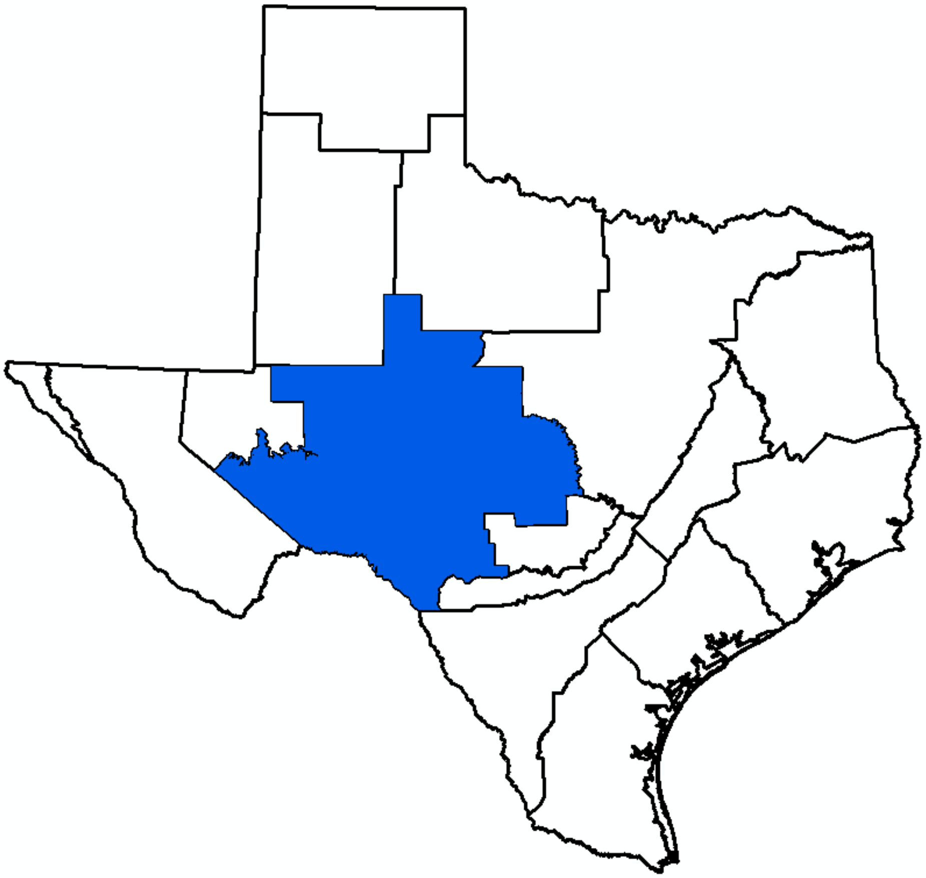
GMA 7 Explanatory Report – Final
Edward-Trinity (Plateau), Pecos Valley and Trinity Aquifers



Prepared for:
Groundwater Management Area 7

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August 28, 2021

GMA 7 Explanatory Report – Final
Edward-Trinity (Plateau), Pecos Valley and Trinity Aquifers

Geoscientist and Engineering Seal

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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).

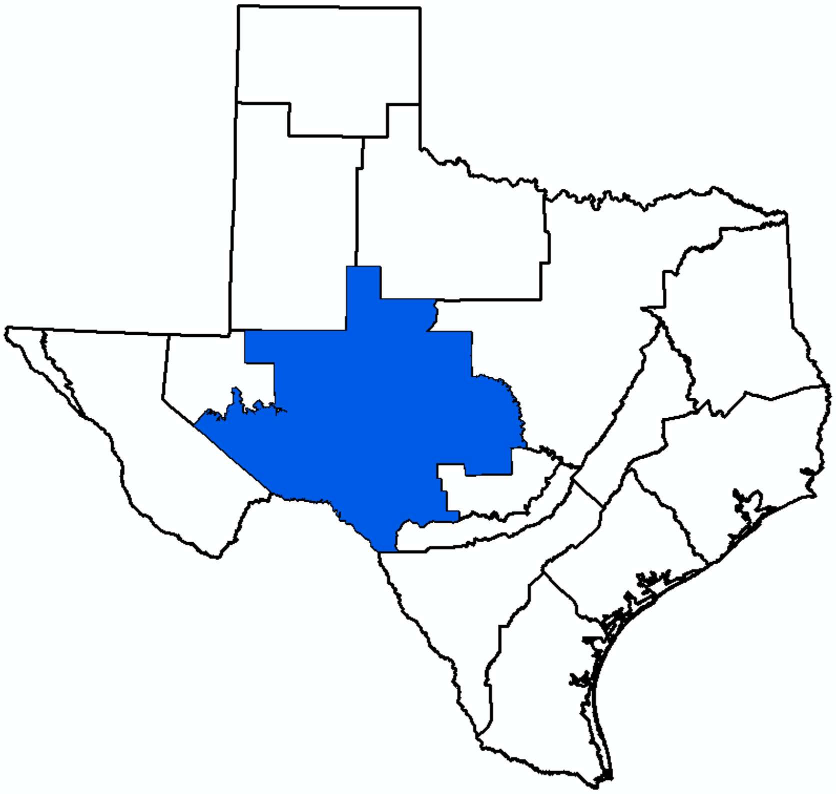


Figure 1. Groundwater Management Area 7

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).

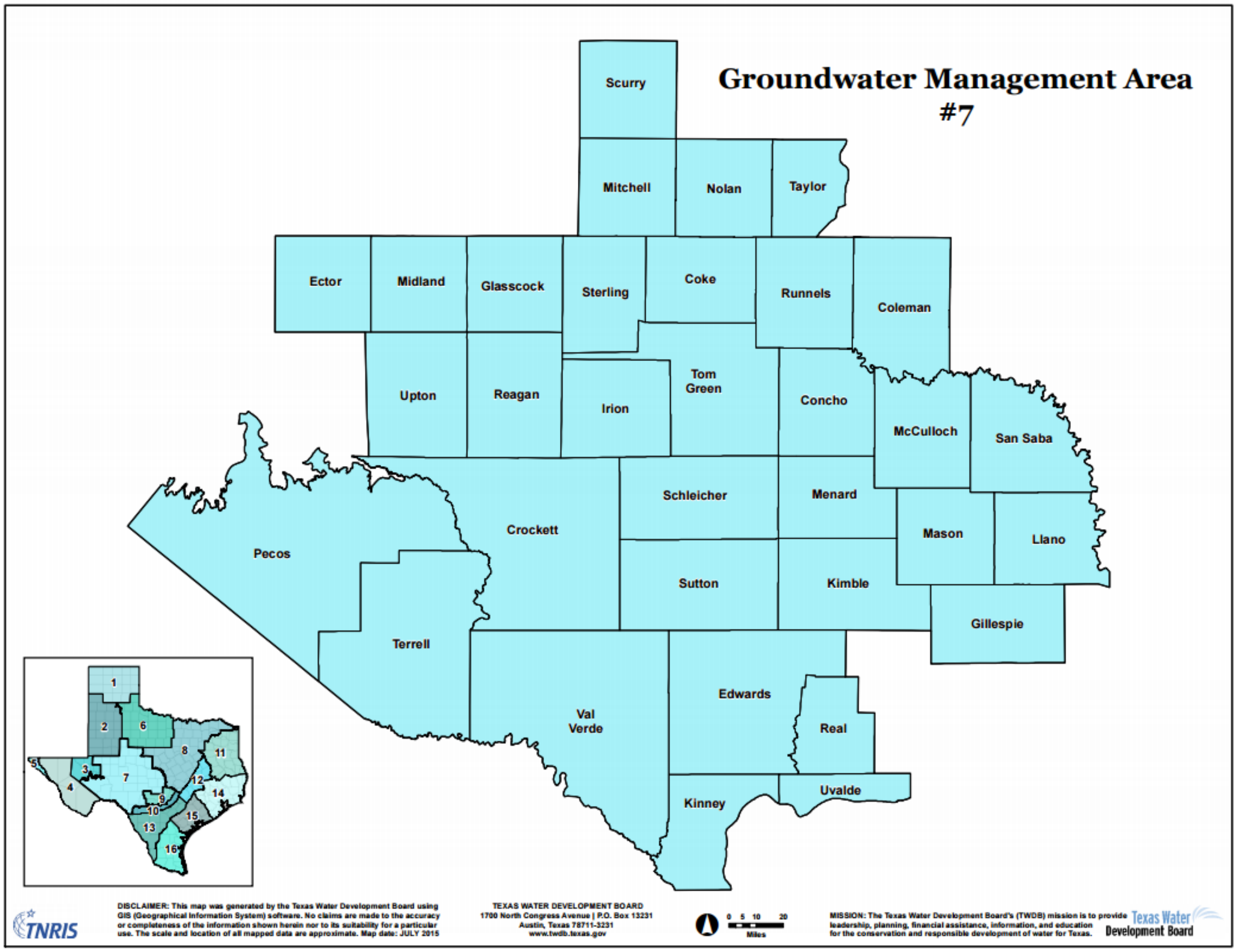


Figure 2. GMA 7 Counties (from TWDB)

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.

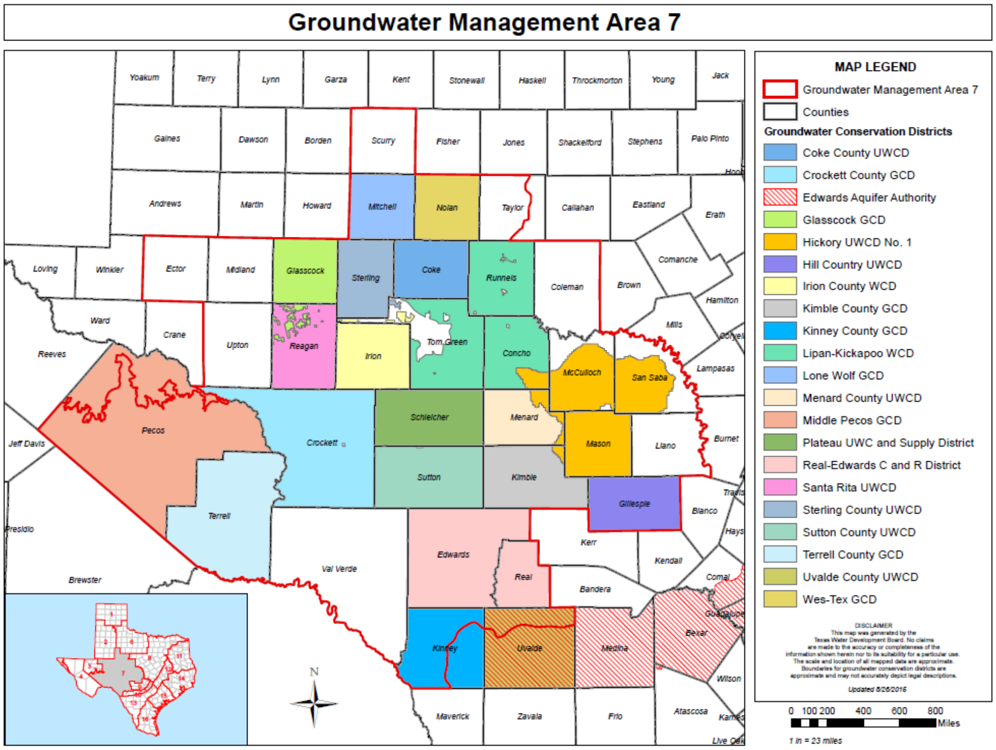


Figure 3. Groundwater Conservation Districts in GMA 7 (from TWDB)

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

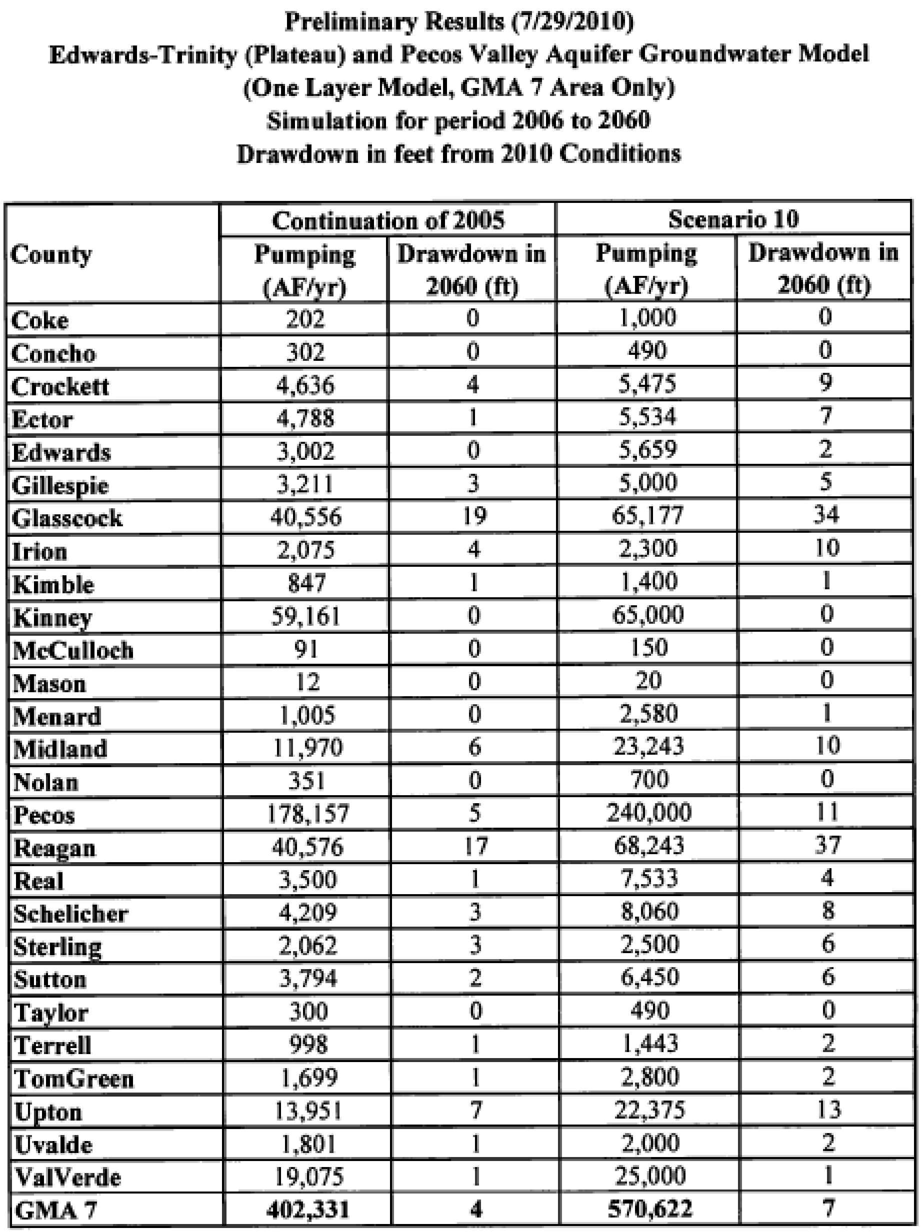
2.1 2010 Desired Future Conditions

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 in the August 19, 2021 resolution. 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 previously adopted on March 23, 2017 for Kinney and Val Verde counties, reaffirmed in the March 22, 2018 resolution, and then adopted again during this round of joint planning in the resolution dated August 29, 2021 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

The resolution that documents the adoption of the desired future condition for the Capitan Reef Complex Aquifer is presented in Appendix A and was adopted on August 19, 2021 by a 14-0 vote at a properly noticed meeting of Groundwater Management Area 7.

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.

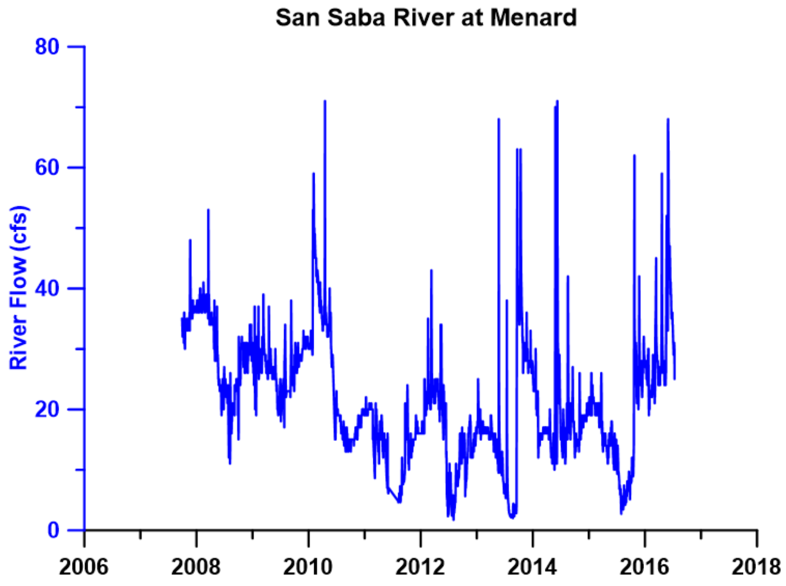


Figure 4. San Saba River at Menard

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.

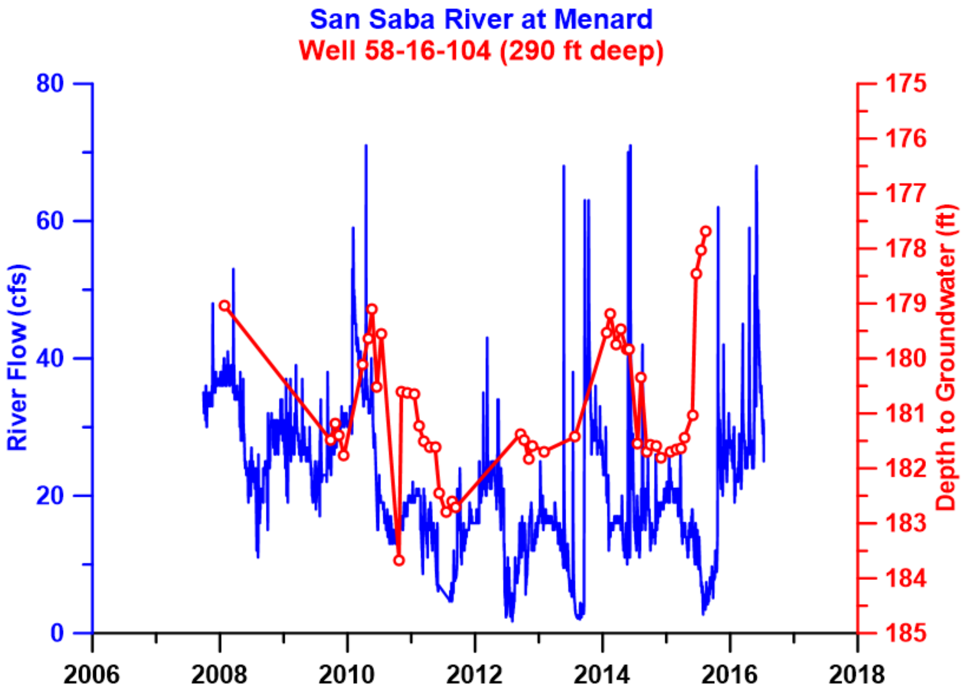


Figure 5. San Saba River at Menard and Well 58-16-104

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 (2010 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

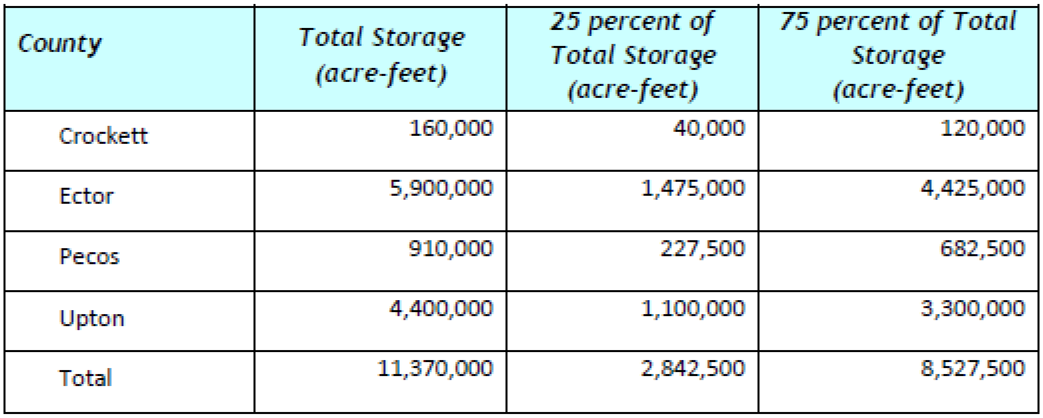
	Water Budget 1930-1939 (acre-feet per year)	Water Budget 1940-1949 (acre-feet per year)	Water Budget 1950-1959 (acre-feet per year)	Water Budget 1960-1969 (acre-feet per year)	Water Budget 1970-1979 (acre-feet per year)	Water Budget 1980-1989 (acre-feet per year)	Water Budget 1990-1999 (acre-feet per 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

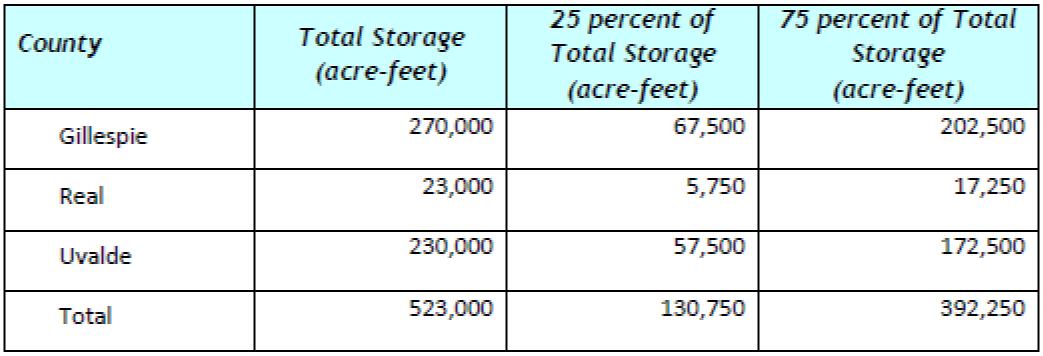
[20] Total storage values for Kinney County are based on the alternative model by Hutchison and others (2011), the other total storage values were based on the groundwater availability model by Anaya and Jones (2009).

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)

5.9.1 Letters from The Nature Conservancy, Devils River Conservancy, and Texas Parks and Wildlife

GMA 7 received two letters regarding the development of 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 (dated December 21, 2020) is presented in Appendix E. The letter from Texas Parks and Wildlife (dated December 17, 2020) 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.

5.9.2 Letter from Devils River Association

GMA 7 received a letter from the Devils River Association, a group composed entirely of Devils River watershed ranchers and landowners. The letter is dated January 14, 2020, and is presented in Appendix G. The letter was written to provide their views in response to the letters provided by The Nature Conservancy, Texas Parks and Wildlife, and the Devils River Conservancy discussed above (Appendices E and F).

The Association believes that the joint planning process requires that a DFC be supported by clearly defined data and appropriate modeling and should be proposed by and enforced by a groundwater conservation district for whom the DFC is adopted. The letter also opines that the current lack of aquifer defining quantitative data and reliable, calibrated and validated modeling assessments precludes the adoption of an accurate and reliable DFC and would make the creation of a GCD an expensive exercise in "sheer folly where permit approvals or denials can be legitimately challenged based upon the quality of evidence presented or lack therof.

The letter concludes by stating that neither facts, science, nor applicable legal authorities" can support to create a Devils River Watershed specific DFC or the creation of a Val Verde County groundwater conservation district based on the "facts, science nor applicable legal authorities".

5.9.3 GMA 7's Consideration of These Letters

The December 17, 2020 letter from Texas Parks and Wildlife and the December 21, 2020 joint letter from The Nature Conservancy and Devils River Conservancy were received early in the planning process and were included as Appendices E and F in a draft explanatory report (dated

January 14, 2021). Moreover, the issues raised in these two letters were discussed in the draft explanatory report in Section 5.9 (Other Information). The letters and the discussion in the draft explanatory report were discussed at the GMA 7 meeting of January 21, 2021.

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	7/13/2021	0
Crockett County GCD	6/7/2021	0
Glasscock County GCD	6/15/2021	0
Hill Country GCD	6/8/2021	0
Irion County WCD	5/10/2021	0
Kimble County GCD	3/22/2021	0
Kinney County GCD	6/10/2021	0
Menard County UWD	4/14/2021	0
Middle Pecos GCD	6/15/2021	3 written, 3 oral
Plateau UWC & SD	4/29/2021	0
Real-Edwards C & RD	4/28/2021	0
Santa Rita UWCD	5/18/2021	0
Sterling County UWCD	5/10/2021	0
Sutton County UWCD	4/13/2021	0
Terrell County GCD	6/15/2021	0
Uvalde County WCD	7/12/2021	0

7.1 Devils River Letters

In addition to the comments received during the public comment period, the GMA 7 coordinator received three letters regarding Val Verde County/Devils River issues. These letters are not strictly part of the public comment period because they were received prior to GMA 7 voting to propose desired future conditions as detailed below:

- December 17, 2020 letter from Texas Parks and Wildlife
- December 21, 2020 joint letter from The Nature Conservancy and Devils River Conservancy
- January 14, 2021 letter from Devils River Association

The December 17, 2020 letter from Texas Parks and Wildlife and the December 21, 2020 joint letter from The Nature Conservancy and Devils River Conservancy were received early in the process and were included as Appendices E and F in a draft explanatory report (dated January 14, 2021). Moreover, the issues raised in these two letters were discussed in the draft explanatory report in Section 5.9 (Other Information). The letters and the discussion in the draft explanatory report were discussed at the GMA 7 meeting of January 21, 2021.

The January 14, 2021 letter from the Devils River Association was used to update the discussion that appeared in the January 14, 2021 draft of the explanatory report, and is included as Appendix G.

7.2 Texas Water Trade

Texas Water Trade submitted a letter (dated June 10, 2021) to Middle Pecos Groundwater Conservation District. Texas Water Trade is involved in an effort to restore perennial flow at Comanche Springs in the Fort Stockton area. The comment letter requests that Middle Pecos Groundwater Conservation District "discuss" how the desired future condition in the GMA 7 portion of Pecos County may or may not impact Comanche Springs.

As documented in Hutchison (2017), a total of 22,636 groundwater simulations were completed with the Western Pecos Groundwater Model (WPC Model) developed by R.W. Harden & Associates and others (2011). These simulations calculated the capture of flow to Comanche Springs by wells in each cell of the model. Each simulation pumped groundwater from a single cell for 10 years and calculated the impact to the flow at Comanche Springs. If pumping in a cell resulted in a significant impact to the flow at Comanche Springs, the cell was considered part of the revised Management Zone 1.

Based on 55 sensitivity simulations using the WPC model (Hutchison, 2017) that used 2010 pumping as a base case evaluated the correlation between reduced pumping and average annual spring flow in Comanche Springs in 2070:

- A 25 percent reduction in pumping would result in an average annual spring flow of 13 cfs.
- A 50 percent reduction in pumping would result in an average annual spring flow of 27 cfs
- A 75 percent reduction in pumping would result in an average annual spring flow of 38 cfs

Model limitations for these simulations were discussed in Hutchison (2017) and included:

- The underlying assumption in model development that all boundary conditions, except pumping, are constant from 1945 to 2010, which limits the ability to quantify the effects of wet years and dry years (i.e. only average conditions can be simulated).
- The use of annual stress periods means that the WPC Model cannot be used to simulate the seasonal variation in pumping and the effect of groundwater recovery after the irrigation season on spring flow.

In response to other comments, the WPC Model was modified to address specific impacts of seasonal pumping, but only after evaluating the modifications to the model with available data on well drawdown in specific wells in the Belding Farms area. Such an extension to seasonal flow in Comanche Springs is not possible with the WPC Model due to lack of calibration data. Thus, the only current ability to estimate spring flow is using annual averages.

Work is currently underway to develop a more detailed and robust model of Pecos County that address these limitations and other limitations with existing models. The objective of this updated model is to develop an analytical tool that will advance the groundwater planning, management, and regulatory responsibilities of the Middle Pecos Groundwater Conservation District. It is expected that this model will be available for the next round of joint planning (i.e. proposed DFC deadline of May 1, 2026).

Based on this analysis, the desired future condition is consistent with historic pumping amounts, which is inconsistent with a perennial spring flow. In recent years, some spring flow is observed during the winter months (low pumping months), but spring flow ceases when pumping begins in the spring.

7.3 Belding Farms June 4, 2021 Letter

This correspondence is two letters (both dated June 4, 2021). The first notes that the second letter is an updated version of a February 2, 2021 letter.

Belding Farms provided specific comments related to four of the nine statutory factors. These comments, and the responses, are summarized by factor.

Factor 7 – impact on the interests and rights in private property: The stated concern is that Belding Farms' private property rights beneath its land are jeopardized by the DFC silence or lack of specificity on the impacts to landowners in the Middle Pecos GCD of groundwater exports to locations outside the MPGCD.

Belding Farms is in Management Zone 1 of the Middle Pecos Groundwater Conservation District, in the GMA 7 portion of Pecos County. The boundaries of Management Zone 1 were specifically established based as the area of Pecos County that provided groundwater to Comanche Springs, also located in the GMA 7 portion of Pecos County. Groundwater pumping impacts in Management Zone 1 have been evaluated in Hutchison (2017).

As to the specific concern regarding proposed groundwater export, the most significant proposed project authorized by the Middle Pecos Groundwater Conservation District is the Fort Stockton Holdings Operating Permit that was approved in 2017. As part of that approval, Fort Stockton Holdings relinquished an equivalent amount of historic water rights. Thus, there the approval of the operating permit by Middle Pecos Groundwater Conservation District resulted in no net increase in permitted pumping. The groundwater simulations that were the basis for the DFCs in GMA 7 included the use of permitted pumping amounts to ensure that private property rights (in the form of groundwater permits) were protected.

Factor 6 – socioeconomic impacts reasonably expected to occur: the stated concern is that projected groundwater impacts will "jeopardize the availability of groundwater to Belding Farms". Specifically, there is a concern that "planning for continued groundwater depletion rates will very likely cause seasonal or more permanent impacts relative to groundwater availability to specific landowners in the District." The comments noted that seasonal impacts are the significant concern, particularly for agricultural uses, and should be quantified.

The concerns regarding "groundwater depletion" and "seasonal impacts" are misplaced. Desired future conditions are planning goals and are largely policy decisions made after considering nine statutory factors and applying a balancing test. The legislature has created groundwater conservation districts to manage groundwater and has required the districts to meet within designated groundwater management areas to conduct joint planning.

If the overall policy objective was to eliminate "groundwater depletion", then clearly a DFC with some drawdown over a 50- or 60-year period would have to be scrutinized and evaluated to see if the drawdown level did, in fact, constitute a depletion in groundwater storage. However, the joint planning process requires districts to consider other factors and apply a balancing test. It should be noted that concerns about groundwater depletion and the previously stated concern regarding private property rights are part of the balancing test that is required. If groundwater depletion is prohibited, there is a high chance that property rights could be impacted. Conversely, if property rights are exercised, some degree of groundwater storage depletion is possible. The dynamics of this type of balancing is inherent in the joint planning process.

Seasonal impacts are more properly an issue for groundwater management at the district level as opposed to a planning issue for the Groundwater Management Area. However, in the interest of responding to this comment (and follow-up comments made at the public hearing as detailed below), an analysis of the impacts of changes in the timing of 28,400 AF/yr of pumping (i.e. from an agricultural pattern to alternative municipal patters) was completed. The analysis is documented in Technical Memorandum 21-01, which is attached as Appendix H.

The analysis documented in Technical Memorandum 21-01 found that under current installed capacity and annual production limits of each well in the Fort Stockton Holdings (FSH) Operating Permit, the results of simulating pumping on a municipal schedule demonstrate that impacts to the Belding Wells are nearly identical to simulated impacts to the Belding Wells when FSH Operating Permit wells are operated on an irrigation schedule. The current permit conditions require adherence to the current pump capacity and annual production limits of each well. Simulations that assumed relaxation of these limits (i.e. all FSH Operating Permit pumping over a three- or four-month period) did result in higher impacts to Belding Farms wells, but did not impact long-term drawdown, which is a groundwater planning issue.

Factor 2 – the water supply needs, and water management strategies included in the state water plan: the stated concern is that Belding Farms opposes the creation of unmet water needs, particularly those due to the export of groundwater outside the production area. The comment also notes the negative impacts of the area of origin remain a high priority for legislators as noted in interim committee reports.

This factor requires that the districts consider what the regional planning groups have completed in meeting unmet demands (or deficits) by identifying strategies. It is unclear how an unmet water need is created by exporting groundwater. In the regional planning process, an unmet demand (or deficit) exists when a future demand exceeds existing supply. Strategies are identified to make up the deficit within the constraint of availability. In the case of groundwater, the groundwater availability is defined through the joint planning process as the modeled available groundwater. Thus, a strategy that relies on a groundwater exportation strategy is constrained by groundwater availability in the area where the groundwater originates. It appears that this comment is more appropriate for the regional planning process rather than the joint planning process.

Factor 4 – other environmental impacts, including the impacts on spring flow and other interaction between groundwater and surface water: the stated concern is that the absence of restoration and preservation of spring flows as a DFC condition undermines the Middle Pecos GCD's mission to maintain a sustainable, adequate, reliable, cost effective and high-quality source of groundwater to promote the vitality, economy and environment of the District.

The comment appears to suggest that Factor 4 be given high (if not the highest) weight of all the factors. However, it should be noted that earlier in this comment letter, there is a comment regarding property rights protection (Factor 7) which means that, at a minimum, existing permits be recognized and protected. This section of the letter argues that spring flows should be restored and preserved (Factor 4). The incongruity of these two arguments highlights the difficulty that groundwater districts face in the joint planning process.

7.4 Oral Comments at Public Hearings (June 15, 2021 - MPGCD)

Mike Thornhill (on behalf of Fort Stockton Holdings): Noted that past critiques have worked themselves out and the current DFCs are working since most of the pumping in Pecos County is covered by H&E use permits and that H&E use pumping is accounted for in GAM simulations used to develop the DFCs. Mr. Thornhill believes that issues related to Management Zone 1 are not a GMA 7 issue but a MPGCD issue. However, he noted that the Management Zone 1 drought triggers have been evaluated in the context of the DFCs and that they are consistent and are protective of the aquifer. Mr. Thornhill noted that new data and new models are expected for the next round of joint planning, and there is time to incorporate this information into DFCs during the next round.

Ed McCarthy (on behalf of Fort Stockton Holdings): Reinforced what Mr. Thornhill said regarding the potential to update and refine the DFCs during the next round with updated data and model results. Mr. McCarthy also asked that the potential for additional development in the other aquifers in the district (other than the Edwards-Trinity (Plateau) Aquifer) be considered.

Ryan Reed (on behalf of Belding Farms/Cockrell Investments): Noted that Belding Farms had previously submitted a letter with comments. Also emphasized that when the last round of DFCs were adopted, the contract to export water for municipal use was not in place. Consequently, Mr. Reed requested that a quantitative assessment of how pumping about 28,000 AF/yr of water on a municipal schedule would affect the DFCs.

The comments by Mr. Thornhill regarding the Management Zone 1 issues are not a GMA 7 issue but a MPGCD issue and the triggers being consistent with the DFCs are covered in Technical Memorandum 21-01 (Appendix H).

Because Mr. McCarthy began his comments regarding the opportunities associated with updating the DFCs in the next round with updated model data and results, his comment regarding the consideration additional development in other aquifers was taken to be a recommendation for the next round of joint planning and not a recommendation for the current round and the proposed DFCs.

Mr. Reed's comment/request has been addressed in the response to the June 4, 2021 Belding Farms letter above and in Technical Memorandum 21-01 (Appendix H).

7.5 Belding Farms June 17, 2021 Letter

This letter was a follow-up to the June 4, 2021 letter and the oral comments made by Reed Ryan at the MPGCD public hearing on June 15, 2021. Three issues are discussed:

Aquifer transmissivity and hydraulic interconnection: The comment requests that MPGCD "should give greater consideration to the transmissivity and hydrologic interconnection of the respective aquifers". The letter stated that "before the DFCs are modified in a manner that allows for greater drawdown of the aquifers, the comment encourages "MPGCD to complete the additional modeling and gain a better understanding of upwelling and transmissivity".

The DFCs for all aquifers in GMA 7 that were proposed on March 18, 2021 by the groundwater conservation districts in GMA 7 were the same as the DFCs in 2016. Because this letter was a follow-up to the previous comments, it is possible that this comment is in response to Mr. McCarthy's comment at the June 15, 2021 public hearing. As noted above, because there is no proposed change to any DFC in this round of joint planning, it was taken as a recommendation for the next round of joint planning and not a recommendation for the current round and the proposed DFCs.

Purpose of DFCs and relationship to permitting decisions of MPGCD: The comment encourages MPGCD "treat adoption of the DFCs as much more than a planning exercise" because "the DFCs are inextricably linked to regulatory activities of the GCDs and more importantly the sustainability, reliability, and protection of everyone's property rights with respect to groundwater".

An example of how MPGCD has already linked DFCs and its regulatory responsibilities is contained in Section 5.10 of the most recent Management Plan, adopted by MPGCD on July 16, 2020. Specifically, the special conditions associated with the Fort Stockton Holdings Operating Permit in Management Zone 1 that includes several thresholds that can trigger pumping reductions. The thresholds were established based on avoiding groundwater elevations dropping below historic minima. This will be accomplished by routine monitoring of groundwater elevations in 11 wells and requiring non-historic use pumping reductions if certain thresholds are exceeded (i.e. groundwater elevations drop below the threshold value set for each well). When developing the thresholds, a comparison was made to evaluate the consistency with the adopted desired future condition. Figure 6 shows the results of the comparison.

Please note that the blue data points represent the groundwater elevation where pumping cutbacks begin for each well. The red dots represent the groundwater elevation where a shut-down in non-historic groundwater pumping would be required, thus providing an opportunity for groundwater elevation recovery. The black line represents one-to-one line between the DFC depth to water at each well and the threshold depth to water in each well. The data points generally fall just above or just below the black line demonstrating that the thresholds are consistent with the DFC.

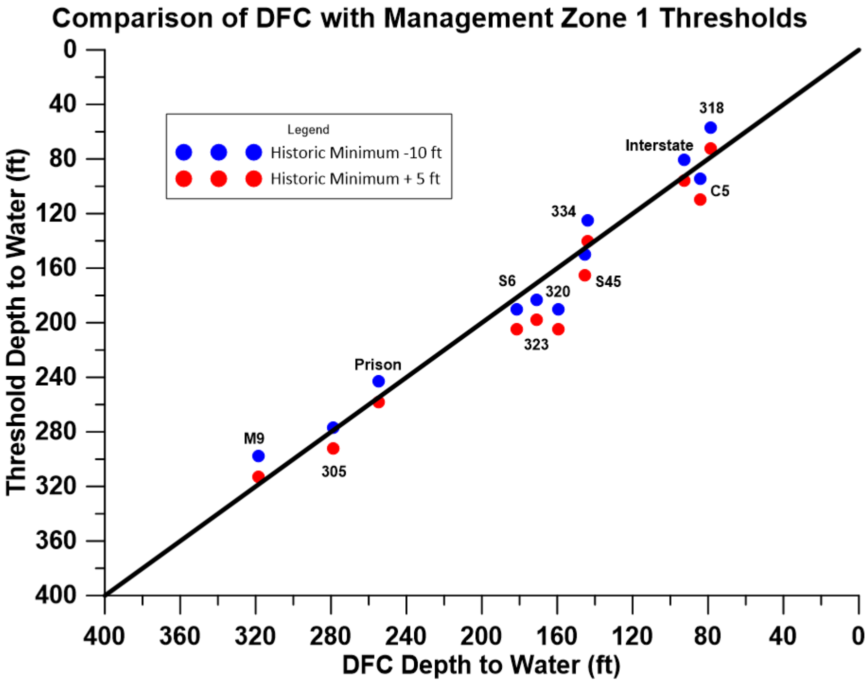


Figure 6. Comparison of DFC with Management Zone 1 Thresholds

Term Permits: The comment encourages "MPGCD to understand the effect of recently enacted section 36.1145 of the Texas Water Code on 'term' permits". Specifically, the letter recommended that "MPGCD give consideration to the noted legislation and how term permits play into the DFCs.

This comment is not strictly relevant to the joint planning process. It was specifically addressed to MPGCD regarding constraints on permit renewals and pumping curtailments, which are issues related to groundwater management and regulation and not joint planning.

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

STATE OF TEXAS §
§ **RESOLUTION # 08-19-2021-3**
GROUNDWATER §
MANAGEMENT AREA 7 §

Resolution Adopting Desired Future Conditions for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers in Groundwater Management Area 7

WHEREAS, Groundwater Conservation Districts (GCDs) located within or partially within Groundwater Management Area 7 (GMA 7) are required under Chapter §36.108, Texas Water Code to conduct joint planning and designate the Desired Future Conditions of aquifers within GMA 7 and;

WHEREAS, the Board Presidents or their Designated Representatives of GCDs in GMA 7 have met in various meetings and conducted joint planning in accordance with Chapter §36.108, Texas Water Code since October 2019 and;

WHEREAS, the GMA 7 Districts have received and considered Groundwater Availability Model runs and other technical advice regarding local aquifers, hydrology, geology, recharge characteristics, local groundwater demands and usage, population projections, other factors set forth in §36.108(d) of the Texas Water Code, from all aquifers within the respective GCDs, ground and surface water inter-relationships, that affect groundwater conditions through the year 2070; and

WHEREAS, the member GCDs of GMA 7, having given proper and timely notice, held an open meeting on March 18, 2021 at the Sutton County Civic Center, 1700 N Crockett, Sonora, Texas, and voted to adopt proposed Desired Future Conditions for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers within the boundaries of GMA 7, noting these proposed DFCs are unchanged from the previously adopted DFCs; and

WHEREAS, the member GCDs in which the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers is relevant for joint planning purposes held open meetings within each said district between March 22, 2021 and July 22, 2021 to take public comment on the proposed DFCs for that district; and

WHEREAS, on this day of August 19, 2021, at an open meeting duly noticed and held in accordance with law, at the Sutton County Civic Center, 1700 N Crockett, Sonora, Texas, the GCDs within GMA 7 voted, upon motion made and seconded, 14 districts in favor, 0 districts opposed, to adopt the following DFCs for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers in the following counties and districts through the year 2070:

a) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **0 feet in Coke County** in 2070 as compared with 2010 aquifer levels.
b) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **10 feet in Crockett County** in 2070 as compared with 2010 aquifer levels.
c) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **4 feet in Ector County** in 2070 as compared with 2010 aquifer levels.
d) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **2 feet in Edwards County** in 2070 as compared with 2010 aquifer levels.

e) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **5 feet in Gillespie County** in 2070 as compared with 2010 aquifer levels.
f) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **42 feet in Glasscock County** in 2070 as compared with 2010 aquifer levels.
g) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **10 feet in Irion County** in 2070 as compared with 2010 aquifer levels.
h) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **1 foot in Kimble County** in 2070 as compared with 2010 aquifer levels.
i) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **1 foot in Menard County** in 2070 as compared with 2010 aquifer levels.
j) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **12 feet in Midland County** in 2070 as compared with 2010 aquifer levels.
k) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **14 feet in Pecos County** in 2070 as compared with 2010 aquifer levels.
l) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **42 feet in Reagan County** in 2070 as compared with 2010 aquifer levels.
m) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **4 feet in Real County** in 2070 as compared with 2010 aquifer levels.
n) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **8 feet in Schleicher County** in 2070 as compared with 2010 aquifer levels.
o) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **7 feet in Sterling County** in 2070 as compared with 2010 aquifer levels.
p) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **6 feet in Sutton County** in 2070 as compared with 2010 aquifer levels.
q) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **0 feet in Taylor County** in 2070 as compared with 2010 aquifer levels.
r) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **2 feet in Terrell County** in 2070 as compared with 2010 aquifer levels.
s) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **20 feet in Upton County** in 2070 as compared with 2010 aquifer levels.
t) Total net drawdown of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers not to exceed **2 feet in Uvalde County** in 2070 as compared with 2010 aquifer levels.
*(Reference items *a)* through *t)*: GMA 7 Technical Memorandum 18-01)
u) 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 and others, 2011).*
v) 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.**
**(Reference: EcoKai, 2014)*
w) The Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers are not relevant for joint planning purposes in all other areas of GMA 7.

NOW THEREFORE BE IT RESOLVED, that Groundwater Management Area 7 does hereby document, record, and confirm the above-described Desired Future Conditions for the **Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers** which were adopted by vote of the following Designated Representatives of Groundwater Conservation Districts present and voting on August 19, 2021:

AYES:

Stanton Milliff
DESIGNATED REPRESENTATIVE – Coke County Underground Water Conservation District

Slater Wilkins
DESIGNATED REPRESENTATIVE – Crockett County Groundwater Conservation District

DESIGNATED REPRESENTATIVE – Glasscock Groundwater Conservation District

DESIGNATED REPRESENTATIVE – Hickory Underground Water Conservation District No. 1

DESIGNATED REPRESENTATIVE – Hill Country Underground Water Conservation District

Scott Hall
DESIGNATED REPRESENTATIVE - Irion County Water Conservation District

Meredith E Allen
DESIGNATED REPRESENTATIVE – Kimble County Groundwater Conservation District

Genell Hobbs
DESIGNATED REPRESENTATIVE - Kinney County Groundwater Conservation District

Leon Brooks
DESIGNATED REPRESENTATIVE - Lipan-Kickapoo Water Conservation District

DESIGNATED REPRESENTATIVE - Lone Wolf Groundwater Conservation District

Meredith E. Allen
DESIGNATED REPRESENTATIVE – Menard County Underground Water District

DESIGNATED REPRESENTATIVE – Middle Pecos Groundwater Conservation District

Jon Cartwright
DESIGNATED REPRESENTATIVE - Plateau Underground Water Conservation and Supply District

Brian
DESIGNATED REPRESENTATIVE - Real-Edwards Conservation and Reclamation District

DESIGNATED REPRESENTATIVE - Santa Rita Underground Water Conservation District

DESIGNATED REPRESENTATIVE - Sterling County Underground Water Conservation District

Meredith E Allen
DESIGNATED REPRESENTATIVE – Sutton County Underground Water Conservation District

Debbie Deaton
DESIGNATED REPRESENTATIVE - Terrell County Groundwater Conservation District

DESIGNATED REPRESENTATIVE - Uvalde County Underground Water Conservation District

DESIGNATED REPRESENTATIVE - Wes-Tex Groundwater Conservation District

NAYES:

____
DESIGNATED REPRESENTATIVE – Coke County Underground Water Conservation District

____
DESIGNATED REPRESENTATIVE – Crockett County Groundwater Conservation District

____
DESIGNATED REPRESENTATIVE – Glasscock Groundwater Conservation District

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DESIGNATED REPRESENTATIVE – Hickory Underground Water Conservation District No. 1

____
DESIGNATED REPRESENTATIVE – Hill Country Underground Water Conservation District

____
DESIGNATED REPRESENTATIVE - Irion County Water Conservation District

____
DESIGNATED REPRESENTATIVE – Kimble County Groundwater Conservation District

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DESIGNATED REPRESENTATIVE - Kinney County Groundwater Conservation District

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DESIGNATED REPRESENTATIVE - Lipan-Kickapoo Water Conservation District

____
DESIGNATED REPRESENTATIVE - Lone Wolf Groundwater Conservation District

____
DESIGNATED REPRESENTATIVE – Menard County Underground Water District

____
DESIGNATED REPRESENTATIVE – Middle Pecos Groundwater Conservation District

____
DESIGNATED REPRESENTATIVE - Plateau Underground Water Conservation and Supply District

____
DESIGNATED REPRESENTATIVE - Real-Edwards Conservation and Reclamation District

____
DESIGNATED REPRESENTATIVE - Santa Rita Underground Water Conservation District

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DESIGNATED REPRESENTATIVE - Sterling County Underground Water Conservation District

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DESIGNATED REPRESENTATIVE – Sutton County Underground Water Conservation District

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DESIGNATED REPRESENTATIVE - Terrell County Groundwater Conservation District

____
DESIGNATED REPRESENTATIVE - Uvalde County Underground Water Conservation District

____
DESIGNATED REPRESENTATIVE - Wes-Tex Groundwater Conservation District

Groundwater Management Area # 7
Joint Planning Meeting

Notice is hereby given that on Thursday, **August 19, 2021 at 10:00 a.m.** that one or more members of the Board of Directors and/or the designated representative of said boards of Groundwater Conservation Districts within the Texas Water Development Board-designated **Groundwater Management Area # 7** of the State of Texas will meet at the **Sutton County Civic Center, 1700 North Crockett Street, Sonora, TX 76950,** for the purposes of conducting joint planning in compliance with the requirements of Section 36.108 of the Texas Water Code.

Agenda

1. Call to Order and Invocation
2. Introduction of Member Districts and other persons in attendance
3. Public Comment
4. Consider and Possible Action on Minutes of the March 18, 2021 meeting
5. Update from the Texas Water Development Board
6. Review of public comments received during 90-day period
7. Presentation by Dr. Bill Hutchison on draft responses to public comments on proposed DFCs
8. Consider and Possible Action on Adoption of Resolution to declare the Blaine, Igneous, Lipan, Marble Falls, Seymour, and Cross Timbers aquifers not relevant for joint planning purposes within GMA 7 and consequently not requiring adoption of a proposed Desired Future Condition or development of Managed Available Groundwater numbers by the Texas Water Development Board.
9. Consider and Possible Action on Adoption of Resolutions for proposed DFCs for the following aquifers within boundaries of GMA 7:
    a. Capitan Reef Complex Aquifer
    b. Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers.
    c. Llano Uplift region (Ellenburger-San Saba, Hickory, Marble Falls aquifers)
    d. Ogallala and Dockum aquifers
    e. Rustler Aquifer
10. Next steps in Joint Planning Process
11. Other Matters to come before the membership
12. Set date and preliminary agenda for next meeting
13. Adjourn

Groundwater Conservation Districts located partially or wholly within
Groundwater Management Area # 7 are:

Coke County UWCD; Crockett County GCD; Glasscock GCD; Hickory UWCD No. 1; Hill Country UWCD; Irion County WCD; Kimble County GCD; Kinney County GCD; Lipan-Kickapoo WCD; Lone Wolf GCD; Menard County UWD; Middle Pecos GCD; Plateau UWC&SD; Real-Edwards C&RD; Santa Rita UWCD; Sterling County UWCD; Sutton County UWCD; Terrell County GCD; Uvalde County UWCD; Wes-Tex GCD

Requests for additional information and comments may be submitted to:

Meredith Allen
GMA # 7 Coordinator
Sutton County Underground Water Conservation District
301 S. Crockett Ave, Sonora, Texas 76950
Telephone: 325-226-9093 / Fax: 325-387-5737
e-mail: manager@suttoncountyuwcd.org

FILED
THE 5 DAY OF August, 2021
AT O'CLOCK 8:40 A M.
SHIRLEY GRAHAM
COUNTY DIST. CLERK, IRION COUNTY, TX
BY
DEPUTY

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
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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

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
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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

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
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
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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

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
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

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

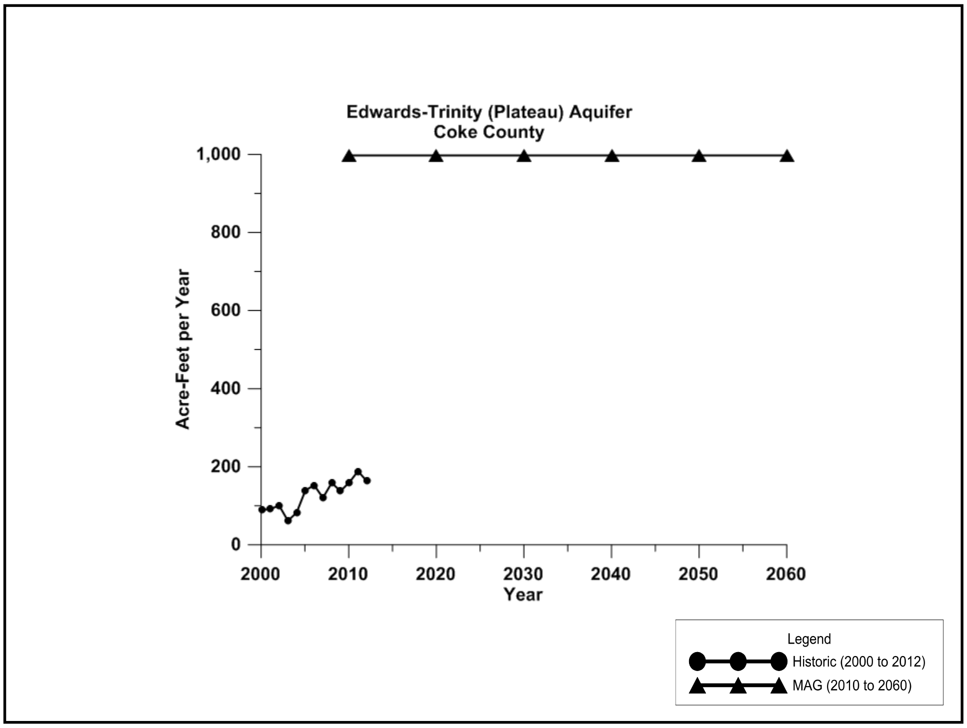
Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2007	UPTON	PECOS AQUIFER	0	0	0	0	0	1	1
2008	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2009	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2010	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2011	UPTON	PECOS AQUIFER	0	0	0	0	0	0	0
2012	UPTON	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

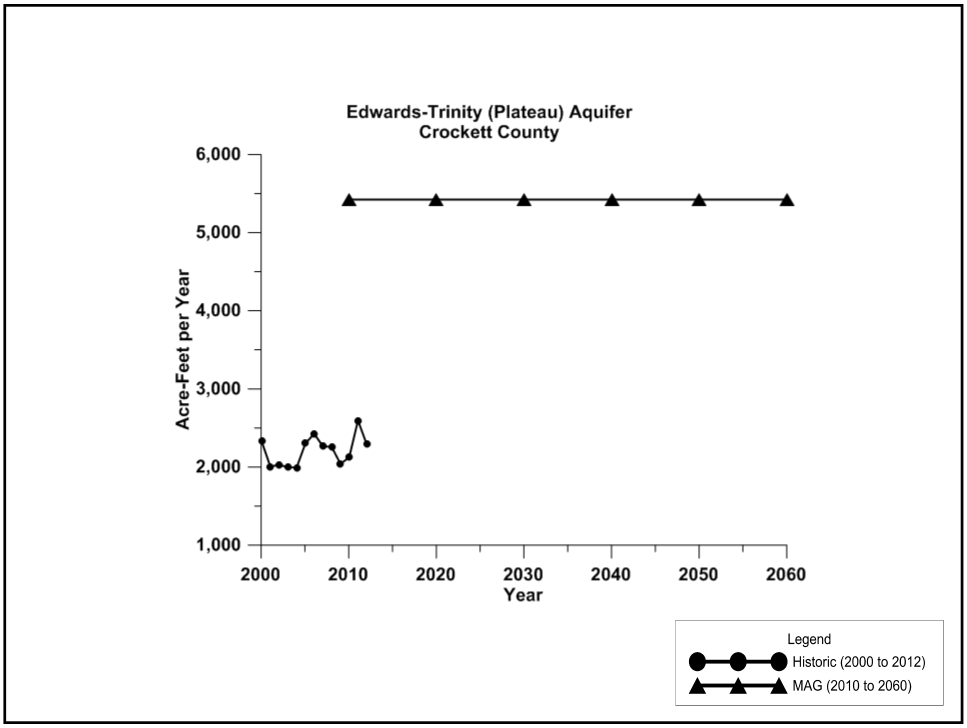
Appendix B - Historic Pumping from the Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers

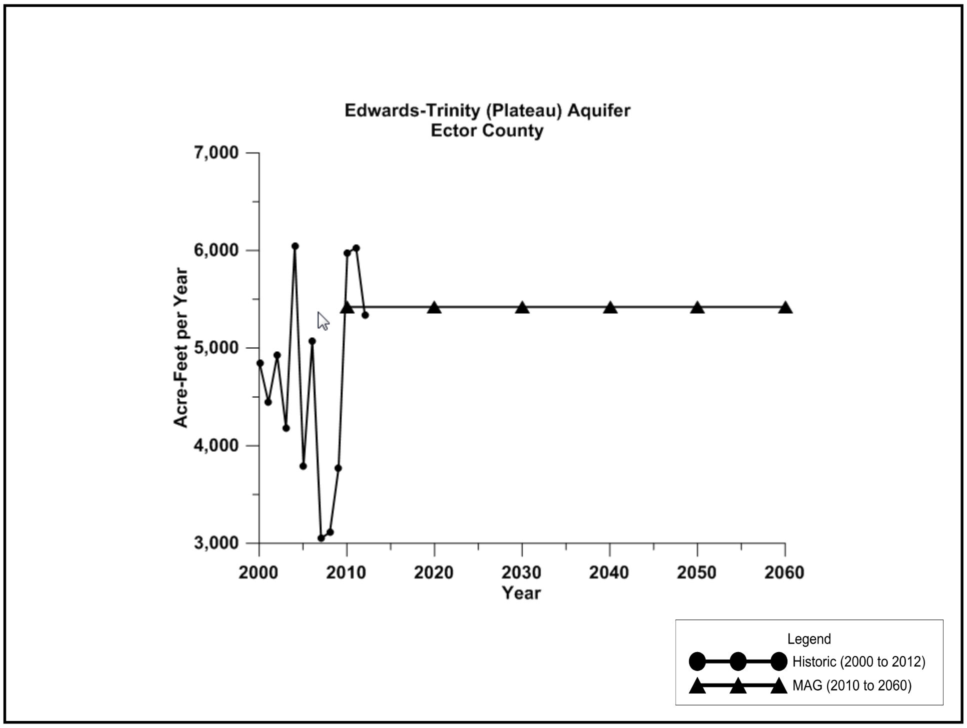
Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2000	UVALDE	TRINITY AQUIFER	0	0	0	0	0	49	49
2001	UVALDE	TRINITY AQUIFER	0	0	0	0	0	46	46
2002	UVALDE	TRINITY AQUIFER	0	0	0	0	0	45	45
2003	UVALDE	TRINITY AQUIFER	0	0	0	0	0	43	43
2004	UVALDE	TRINITY AQUIFER	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

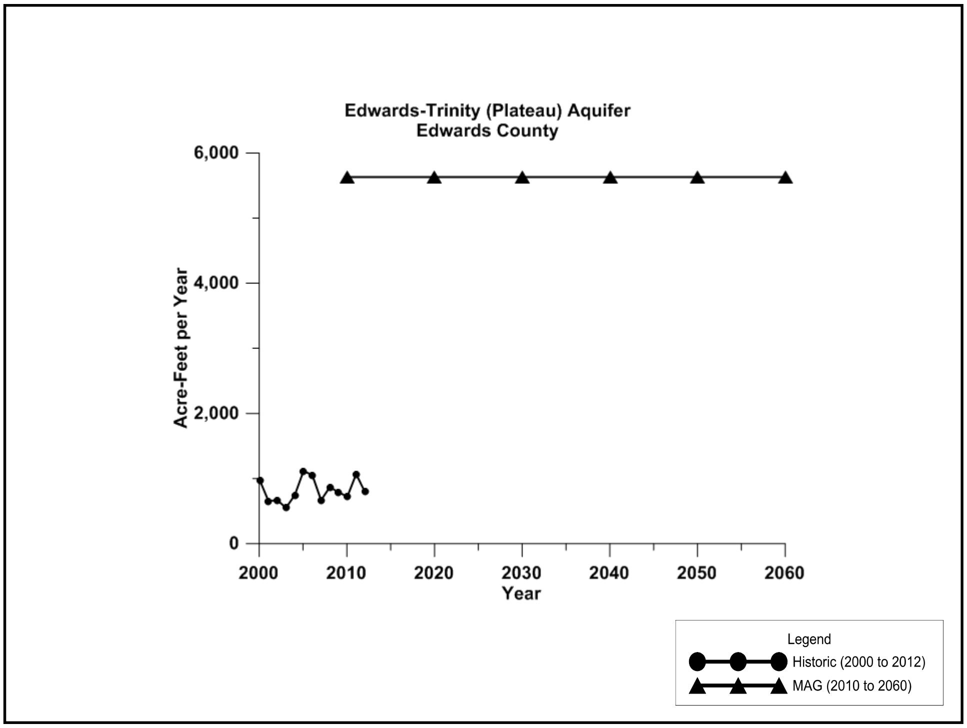
Hydrographs Comparing Historic Pumping and Modeled Available Groundwater from the Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers


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)

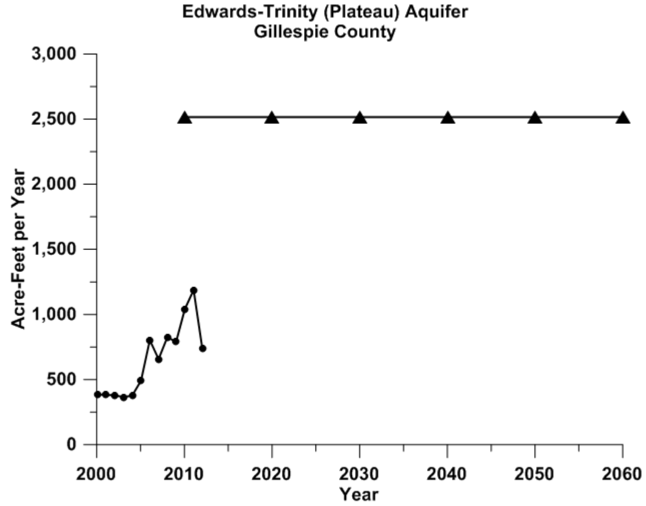

Edwards-Trinity (Plateau) Aquifer
Crockett County
Acre-Feet per Year
6,000
5,000
4,000
3,000
2,000
1,000
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)

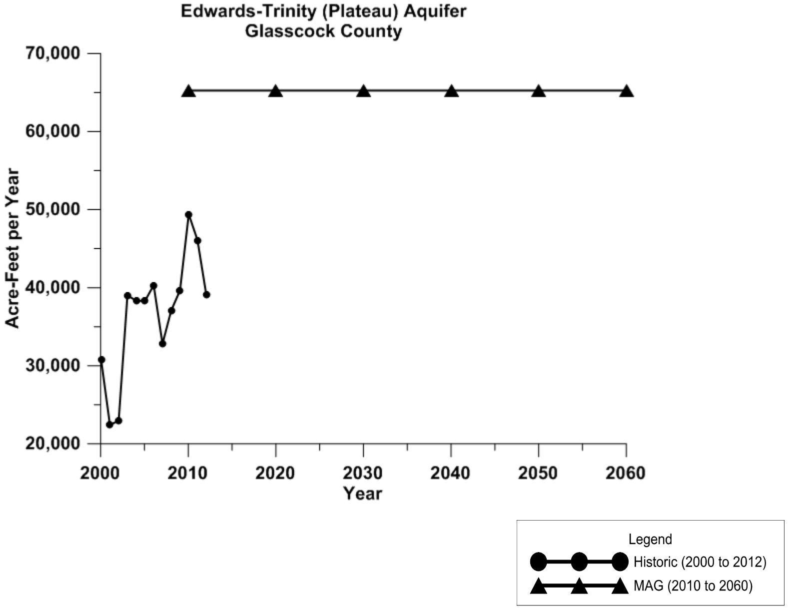


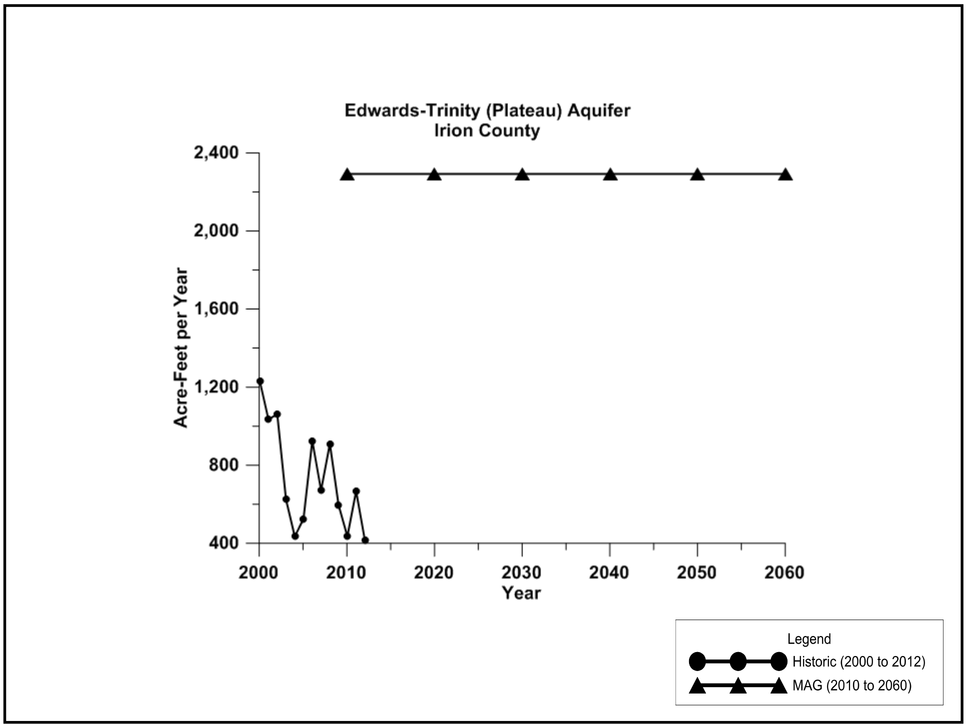
Edwards-Trinity (Plateau) Aquifer
Ector County
7,000
6,000
5,000
4,000
3,000
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)



Edwards-Trinity (Plateau) Aquifer
Edwards County
6,000
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
3,000
2,500
2,000
1,500
1,000
500
0
2000
2010
2020
2030
2040
2050
2060
Year


Edwards-Trinity (Plateau) Aquifer
Glasscock County
Acre-Feet per Year
70,000
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
Acre-Feet per Year
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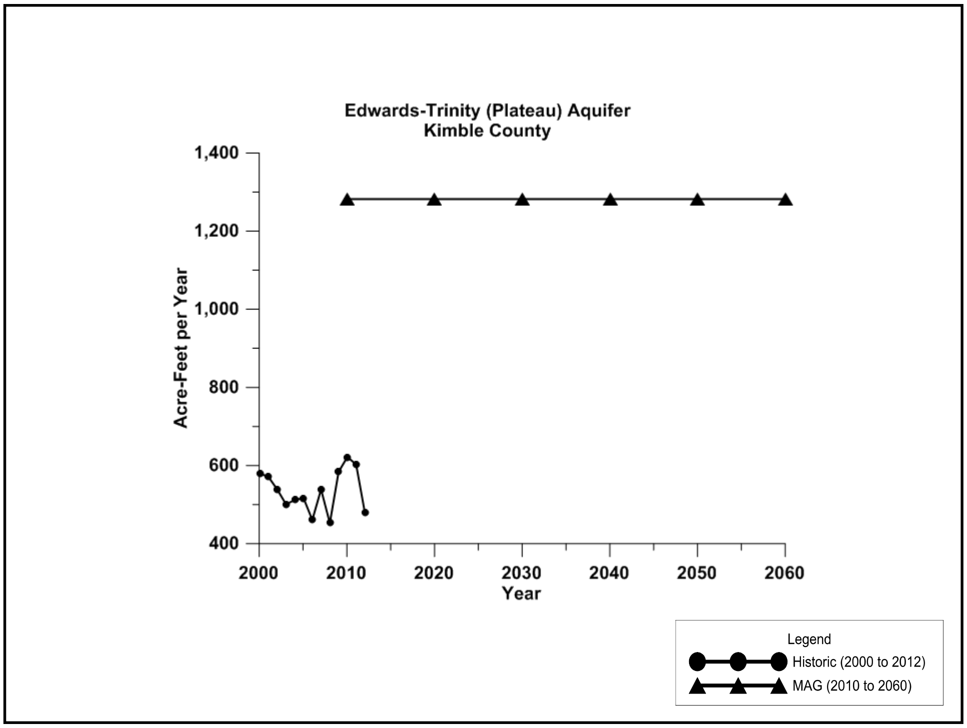
2,000
1,600
1,200
800
400
2000
2010
2020
2030
2040
2050
2060
Year
Legend
● Historic (2000 to 2012)
▲ MAG (2010 to 2060)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Kimble County
Acre-Feet per Year
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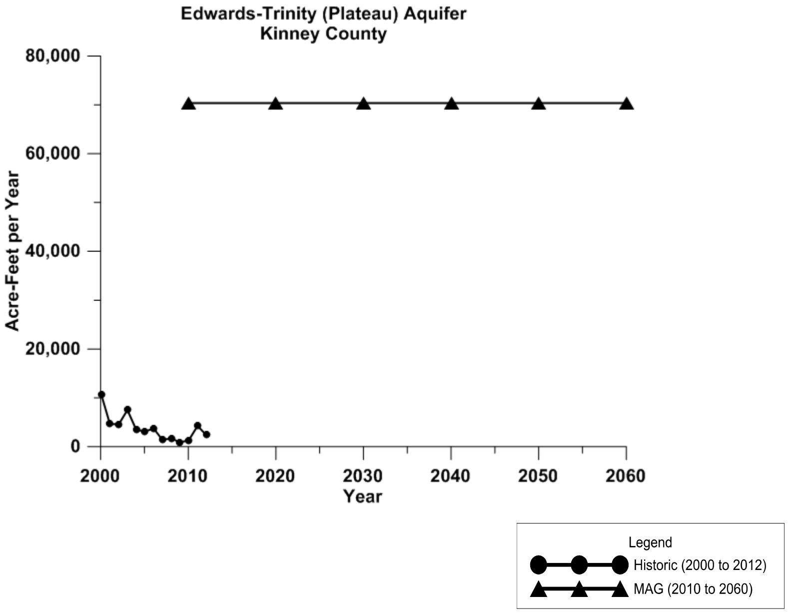
1,200
1,000
800
600
400
2000
2010
2020
2030
2040
2050
2060
Year
Legend
● Historic (2000 to 2012)
▲ MAG (2010 to 2060)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Kinney County
Acre-Feet per Year
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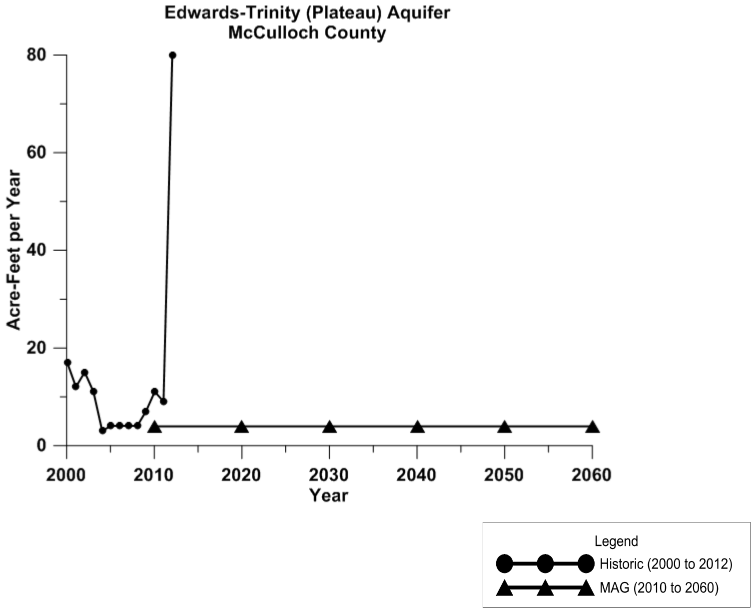
60,000
40,000
20,000
0
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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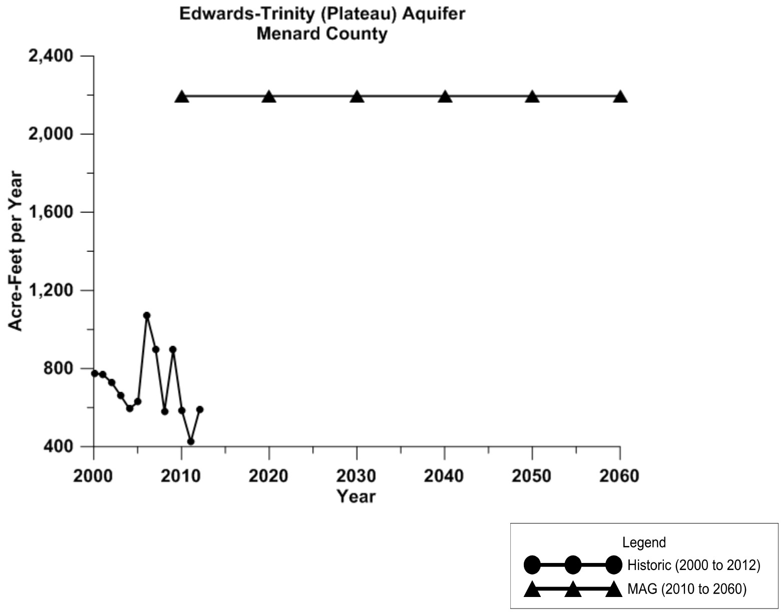
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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Acre-Feet per Year
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1,600
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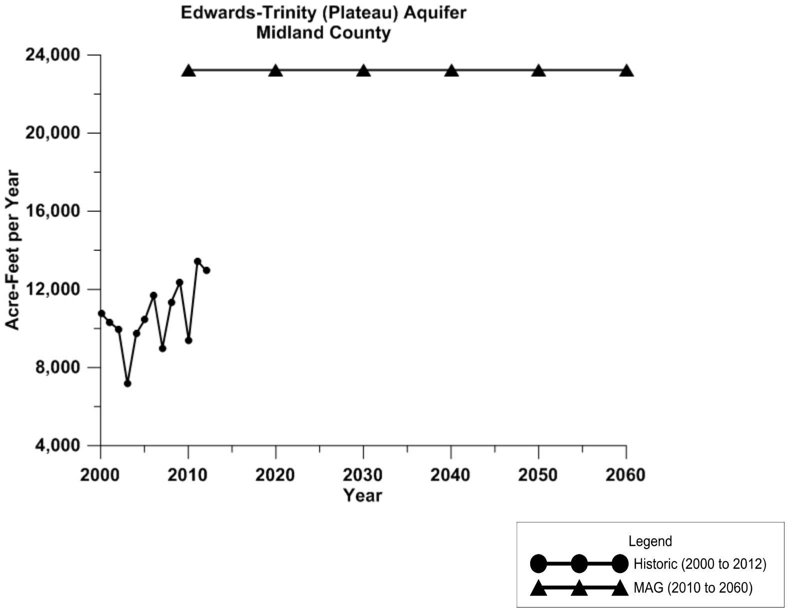
800
400
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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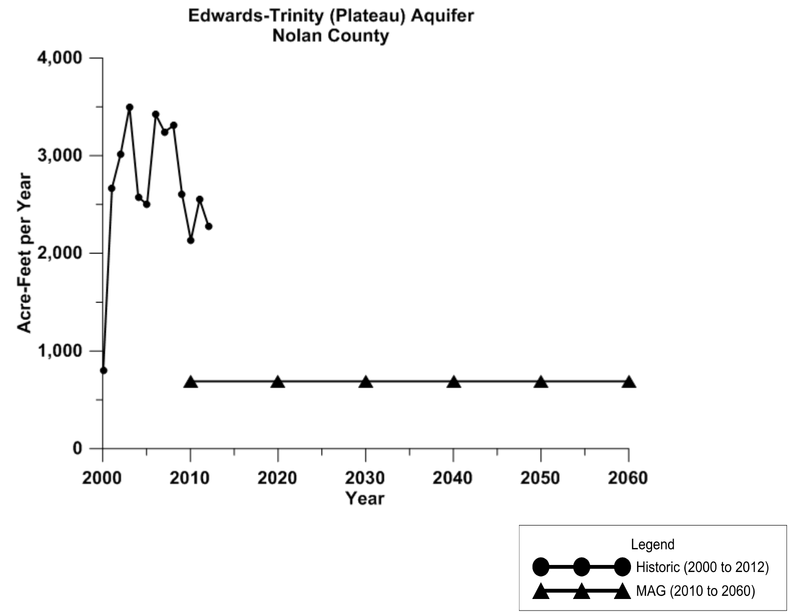
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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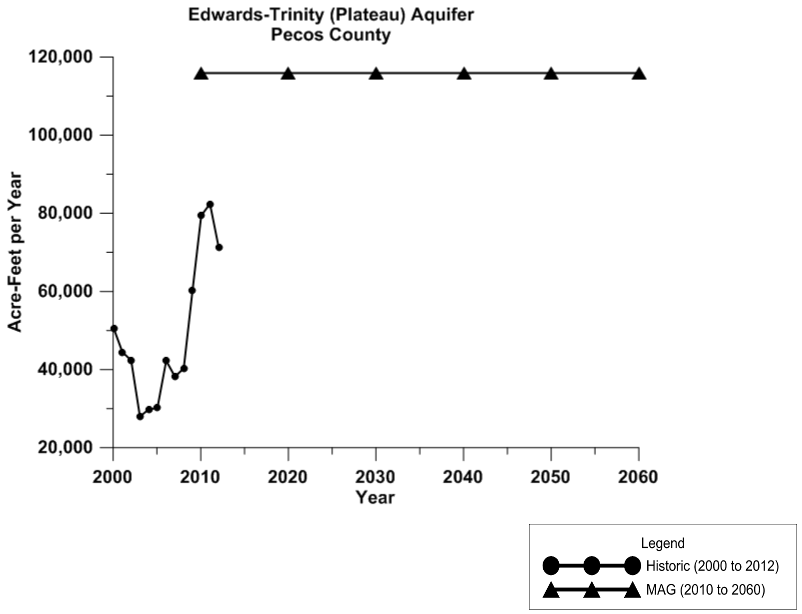
3,000
2,000
1,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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Pecos County
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80,000
60,000
40,000
20,000
Acre-Feet per Year
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Year
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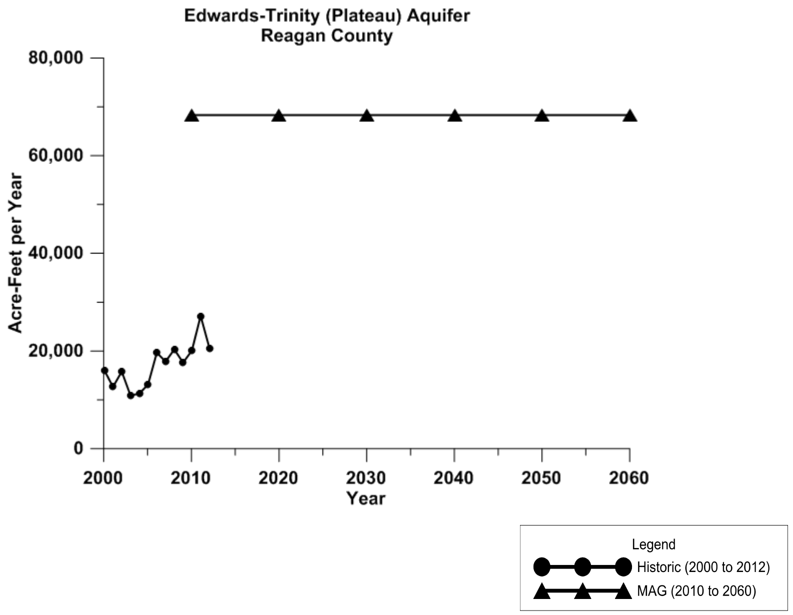
Historic (2000 to 2012)
MAG (2010 to 2060)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40,000
20,000
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Acre-Feet per Year
2000
2010
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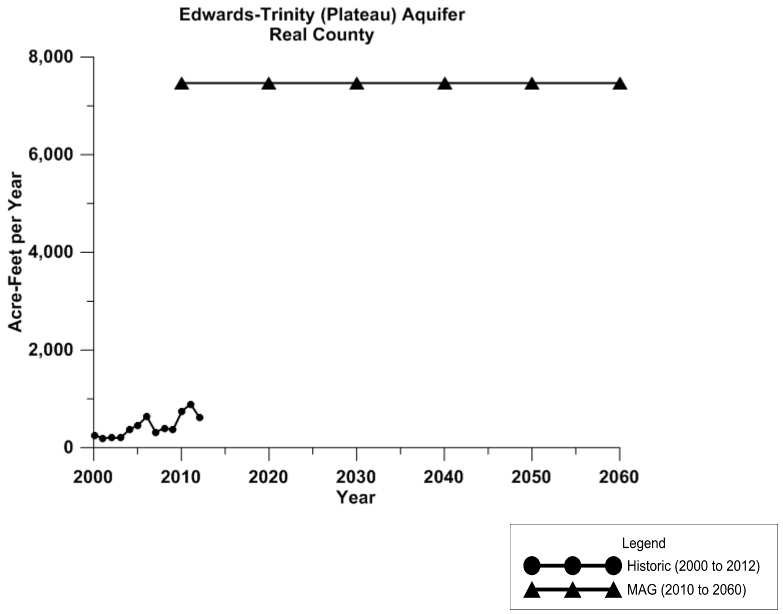
Historic (2000 to 2012)
MAG (2010 to 2060)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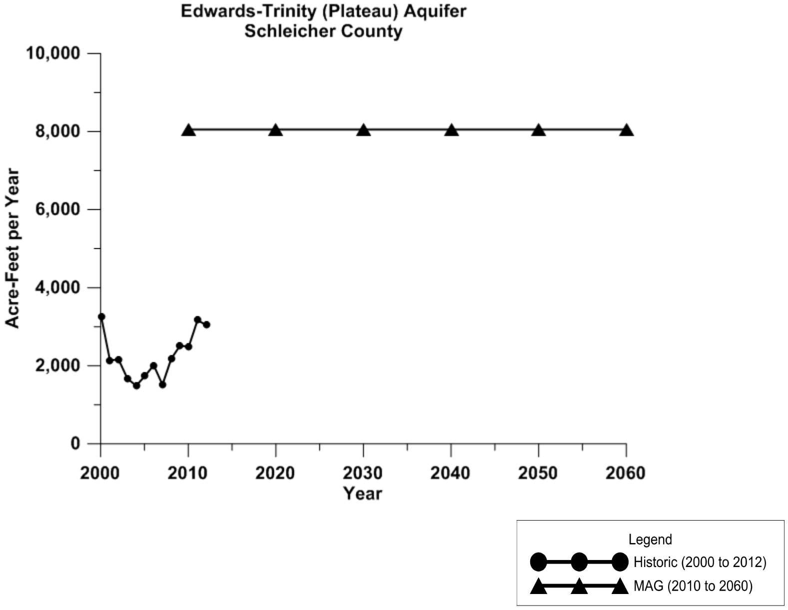
Real County
8,000
6,000
4,000
2,000
0
Acre-Feet per Year
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)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Schleicher County
Acre-Feet per Year
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8,000
6,000
4,000
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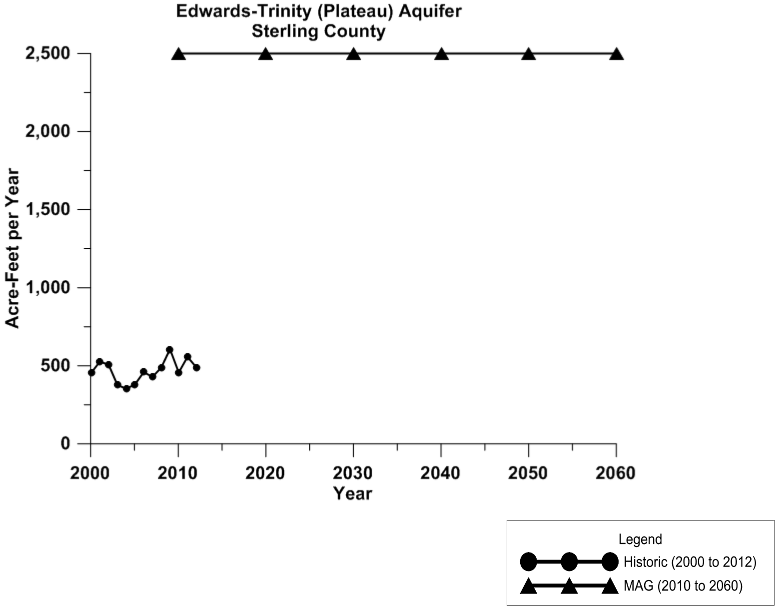
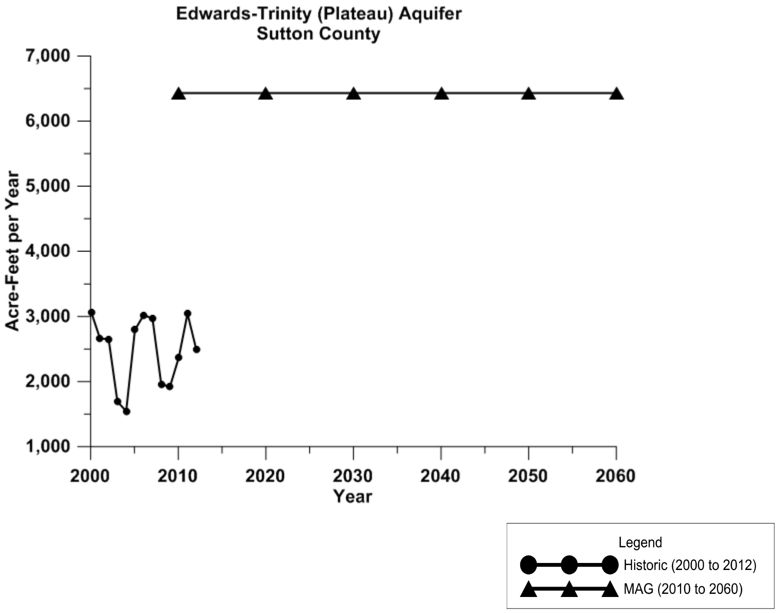
2000
2010
2020
2030
2040
2050
2060
Year
Legend
Historic (2000 to 2012)
MAG (2010 to 2060)


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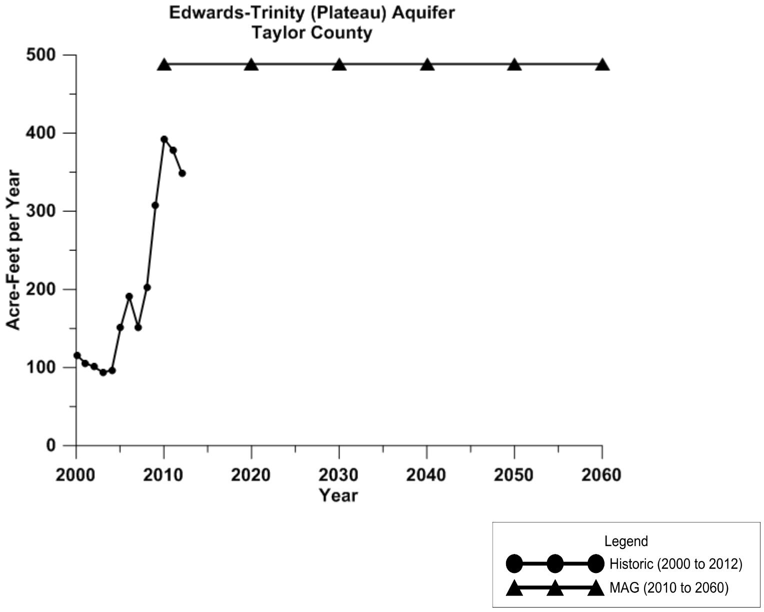
Sutton County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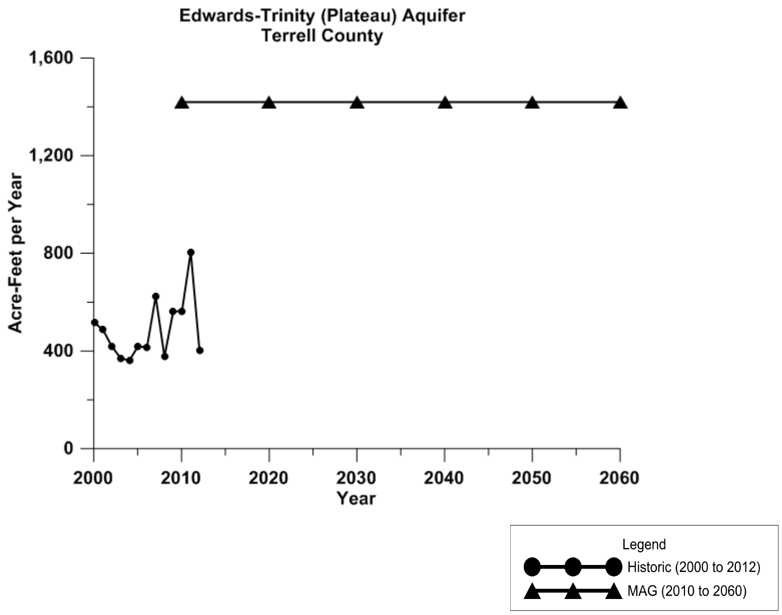
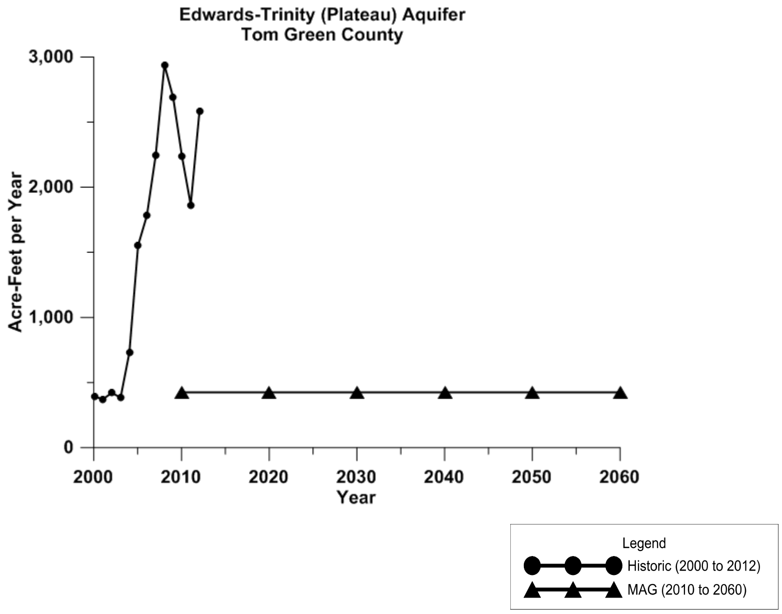
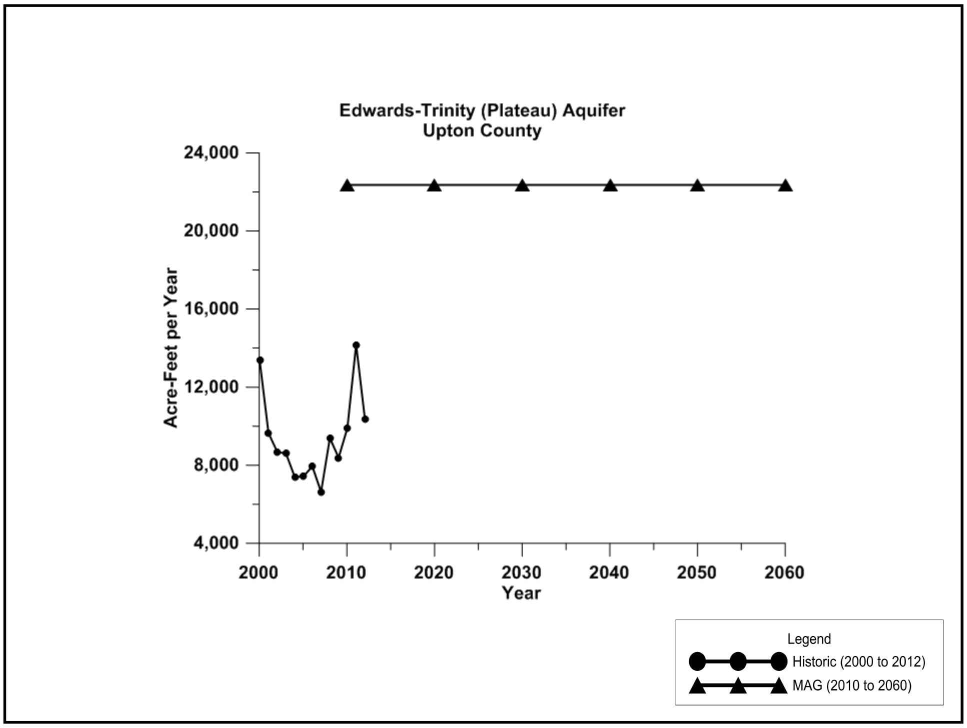
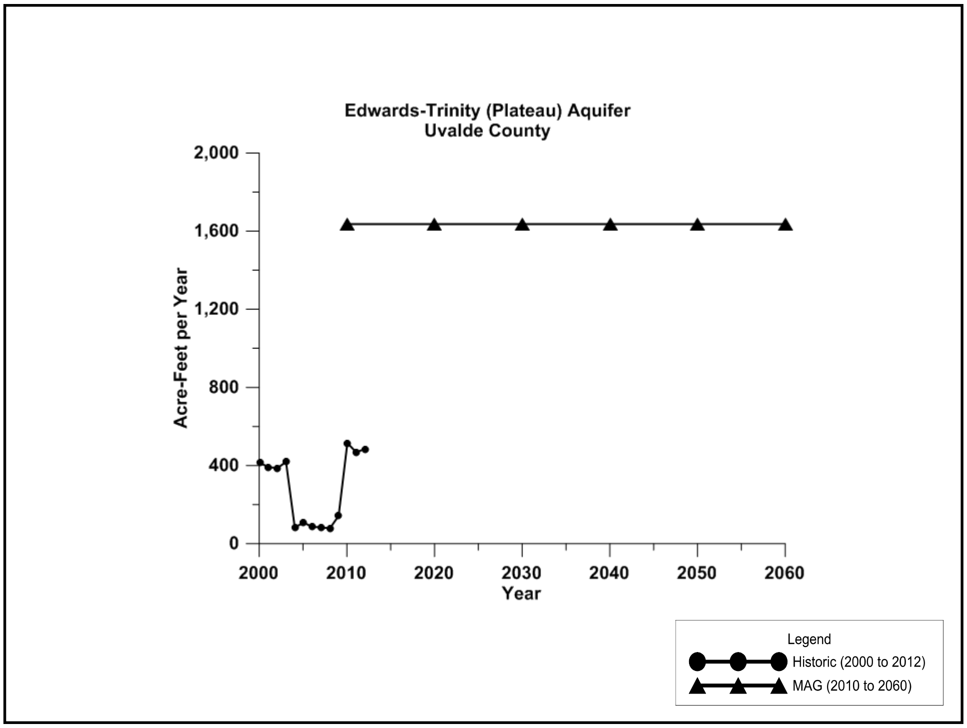
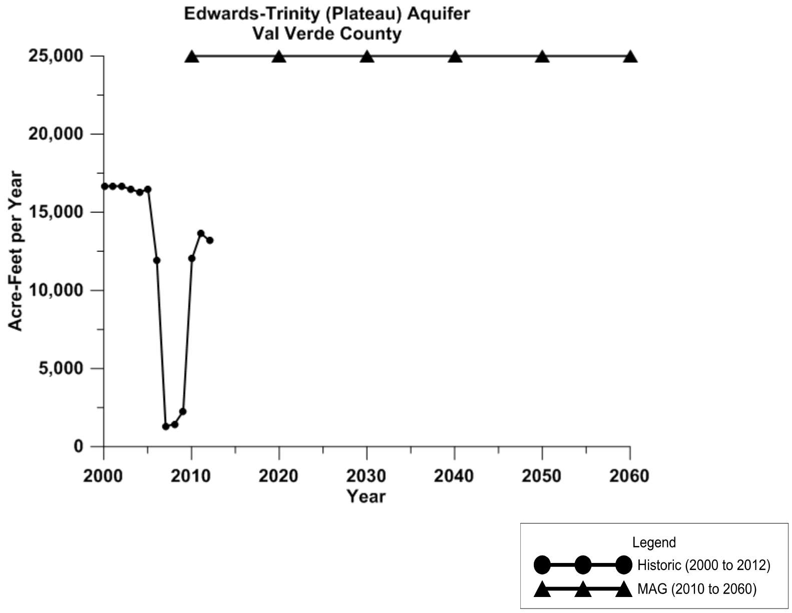
Taylor County


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
24,000
20,000
16,000
12,000
8,000
4,000
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
Uvalde County
2,000
1,600
1,200
800
400
0
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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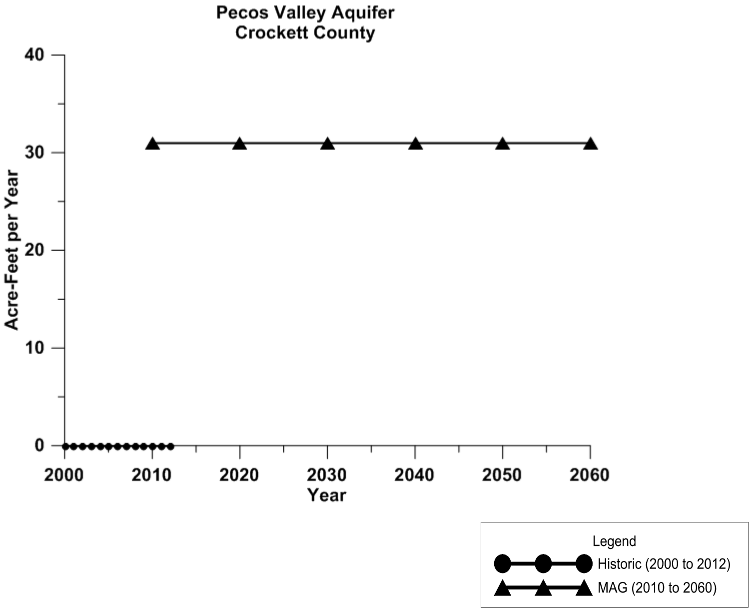
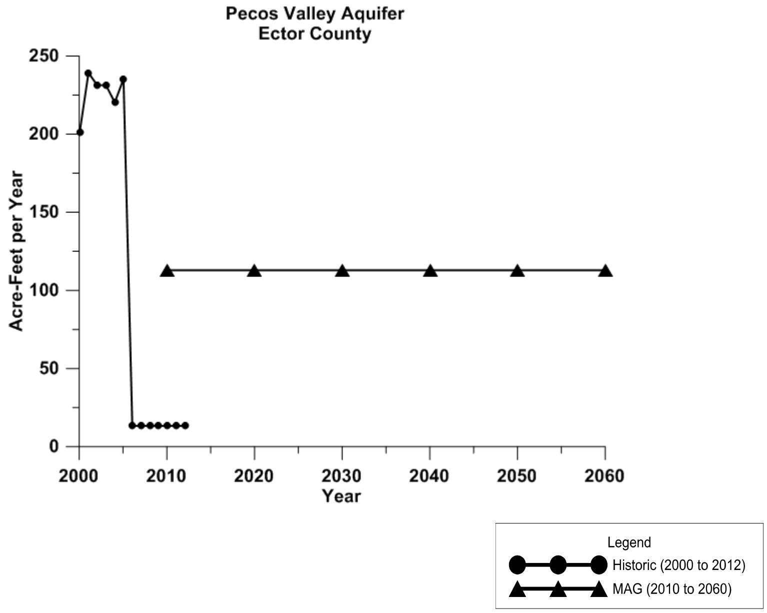
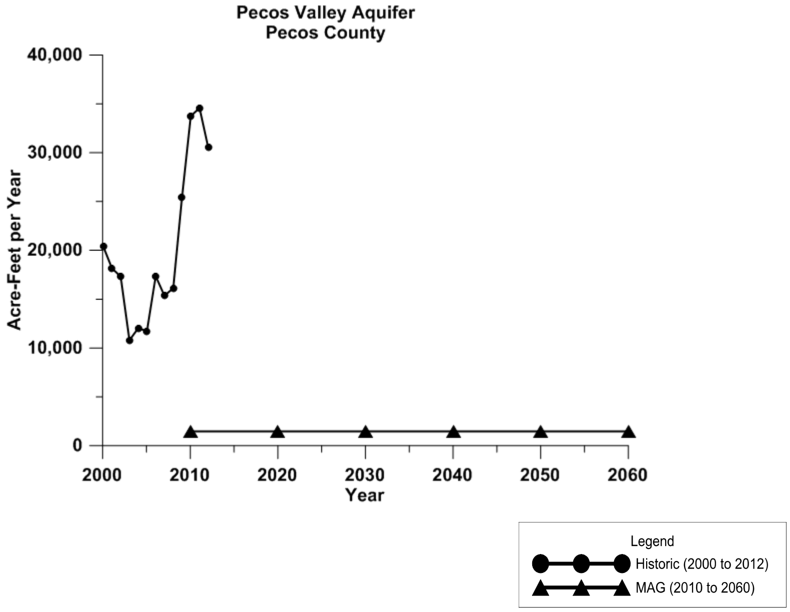
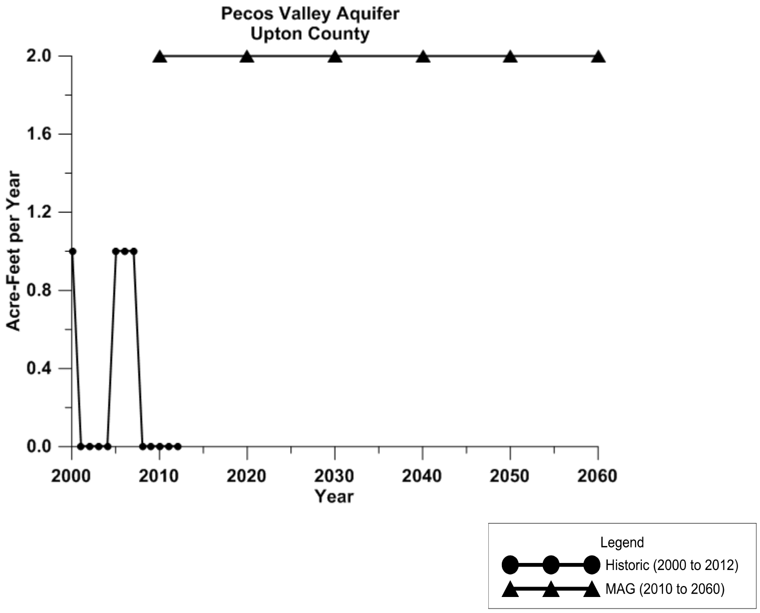
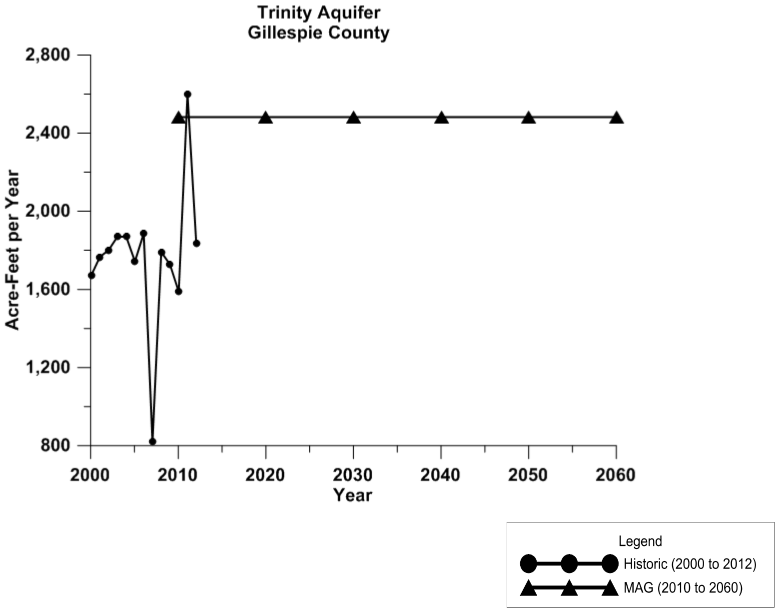
Val Verde County

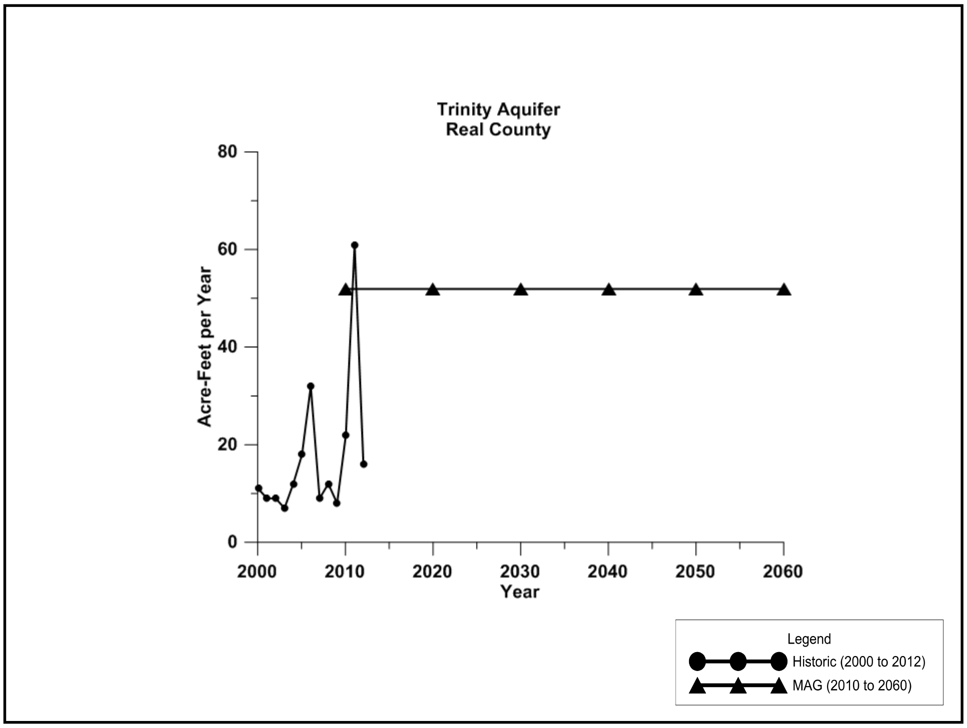

Pecos Valley Aquifer
Crockett County


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

Texas Water Development Board

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

November 2021

Table of Contents

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.

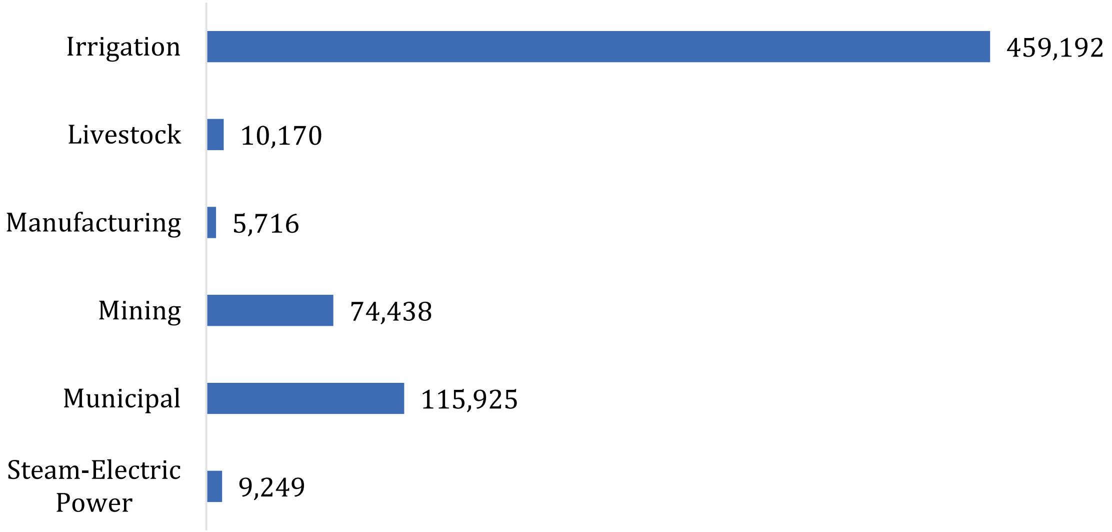
Table 1-1 Region F regional economy by economic sector*

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)

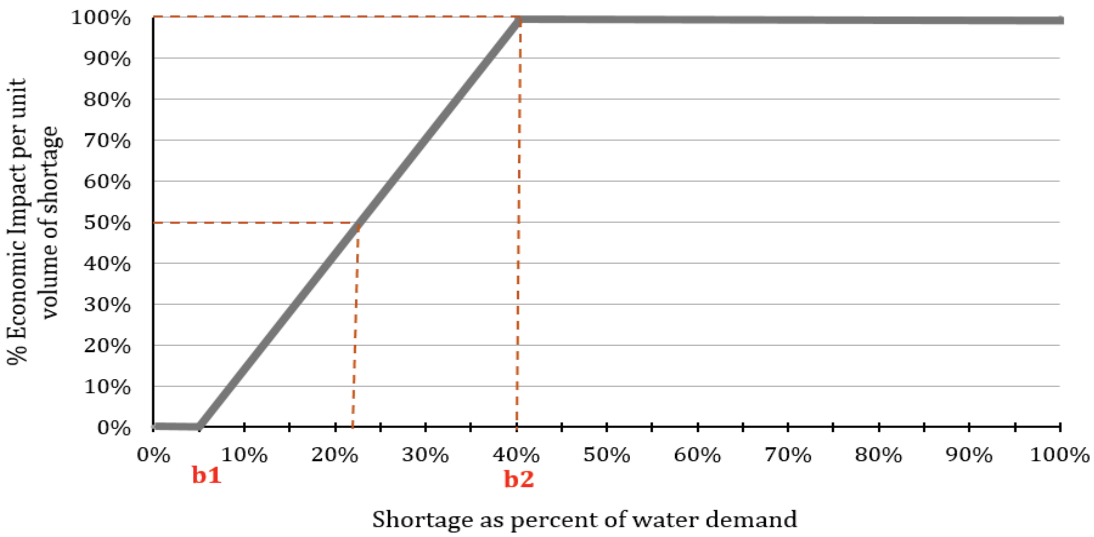


Table 3-1 Economic impact elasticity function lower and upper bounds

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

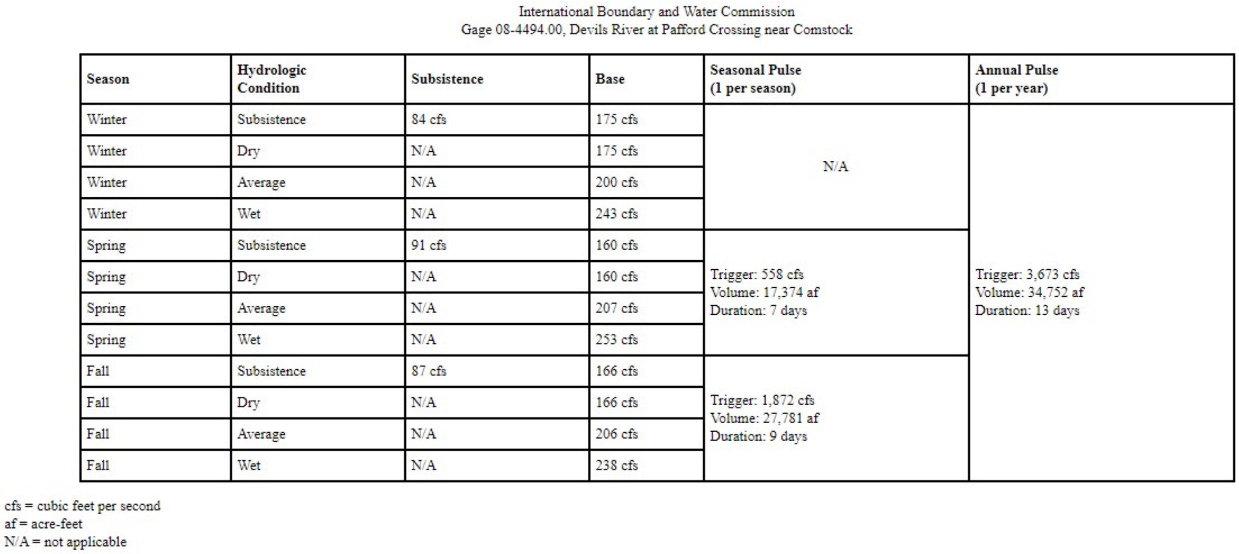
Much information has been developed over the last ten years on the Devils River. This work is the result of multi-partner collaborations and has brought more than $2 million in federal and private funding to research in the Devils River watershed. Key contributions have been made by stakeholders and 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.

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Appendix F

Letter from Texas Parks & Wildlife

TEXAS PARKS & WILDLIFE
Life's better outside.®

December 17, 2020

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

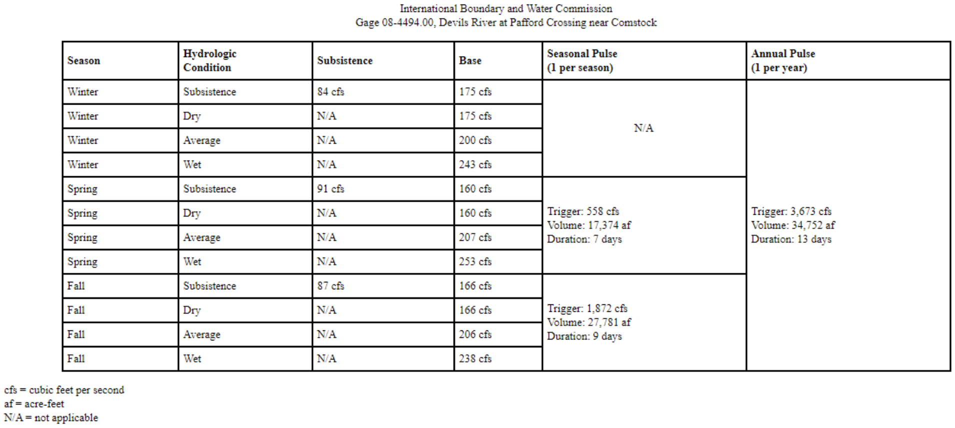
Much information has been developed over the last ten years on the Devils River. This work is the result of multi-partner collaborations and has brought more than $2 million in federal and private funding to research in the Devils River watershed. Key contributions have been made by stakeholders and 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

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Appendix G

Letter from Devils River Association

Devils River Association
1566 Private Road 1500
Del Rio, Texas 78840

January 14, 2021

Ms. Meredith E. Allen
GMA7 Coordinator
General Manager
Sutton County Underground Water Conservation District
301 South Crockett Avenue
Sonora, Texas 76950

Re: Proposed Consideration of a Desired Future Condition for the Devils River Watershed in Val Verde County

Dear Ms. Allen,

As Coordinator for GMA7, you likely know that the Devils River Association (DRA) has been composed entirely of Devils River Watershed ranchers and landowners since its creation. As the River's historic multi-generational stewards, DRA's membership has played a strategic role in the conservation and protection of the Devils River and its resources from prior to the Texas drought of record through to the present. It has come to DRA's attention that GMA7 has received correspondence from The Nature Conservancy and the Devils River Conservancy urging consideration for the adoption of a Devils River specific DFC (Desired Future Condition) for Val Verde County. While the DRA shares many of the preservation goals of these Conservancies, the Association believes it imperative that you and your fellow directors also consider the independent views of the DRA membership on such matters. Accordingly, at your direction and convenience, please distribute a copy of this letter to each of your member representatives.

It should be first noted that the importance and complexity of Val Verde County's water resources is not an only recently recognized phenomenon. Due to their long acknowledged value and importance, the county's groundwater resources have been extensively studied over the past 50 years, albeit without meaningful consensus among hydrogeological professionals as to critical aquifer properties and spring flow parameters. Indeed, the Texas Water Development Board (TWBD), in its 2018 Overview of Val Verde County groundwater conditions, advises that the primary obstacle preventing both such consensus and an accurate and reliable assessment of potential pumping impacts, critical to the formation of a DFC, has been the absence of adequate historic spring flow and pumping correlation data, not a lack of modeling efforts or impact studies. Texas' Region J Planning Group has also recognized this lack of correlative data in its 2021 Regional Water Plan, and rejected a proposed Water Plan recommendation that a groundwater conservation district be created for Val Verde County. It also should also be noted that there is no known urgency associated with the adoption of a watershed specific DFC, as there are no existing or proposed water development projects within Val Verde County which threaten our county's groundwater or surface water resources. Indeed, all foreseeable water needs of all significant regional water development candidates, like the cities of San Antonio, San Angelo, Midland and Abilene, have been met with executed long term supply contracts from other groundwater formations.

The Association believes that the joint planning process prescribed by Texas Water Code §36.108 requires that a DFC be supported by clearly defined data and appropriate modeling methodologies and is to be proposed by and enforced by the groundwater conservation district (GCD) for whom the DFC is adopted. The Water Code does not authorize that a DFC be created in order to be used in an effort to "define the scope of '' or otherwise serve as a prelude to an undefined and undetermined GCD that may or may not be created in the future. For the reasons further set forth below, the Association believes that a Devils River specific DFC, and any GCD creation based upon such DFC, is ill advised at this time as such proposed DFC adoption would lack the support of both critical historic data and appropriate, accurate and reliable modeling, and the creation of a GCD, without such critical data and appropriate modeling, would be premature, exceedingly costly and pose a significant "takings" liability risk.

Texas Water Code §36.1132(a) mandates that a GCD accurately and reliably ascertain "the point that total volume of exempt and permitted groundwater production will achieve an applicable desired future condition." Such an undertaking, according to the Texas Water Development Board's 2018 Overview, requires that the GCD perform a

> quantitative evaluation of the effects of potential future pumping on recharge, stream flow and groundwater-surface water interaction (requiring) an appropriately scaled, calibrated, and validated numerical model of coupled groundwater and surface water processes. (p.66)

The problem, as further explained by the TWDB in late 2018, is that "such a model is not currently available and key inputs needed to develop one are not well constrained." (Id)

The lack of adequate data and reliable, accurate modeling also precludes the development of a DFC specific to the Devils River. As frequently noted in the TWDB's 2018 Overview:

> Aquifer properties are poorly defined in most of Val Verde County because there are few data on aquifer responses to pumping stresses. These data are needed to estimate critical parameters such as aquifer hydraulic conductivity and storage. Preferably, aquifer tests could be designed and conducted on wells constructed for this purpose and located where data are most needed. (p. 76)
>
> Water level measurements are the fundamental record required to assess groundwater resources. The current network of observation wells does not provide adequate spatial or temporal detail over the extent of Val Verde County. (p. 75)
>
> Models need to incorporate higher temporal and spatial resolution than the regional Edwards-Trinity (Plateau) Aquifer GAM to assess compliance with desired future conditions, but data to support more detailed models are generally lacking. (p. 66)
>
> Several lines of evidence suggest that a large part of the Val Verde water budget actually originates outside the model domain; if so, these models are not properly calibrated and estimates of aquifer properties and the groundwater volumes available for use are likely in error. (p. 66)

No matter how well intentioned a Val Verde County GCD creation might be, because of the county's general lack of wealth, its geologic complexity and absence of correlative data, the proper functioning and development of a meaningful and enforceable management plan and permitting program, requiring 1) the acquisition and implementation of test wells and testing protocols, 2) the performance of the "quantitative evaluation" of groundwater surface water interactions described by the TWBD, and 3) the development and employment of an "appropriately scaled, calibrated, and validated numerical model of coupled groundwater and surface water processes" required for both predictive accuracy and reliability, the tax base of any Val Verde County GCD would be sorely strained if not wholly overwhelmed. Such limited tax base would be further negatively impacted by "takings" litigation, as encountered by a number of GCDs whose regulatory process and licensing efforts have been challenged for regulatory overreach and property right confiscation. The *Edwards Aquifer Authority v. Bragg* case, for example, resulted in a final takings liability award of $4.5 million against the Aquifer Authority. Unfortunately, in these litigious times, groundwater conservation districts can be easy targets for takings claims whenever such districts attempt to balance the interests of property owners wishing to maximize their business opportunities with the public goal of resource conservation. Creating a GCD without the tools and evidentiary support needed to fight off such legal challenges can only compound the prospect of fiscal failure and, in the interim, result in a false sense of resource protection.

The current lack of aquifer defining quantitative data and reliable, calibrated and validated modeling assessments both precludes the adoption of an accurate and reliable DFC and would make the creation of a GCD an expensive exercise in sheer folly where permit approvals or denials can be legitimately challenged based upon the quality of evidence presented or lack thereof. It should be noted that the lack of adequate available data and/or expert modeling analysis to support a district's regulatory decisions will not qualify as a defense of such determinations, but could readily support claims that such actions are arbitrary or capricious, thereby resulting in monetary liability.

The creation of a groundwater conservation/management district in Val Verde County has been the topic of considerable debate since the establishment of Texas Water Code Chapter 36's enabling legislation. Such creation has been repeatedly presented and rejected at the Texas Legislature over the last several legislative sessions as well as by the Region J Water Planning Group in its 2021 Water Plan. How such a district would protect either private property rights or potentially at risk water resources has beguiled stakeholders ever since such questions first arose. The lack of consensus among geohydrology professionals as to Val Verde County's aquifer recharge, conductivity and storage properties, compounded by an inadequate level of recorded water data details that can be accurately and reliably correlated to aquifer pumping in or near the Devils River Watershed, has been and continues to be a serious obstacle to the development of a DFC specific to the Devils Watershed, much less any appropriate groundwater management effort. It is beyond the purpose of a DFC to define the scope of or otherwise serve as a prelude to the creation of a DFC. Additionally, the costs and legal consequence uncertainties posed by a GCD creation confound any proposition that one be created near term. Under the totality of circumstances presented, neither the facts, nor the science nor applicable legal authorities support the adoption of a Devils River Watershed specific Desired Future Condition or the creation of a Val Verde County groundwater conservation district at this time.

Sincerely,

Skip Newsom

Skip Newsom
Water Resource Committee Chair
On Behalf of the Board of Directors
Devils River Association

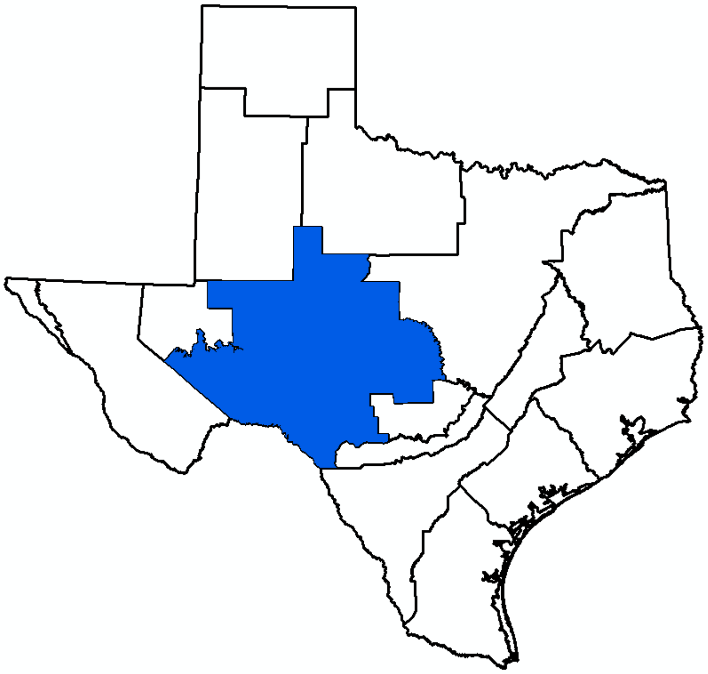
cc: Ryan Smith, The Nature Conservancy
Julie Lewey, Devils River Conservancy

Appendix H

Technical Memorandum 21-01
Analysis of Seasonal Pumping in Management Zone 1 of MPGCD

GMA 7 Technical Memorandum 21-01 - Final

Quantitative Assessment of Impacts: Conversion of Historic Groundwater Pumping from Irrigation Use to Municipal Use in Management Zone 1 of the Middle Pecos Groundwater Conservation District



Prepared for:
Groundwater Management Area 7

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August 28, 2021

GMA 7 Technical Memorandum 21-01 - Final

Quantitative Assessment of Impacts: Conversion of Historic Groundwater Pumping from Irrigation Use to Municipal Use in Management Zone 1 of the Middle Pecos Groundwater Conservation District

Geoscientist and Engineering Seal

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

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

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

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8/28/2021

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A – Belding Farms Drawdown Hydrographs

1.0 Introduction

1.1 Background

The groundwater conservation districts in Groundwater Management Area 7 proposed desired future conditions for the Edwards-Trinity (Plateau) Aquifer (and other aquifers) at their meeting of March 18, 2021. After the meeting, the Groundwater Management Area 7 coordinator sent each groundwater conservation district the proposed desired future conditions, which began a 90-day public comment period. During the public comment period, each groundwater conservation district held a public hearing and received written comments.

Belding Farms provided written comments to Middle Pecos Groundwater Conservation District in a letter dated June 4, 2021, which was an updated version of a letter sent on February 2, 2021. Mr. Ryan Reed, representing Belding Farms/Cockrell Investments, provided oral comments at the Middle Pecos Groundwater Conservation District public hearing on June 15, 2021. Finally, Belding Farms provided additional written comments in a letter to Middle Pecos Groundwater Conservation District dated June 17, 2021.

The June 4, 2021 letter stated that, since the adoption of the 2016 desired future conditions, "a permit has been granted which would allow the export of water from the MPGCD for municipal use". Further, the letter stated that "groundwater production for municipal purposes can have different pumping patterns as compared with agricultural uses". The stated concern in the letter is that the "differences can have significant effects on localized groundwater availability and reliability, and to the anticipated aquifer recovery rate". Finally, the comment concluded that "we anticipate these impacts to be most pronounced during high water use demands typical of the summer months".

The June 4, 2021 letter also characterized the modeling that has been completed as "flawed, lacks specificity in identifying the changes in pumping cycles on a monthly basis, and is not representative of the impacts seen during actual pumping".

At the public hearing, Mr. Reed requested that a quantitative assessment be completed to evaluate how pumping of about 28,000 AF/yr of water on a municipal schedule would affect the proposed desired future conditions.

1.2 Scope of Analyses

The issue raised by Mr. Reed refers to the Fort Stockton Holdings operating permit that was approved by the Middle Pecos Groundwater Conservation District in 2017. This operating permit authorizes pumping 28,400 AF/yr for agricultural, municipal, or industrial use and the groundwater can be exported outside of Pecos County. As part of approval process for the operating permit, Fort Stockton Holdings reduced their Historic and Existing Use permit by the same amount (28,400 AF/yr). Thus, the total permitted pumping for Fort Stockton Holdings (and other wells within Management Zone 1) remained the same. Thus, the stated concern revolves around the potential impact of changing the timing of the pumping from an irrigation season to a "municipal" schedule. Potentially, this could mean pumping anytime during the year rather than only during the irrigation season. In Pecos County, the irrigation season can extend from February or March to September or October depending on several factors (crop type, rainfall, etc.).

The timing of "municipal" pumping in the operating permit is not as clear, because the permit only provides limitations on annual production. It is possible that the pumping would represent a baseline supply and pumping could be constant each month (January to December). It is also possible that the pumping would be highest in the typical peak municipal demand period (June to September), and the pumping would represent a peaking supply. In general, pumping for municipal use during the summer would have similar effects as pumping for irrigation since the timing of the pumping would be similar, but concentrating the pumping over a few months at the end of the irrigation season would have greater impacts than if the pumping was spread out over the entire irrigation season. At the current time, there is no specific "municipal" schedule associated with the Fort Stockton Holdings operating permit.

Many of the comments are misplaced regarding the scope and purpose of joint planning and the development of desired future conditions. Some of the specificity that is requested is generally outside the scope of joint planning given the size of the area involved and the time frame of the planning period. It must be emphasized that the joint planning process is a "planning process" that has different goals and objectives than "management" activities or groundwater pumping "regulation".

Specifically, in the June 4, 2021 letter at the bottom of page 4, there is a statement that requests an analysis that links the desired future conditions (that are defined as an average drawdown over the GMA 7 portion of Pecos County, an area of over 3,000 square miles over a 60-year period), to the "establishment of a summer threshold". The special permit conditions in the Fort Stockton Holdings operating permit that established a series of winter and summer thresholds in 11 individual monitoring wells. Pumping reductions are specifically tied to the winter thresholds. No such pumping reduction requirements are in the special permit conditions for not meeting summer thresholds. The lack of pumping reductions associated with the summer threshold in the operating permit has been an issue of concern for Belding Farms since 2017 when the permit was approved.

Although the joint planning process and the establishment of desired future conditions is a planning activity by GMA 7, and many of the issues raised in the comments are more properly considered management or regulatory activities by Middle Pecos GCD, this technical memorandum addresses the modeling-related comments.

1.3 Organization of Technical Memorandum

The technical memorandum is organized as follows:

- Section 2 presents a summary of findings and conclusions
- Section 3 documents the pumping capacities and permit limits of the 25 wells in the Fort Stockton Holdings operating permit.

- Section 4 documents an analysis of groundwater levels in 24 Belding Farms wells. The stated concern since 2017 of Belding Farms is the ability of the Belding Farms wells to maintain production during the irrigation season. The data for these wells was previously provided to Middle Pecos Groundwater Conservation District in 2018. Middle Pecos Groundwater Conservation District previously completed a review of these data (Hutchison, 2018).
- Section 5 presents a summary of the two groundwater models used in these analyses.
- Section 6 summarizes results of four simulations that were completed using the Groundwater Availability Model used in the joint planning process in GMA 7. The results are applicable when addressing comments related to the impacts of seasonal pumping on the desired future conditions.
- Section 7 summarizes four initial simulations that were completed using the Western Pecos County groundwater model, which is more appropriate to use when addressing comments that are related to specific issues in Management Zone 1 and in individual wells. Results of these simulations are reported as drawdowns in individual Belding Farms wells.
- Section 8 summarizes four baseline simulations (two with no pumping from the FSH operating permit wells and two with pumping on an irrigation schedule) and eight simulations that consider the shift of 28,400 AF/yr of agricultural pumping to alternative municipal pumping schedules and evaluates the impacts on Belding Farms wells.

2.0 Summary of Findings and Conclusions

FSH Operating Permit Wells: Based on operating permit limits, there is significant variability in the installed capacity of the 25 FSH wells. Each well has its own installed capacity and annual production limits. Assuming 24-hour per day production at the listed capacities, 12 wells can pump their annual limit in less than four months, but nine wells require over six months to reach their annual limit.

Belding Farms Wells Groundwater Data: Minimum groundwater elevations (maximum depth to water) in the Belding Farms wells typically occur at the end of the irrigation season. An analysis of data provided by Belding Farms in 2018 shows that the most frequent month with minimum groundwater elevations is August.

GAM Simulations: The Groundwater Availability Model for the Edwards-Trinity (Plateau) Aquifer (GAM) is the model used in the joint planning process that leads to the development of desired future conditions. Simulations using the GAM quantitatively demonstrated that there is no substantial difference in predicted average drawdown in the GMA 7 portion of Pecos County and in Management Zone 1 over a 60-year period when using annual stress periods, monthly stress periods with constant pumping, and monthly stress periods using different patterns of seasonal pumping.

Initial WPC Model Simulations: Simulations with alternative patterns of seasonal pumping using the Western Pecos County Groundwater Model (WPC Model) quantified the changes in monthly groundwater elevations at 22 well sites associated with Belding Farms wells. The simulated interannual fluctuations in simulated groundwater elevation from these simulations are consistent with groundwater drawdown data provided by Belding Farms in 2018. Thus, it was concluded that the WPC could be used to simulate alternative schedules of municipal pumping from the FSH Operating Permit wells and evaluate the impacts on Belding Farms wells.

Alternative Municipal Pumping Simulations with WPC Model: Simulations with alternative patterns of seasonal pumping and alternative operations of FSH operating permit wells quantified the changes in monthly groundwater elevations at 22 well sites associated with Belding Farms wells. The significant findings and conclusions are:

- If the FSH operating permit wells were not pumped at all, the interannual variation in groundwater elevations in the Belding Farms well would be between 9 and 16 feet, depending on the length of the irrigation season.
- The interannual variation in groundwater elevations in the Belding Farms wells under scenarios where all wells in Management Zone 1 are operating on an irrigation schedule is between about 20 and 29 feet, depending on the length of the irrigation season.
- As noted above, the current installed pump capacity and per well limits associated with each FSH operating permit well means that 12 wells can pump

the full annual permit limit in less than 4 months, but nine wells must be pumped for over six months to achieve the full permit limit. Under the installed pump capacity and current annual production limits in the operating permit, the interannual variation in the groundwater elevations of the Belding Farms wells is between about 22 and 27 feet, depending on the length of the irrigation season.

- If the constraint of installed pump capacity and the current annual production limits (on a per well basis) for the FSH operating permit were relaxed and the full amount of permitted annual pumping could be extracted in four months, the interannual variation in the groundwater elevations in the Belding Farms wells is about 31 feet.

- If the constraint of installed pump capacity and the current annual production limits (on a per well basis) for the FSH operating permit were relaxed and the full amount of permitted annual pumping could be extracted in three months, the interannual variation in the groundwater elevations in the Belding Farms wells is about 33 feet.

Summary Conclusion: Under current installed capacity and annual production limits of each well in the FSH Operating Permit, the results of simulating pumping on a municipal schedule demonstrate that impacts to the Belding Wells are nearly identical to simulated impacts to the Belding Wells when FSH Operating Permit wells are operated on an irrigation schedule. The current permit conditions require adherence to the current pump capacity and annual production limits of each well. Simulations that assumed relaxation of these limits (i.e. all FSH Operating Permit pumping over a three- or four-month period) did result in higher impacts to Belding Farms wells, but did not impact long-term drawdown, which is a groundwater planning issue.

Groundwater Management and Regulation Issues: The significance of the additional impacts associated with concentrated pumping of FSH Operating Permit wells over a three- or four-month period are unknown. However, understanding the significance are more properly groundwater management and groundwater regulation issues, not groundwater planning process issues. Additional data and a more robust analytical exercise with a more appropriate model would be needed to assess the significance of these simulated impacts. Currently, there has been no request submitted to modify the installed pump capacity and/or the annual limits of individual wells, so there is no urgent need to evaluate the significance further. However, this analysis does provide some background if such a request is made in the future. Any such request would be made to the Middle Pecos Groundwater Conservation District (not Groundwater Management Area 7). Such a request would be analyzed by and would be approved by the Middle Pecos Groundwater Conservation District as part of its groundwater management and groundwater regulation activities.

3.0 Fort Stockton Holdings Wells in Operating Permit

Table 1 summarizes data taken from the Fort Stockton Holdings operating permit application for the 25 wells in the permit. Data include the well name, well coordinates, elevation, aquifer, permit limit (in AF/yr) and the peak production rate of the well (in gallons per minute). Table 1 also includes columns that show the results of the following calculations:

- Peak rate of production in AF/month and in AF/day. These values were calculated assuming operation at peak rate 24 hours per day.
- The number of months to reach annual permit limits when pumping at the peak rate (assumed a 30-day month) and the number of days to each annual permit limits when pumping at the peak rate.

Table 1. Summary of FSH Wells in Operating Permit

From Appendix B-1 of Permit Application							Calculated Values Based on Peak Rate of Production and Annual Permit Limits			
Well	Longitude	Latitude	Elevation (feet AMSL)	Aquifer	Operating Permit (AF/yr)	Peak Rate of Production (gpm)	Peak Rate of Production (AF/30 day month)	Peak Rate of Production (AF/day)	Months at Peak Rate to Reach Annual Permit Limit	Days at Max Rate to Reach Annual Limit
C-1	-103.0287	30.89099	3,005	Edwards	849	2,000	265.15	8.84	3.20	96.06
C-2	-103.0314	30.89109	3,006	Edwards	1,273	3,000	397.73	13.26	3.20	96.02
C-3	-103.0346	30.89126	3,008	Edwards	1,273	3,000	397.73	13.26	3.20	96.02
C-4	-103.0258	30.88655	3,006	Edwards	849	2,000	265.15	8.84	3.20	96.06
M-1	-103.0261	30.757445	3,293	Edwards	2,129	2,200	291.67	9.72	7.30	218.98
M-2	-103.0262	30.764695	3,279	Edwards	1,419	1,500	198.86	6.63	7.14	214.07
M-3	-103.0262	30.768281	3,277	Edwards	2,149	2,200	291.67	9.72	7.37	221.04
M-4	-103.0261	30.779308	3,262	Edwards	1,758	1,800	238.64	7.95	7.37	221.01
M-5	-103.0077	30.792598	3,238	Edwards	1,328	2,200	291.67	9.72	4.55	136.59
M-6	-103.006	30.792928	3,231	Edwards	1,727	2,000	265.15	8.84	6.51	195.40
M-7	-103.0064	30.794657	3,213	Edwards	1,727	2,000	265.15	8.84	6.51	195.40
M-8	-102.9936	30.800244	3,195	Edwards	928	1,000	132.58	4.42	7.00	209.99
M-9	-103.0262	30.772017	3,282	Edwards	332	800	106.06	3.54	3.13	93.91
NC-2	-102.9637	30.899027	2,981	unknown	212	500	66.29	2.21	3.20	95.95
S-1	-103.0435	30.815876	3,152	Edwards	458	1,400	185.61	6.19	2.47	74.03
S-2	-103.0438	30.823565	3,144	Edwards	1,352	1,800	238.64	7.95	5.67	169.97
S-4	-103.0135	30.827628	3,141	Edwards-Trinity	1,839	2,100	278.41	9.28	6.61	198.16
S-6	-103.0435	30.830453	3,121	Edwards	424	1,000	132.58	4.42	3.20	95.95
S-11	-103.0259	30.83056	3,128	Edwards-Trinity	1,381	2,500	331.44	11.05	4.17	125.00
S-13	-103.0172	30.830579	3,131	Edwards	920	1,800	238.64	7.95	3.86	115.66
S-18	-103.0103	30.859055	3,066	Edwards	406	1,000	132.58	4.42	3.06	91.87
S-19	-103.0218	30.859023	3,074	Edwards-Trinity	406	1,200	159.09	5.30	2.55	76.56
S-20	-103.0218	30.860309	3,064	Edwards	406	1,400	185.61	6.19	2.19	65.62
S-26	-103.0372	30.85887	3,077	Edwards	1,318	2,000	265.15	8.84	4.97	149.12
S-32	-103.0351	30.858848	3,088	Edwards	1,537	1,650	218.75	7.29	7.03	210.79
Totals					**28,400**	**44,050**	**5,840**			

Please note that the installed capacity of the wells and the annual permit limits suggest that it takes several months operating at full capacity to pump the annual limit of the operating permit. Twelve of the wells can reach the full limit in less than 4 months. However, nine wells require over six months of pumping to reach the operating permit limit.

4.0 Annual Minimum Depth to Water in 24 Belding Farms Wells

The data provided to Middle Pecos Groundwater Conservation District by Belding Farms for 24 of their wells in 2018 were analyzed to find the annual minimum depth to water reading for each year and for each well. The FORTRAN program *minmo.exe* was written for this purpose. All files associated with this analysis using a Google Drive folder that can be accessed at:

https://drive.google.com/drive/folders/15UanCjnyORvf9YgG72uEJQO0i7tlMnrT?usp=sharing

The program reads the file *BeldingStaticDTW.csv* (which was extracted from the data provided by Belding Farms in 2018). The program then finds the minimum depth to water for each well in each year and fills an array with the month number.

The program then writes the results to an output file named *minmo.dat*. This file was imported into Excel and saved as *BeldingMinMoCount.xlsx* for further processing. Each row of the file *minmo.dat* is a year and each column is a well. The month with the minimum depth to water is written to *minmo.dat*. If there are no data for a well in a particular year, the default value is -999. The first tab of *BeldingMinMoCount.xlsx* is the data from *minmo.dat.* The -999 values are removed from the results. The second tab of *BeldingMinMoCount.xlsx* is a summary that presents a monthly count of the minimum values.

There are 440 well-year results in the *minmo.dat* tab, and the *Summary* tab shows that August has the most minimum depth-to-water values. Figure 1 summarizes the data in the *Summary* tab. Thus, August is the month with the most minimum depth-to-water data. September has the next most, and July is slightly less than September.

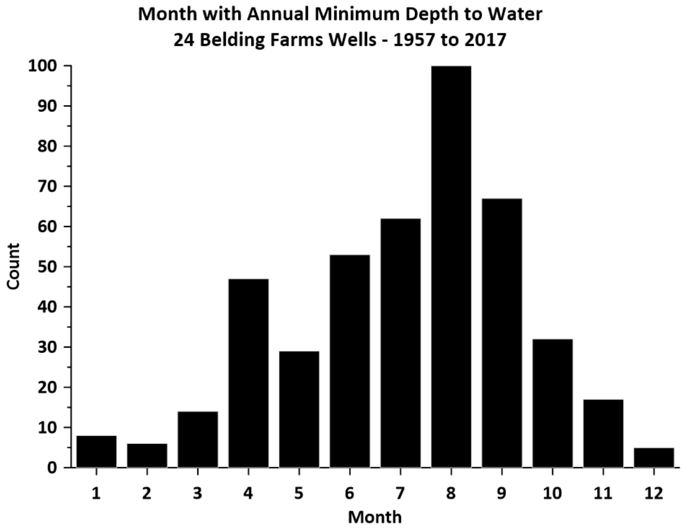


Figure 1. Month with Annual Minimum Depth to Water

There are instances in the Belding data where depth to water data were not collected in every month. Therefore, this analysis can only be considered cursory. However, the results demonstrate that the lowest groundwater levels each year tend to occur at the end of the irrigation season.

5.0 Groundwater Model Summary Descriptions

Two groundwater models were used for this effort:

- The alternative Groundwater Availability Model for the Edwards-Trinity (Plateau) Aquifer, also known as the one-layer model (Hutchison and others, 2011), has been used in the joint planning process since 2010. The model fully covers Pecos County and has one square mile grid cells (640 acres). The model calibration period was 1931 to 2005, with annual stress periods.
- The Western Pecos County Groundwater Model (WPC Model), documented in Harden and others (2011), and was reviewed by Hutchison (2017). The focus of the model development and calibration was the Leon-Belding Area (i.e. Management Zone 1). The model does not cover the full extent of Pecos County, but does fully cover Management Zone 1 as defined by the Middle Pecos Groundwater Conservation District. The model has grid cells that are 2,000 ft by 2,000 ft (about 91 acres or about 0.14 square miles). The model calibration period was 1945 to 2010, with annual stress periods.

5.1 Comparison of Pumping – Calibration Periods

The groundwater pumping from the two model were compared as follows:

- Figure 2 presents the pumping comparison in Management Zone 1,
- Figure 3 presents the pumping comparison for the Fort Stockton Holdings (FSH) wells associated with the operating permit, and
- Figure 3 presents the pumping comparison for the Belding Farm wells.

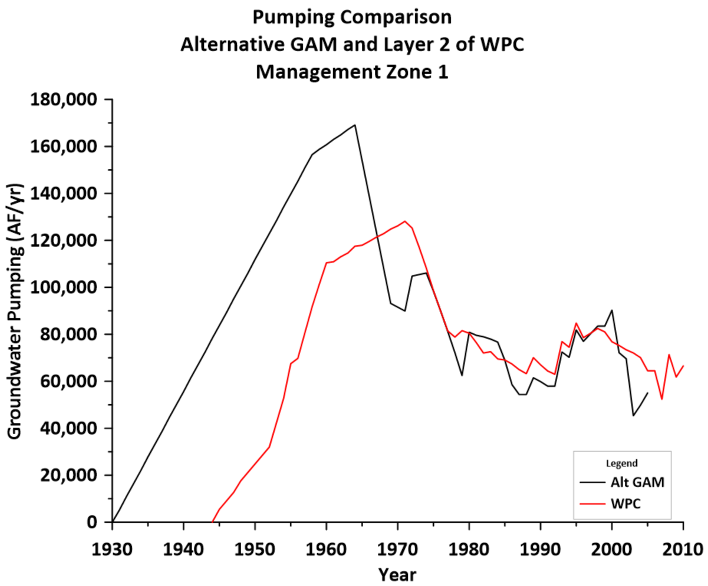


Figure 2. Pumping Comparison - Management Zone 1

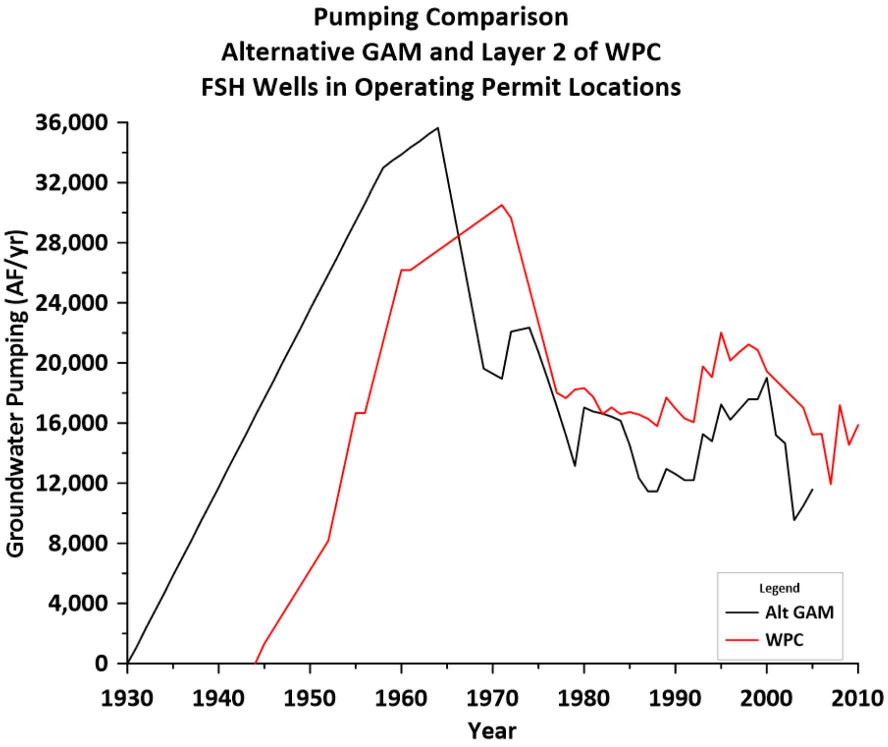


Figure 3. Pumping Comparison - FSH Operating Permit Wells

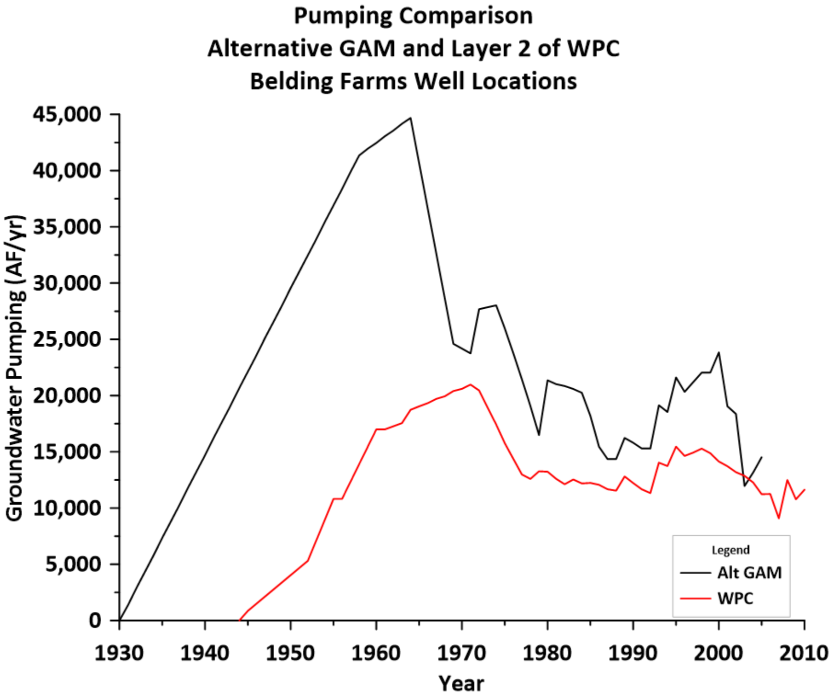


Figure 4. Pumping Comparison - Belding Farms Wells

Please note that both models have similar pumping estimates in Management Zone 1 after the mid-1970s. In general, the Alternative GAM has slightly lower estimates of pumping in the FSH Operating permit wells than the WPC Model. Also, the Alternative GAM has slightly higher estimates of pumping in the Belding Farms wells than the WPC Model.

During development of the desired future conditions starting in 2010, several simulations have been completed using the Alternative GAM. The assumed pumping for the GMA 7 portion of Pecos County is 117,309 AF/yr, and the pumping from Management Zone 1 is 74,134 AF/yr.

The WPC Model was used in a series of evaluations by Hutchison (2017) that used pumping in 2010 (the last year of the calibration period) as the baseline. In the WPC Model in the current Management Zone 1, pumping was 66,561 AF/yr in layer 2 (Edwards) and 6,474 AF/yr in layer 3 (Trinity), for a total Edwards-Trinity pumping of 73,035 AF/yr, which is reasonably close to the GAM estimate of 74,134 AF/yr. Pumping from the FSH wells associated with the operating permit in 2010 was 15,869 AF/yr for layer 2 (Edwards) and 450 AF/yr for layer 3 (Trinity), for a total Edwards-Trinity pumping of 16,319 AF/yr. This total is less than the 28,400 AF/yr associated with the operating permit. As developed further below, the pumping from the FSH wells was modified for simulations using the WPC Model as part of this analysis.

6.0 Simulations with the Alternative GAM

As detailed below, the Alternative GAM was used to complete simulations that quantitatively demonstrated that there is no substantial difference in predicted drawdown over a 60-year period when using annual stress periods, monthly stress periods with constant pumping, and monthly stress periods using different patterns of seasonal pumping.

6.1 Annual Stress Periods

The alternative GAM was used as part of the development of the desired future conditions in 2010 and 2016. The proposed desired future conditions in 2021 are the same as the final desired future conditions in 2016 (Hutchison, 2018b and Hutchison 2018c). In the GMA 7 portion of Pecos County, the desired future condition is expressed as 14 feet of drawdown from 2011 to 2070. The associated pumping in Pecos County (i.e. the modeled available groundwater) is 117,309 AF/yr. All files associated with the base run using a Google Drive folder that can be accessed at:

https://drive.google.com/drive/folders/11Qsqqdo6A6me38XPbdKKTonhMm_JPcho?usp=sharing

For purposes of this analysis, the average drawdown in Management Zone 1 was calculated from 2011 to 2070, and the pumping in Management Zone 1 was also calculated. These were accomplished with a FORTRAN post-processor *postprocann.exe* (also included in the above Google Drive link). Average drawdown in Management Zone 1 from 2011 to 2070 is 45 feet, and pumping is 74,134 AF/yr.

The issue raised in the Belding Farms comments cannot be answered with an annual model. The desired future conditions for GMA 7 were set from 2011 to 2070, and it was assumed that interannual variations were not relevant given the length of the planning period and objectives of the joint planning process. However, in response to the comment and given the nature of the expected change in a significant amount of Management Zone 1 pumping from agricultural to a mix of agricultural and municipal, a preliminary conversion of the alternative GAM to a monthly model was needed to provide preliminary answers to the questions that have been raised. An updated model that is currently in development will use monthly stress periods, at least for recent years, and will be used to address these groundwater management issues more directly and more robustly in the future.

6.2 Monthly Stress Periods – Base Case (Constant Pumping Rate)

The model input files were modified to run the simulation using monthly stress periods. For this base run, average annual rates of pumping and constant rates of recharge were maintained to demonstrate that the average drawdowns do not change using monthly stress periods or annual stress periods. All other input files were modified to handle the monthly stress periods. All files associated with this base run of the monthly stress period alternative GAM can be accessed at:

https://drive.google.com/drive/folders/16jQtUdSRbKl2AIrmfBb_XzbELXRxpCPx?usp=sharing

Average drawdown and pumping were extracted from model results using a FORTRAN post-processor *postprocann.exe* (also included in the above Google Drive link).

For the GMA 7 portion of Pecos County, average drawdown was calculated as 14 feet (13.62 feet for the monthly base model versus 13.67 feet for the annual model). Pumping for all of Pecos County was calculated as 240,206 AF/yr for the monthly base model (as compared with 240,208 AF/yr for the annual model). These differences are attributable to rounding error and are not significant for the purposes of this analysis.

Average drawdown in Management Zone 1 from 2011 to 2070 is using the monthly base model was calculated as 45 feet (45.40 feet for the monthly base model versus 45.33 feet for the annual model) and pumping from the monthly base model is 74,131 AF/yr (as compared to 74,134 for the annual model). As with the GMA 7 portion of Pecos County, these differences are attributable to rounding error and are not significant for the purposes of this analysis.

Based on these results, the change to monthly stress periods results in essentially the same drawdown for the GMA 7 portion of Pecos County and Management Zone 1 as the annual stress period simulation. The base monthly simulation did not change any assumptions relative to the simulated rate of pumping and recharge, just specified them at a constant monthly rate that changes each year rather than at annual rate that changes each year. The objective for this simulation was to test the model code relative to rounding error and other components of the simulated groundwater system.

6.3 Monthly Stress Periods with Seasonal Pumping

Three alternative seasonal pumping simulations were completed:

- Pumping from January to June, no pumping from July to December (6 months on, 6 months off, establish a baseline based on equal pumping and equal recovery time for end of year comparison).
- No pumping from January to March, pumping from April to September, no pumping from October to December (6 months on, 6 months off, agricultural pumping pattern)
- No pumping from January to February, pumping from March to October, no pumping from November to December (8 months on, 4 months off, agricultural pumping pattern)

All files for these simulations, including a pre-processor that was written to develop input pumping files (*ScenWel.exe*) and a post-processor that was written to extract pumping and drawdown results (*MonthlyScenPostProc.exe*) can be accessed at:

https://drive.google.com/drive/folders/1pfQ1wO6HeouqtH3DfiqO1t_VZ4p19BDJ?usp=sharing

6.3.1 January to June Pumping Scenario

As discussed above, the monthly simulation where pumping was held constant throughout the year was completed to quantitatively demonstrate that the average drawdowns do not change using monthly stress periods or annual stress periods. Similarly, this simulation was completed to quantitatively demonstrate that doubling the monthly rate of pumping for six months followed by six months of no pumping would results in essentially the same drawdowns as a constant monthly pumping or as a simulation that used annual stress periods. This pattern is clearly not realistic in terms of an irrigation season but was an important intermediate analytical step to interpret the results of the other two seasonal pumping scenarios.

6.3.2 April to September Pumping Scenario

This scenario has the same rates of pumping as the January to June pumping scenario (double the average annual rate of pumping) but assumes a six-month irrigation season. When evaluating end-of-year groundwater elevations or end-of-year drawdowns (i.e. end of December), this scenario does not have a full six-month recovery period as in the January to June scenario. Thus, this scenario provides a means to quantitatively evaluate differences in end-of-year drawdown without the benefit of a full six months of recovery.

6.3.3 March to October Pumping Scenario

This pumping scenario assumes pumping for eight months and four months of recovery. The pumping rate is 1.5 times the annual average rate (i.e. evenly distributed over the eight months). This is a more realistic scenario as the irrigation season is generally considered to be about eight months with some variation due to crop type and weather. This scenario provides a means to quantitatively evaluate differences in end-of-year drawdown over a short period of recovery (two months).

6.3.4 Summary of Seasonal Pumping Results

Table 2 presents a summary of results from the simulation using the GAM with annual stress periods (i.e. the basis for the desired future condition in 2016 and proposed desired future condition for 2021), and the results of the four simulations using the GAM with monthly stress periods as developed above.

Table 2. Summary of GAM Simulations - Drawdown and Pumping

	Scenario				
	Annual Stress Periods	Monthly Stress Periods			
		Constant Monthly Pumping	Pumping from Janaury to June	Pumping from April to September	Pumping from March to October
GMA 7 Portion of Pecos County					
Drawdown from 2011 to 2070 (ft)	13.67	13.62	13.27	13.65	13.74
Annual Range of Drawdown in 2011 (ft)	N/A	0.34	1.27	1.63	1.23
Annual Range of Drawdown in 2070 (ft)	N/A	0.18	1.34	1.54	1.11
Pumping (AF/yr)	117,309	117,308	116,347	117,633	118,114
Management Zone 1 in Pecos County					
Drawdown from 2011 to 2070 (ft)	45.33	45.40	44.65	45.56	45.85
Annual Range of Drawdown in 2011 (ft)	N/A	0.74	1.09	1.35	1.17
Annual Range of Drawdown in 2070 (ft)	N/A	0.64	1.05	1.29	1.10
Pumping (AF/yr)	74,134	74,131	73,525	74,337	74,640

Please note that there is some rounding error associated with converting the average annual rate of pumping to a seasonal rate of pumping for indivudal months due to the different number of days in each month. However, there is only minimal difference in the calculated drawdowns in the GMA 7 portion of Pecos County and in Management Zone 1 in Pecos County.

The results also include the difference in the maximum and minimum drawdowns in 2011 and 2070 for the GMA 7 portion of Pecos County and Management Zone 1 in Pecos County. For the constant pumping scenario, the interannual variation is the same as the average annual decline in groundwater elevation. For example, in the GMA 7 portion of Pecos County, the average drawdown from 2011 to 2070 is 13.67 feet. Over a 60-year period, this converts to an average annual rate of 0.23 ft/yr. As shown in Table 2, the 2011 rate of decline is 0.34, and the 2070 rate is 0.18. These results provide a baseline to compare the annual change associated with the seasonal pumping results.

Note that, for all scenarios, the interannual variation in average drawdown is less than 2 feet. However, at the end of the planning period (2070) drawdowns in all scenarios are essentially the same. Thus, the scenario with eight months of pumping (March to October) and only two months of recovery results in essentially the same drawdown as the other scenarios where recovery times are longer (i.e. three months or six months).

Please recall that the desired future conditions are expressed without the decimal places (i.e. rounded to the nearest foot). These results demonstrate that the differences in drawdown associated among the different seasonal pumping scenarios are within that rounding standard. It must be emphasized that although these analyses are quantiatiative, some of the assumptions are not particulely realistic (i.e. constant recharge throughout the year). Also, all pumping was assumed to be seasonal as defined by the scenario. Clearly, not all pumping would follow this pattern. The scenarios were designed to evaluate the assumption of seasonal pumping in contrast to the average annual pumping assumption in the annual GAM simulation that are the basis for the desired future conditions. By assuming all pumping as seasonal in the monthly simulations, it provides the best opportunity to evaluate the interannual variation in average drawdown over large areas. The results suggest that, for GMA 7, the assumptions of average annual pumping rates and annual stress periods are appropriate for planning purposes and development of desired future conditions.

With respect to the consitency of the desired future conditions with the FSH Operating Permit conditions, Figure 5 (appears as Figure 2 in the MPGCD Management Plan) compares the desired future condition drawdown at each of the 11 monitoring wells with two of the thresholds for each well (Historic Minimum Winter Depth to Water -10 feet and Historic Winter Minimum Depth to Water +5 feet). Please note that the blue data points represent the groundwater elevation where pumping cutbacks begin for each well. The red dots represent the groundwater elevation where a shut-down in non-historic groundwater pumping would be required, thus providing an opportunity for groundwater elevation recovery. The black line represents one-to-one line between the DFC depth to water at each well and the threshold depth to water in each well. The data points generally fall just above or just below the black line demonstrating that the thresholds are consistent with the DFC.

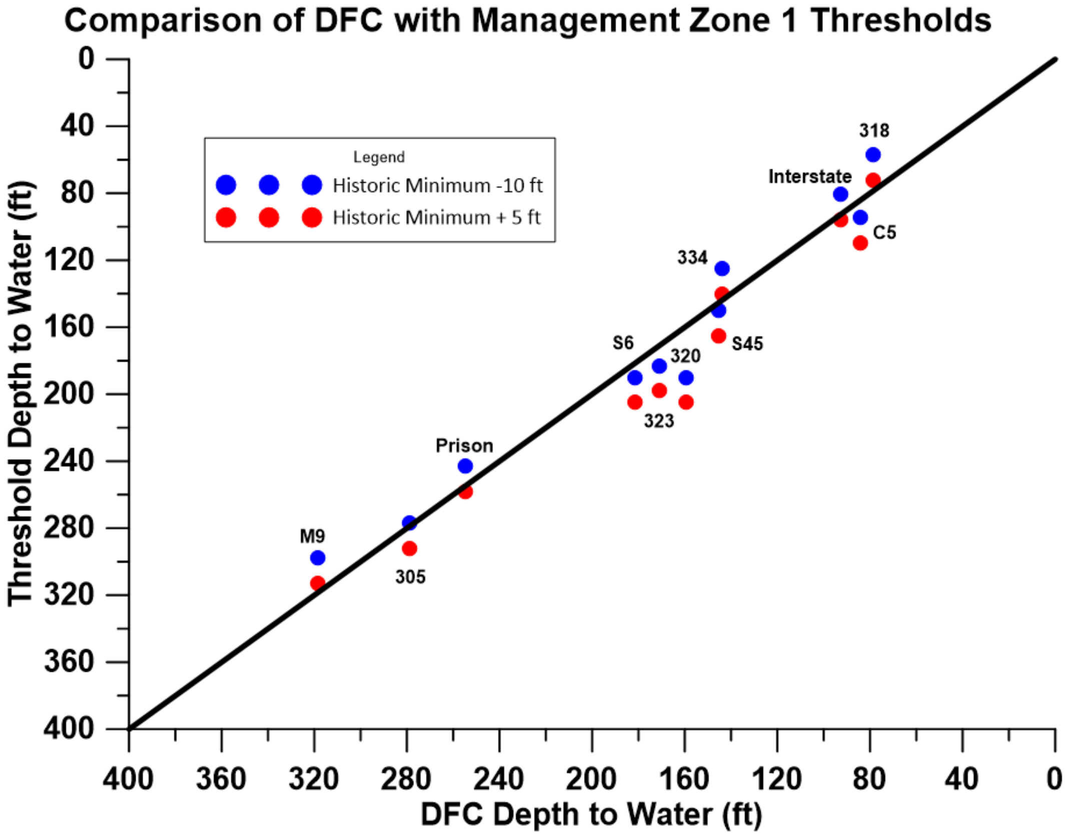


Figure 5. Comparison of DFC with Management Zone 1 Thresholds

7.0 Simulations with the Western Pecos County (WPC) Model

The simulations with the GAM presented above quantiatively demonstrated that the use of the GAM with monthly stress periods and alternative patterns of seasonal pumping provide consistent results with the simulations with annual stress periods that were used to develop desired future conditions. Consequently, it can be concluded that the use of the annual stress periods in the Alternative GAM to calculate average drawdowns in Pecos County for planning purposes is appropriate despite its inability to simulate seasonal pumping. Furthermore, the winter thresholds in the FSH Operating Permit are consistent with the desired future conditons.

The comments received from Belding Farms and the ongoing discussions between MPGCD and Belding Farms suggest that the real issue is not long term average drawdowns (i.e. desired future conditions), but the potential impacts of converting 28,400 AF/yr of agricultural pumping to municipal use. More directly, the issue is the potential impact on Belding Farms wells. The GAM is not the best analytical tool for such an analysis due to its coarse discretization (i.e. one square mile grid cells) and calibration focus over the entire GMA 3/GMA 7 area. The Western Pecos Model (WPC Model) was developed and calibrated specifically for the Leon-Belding area (i.e. Management Zone 1), and is used for additional simulations documented in this section.

As part of the review of the WPC Model (Hutchison, 2017), 55 simulations were completed that evaluated the sensitivity of pumping to average drawdown in the old Management Zone 1 and spring flow at Comanche Springs. The base case for the the effort used pumping from the last stress period of the calibration period (2010):

- Pumping in 2010, as assumed by the WPC Model in the current Management Zone 1, was 66,561 AF/yr in layer 2 (Edwards) and 6,474 AF/yr in layer 3 (Trinity), for a total Edwards-Trinity pumping of 73,035 AF/yr. This total is reasinably close to the GAM estimate of 74,134 AF/yr.
- Pumping from the FSH wells associated with the operating permit in 2010 was 15,869 AF/yr for layer 2 (Edwards) and 450 AF/yr for layer 3 (Trinity), for a total Edwards-Trinity pumping of 16,319 AF/yr. This total is less than the 28,400 AF/yr associated with the operating permit.

Initial simulations were completed that were similar to the GAM simulations described above. These were completed in order to evaluate the drawdown variation at specific Belding Farms well locations drawdown under the following scenarios:

- Annual stress periods using the model files from the base case of Hutchison (2017)
- Monthly stress period simulation using constant rate pumping based on base case of Hutchison (2017), or the same pumping rate as the base case
- Monthly stress period simulation with 6 months of pumping and 6 months of recovery (April to Septmber pumping), or double the pumping rate as the base case
- Monthly stress period simulation with 8 months of pumping and 4 months of recovery (March to October pumping), or 1.5 times the pumping rate as the base case

7.1 Annual Stress Periods

This simulation was the same as the base case documented in Hutchison (2017). All model files are available at:

https://drive.google.com/drive/folders/11g5bMhruMTm9uABmb31C3zp3Vaz-wtIX?usp=sharing

As noted above, pumping was held constant in all years (2011 to 2070) using pumping from the calibrated model in 2010. In the current Management Zone 1, pumping was 66,561 AF/yr in layer 2 (Edwards) and 6,474 AF/yr in layer 3 (Trinity), for a total Edwards-Trinity pumping of 73,035 AF/yr. This total is reasinably close to the GAM estimate of 74,134 AF/yr.

Pumping from the FSH wells associated with the operating permit in 2010 was 15,869 AF/yr for layer 2 (Edwards) and 450 AF/yr for layer 3 (Trinity), for a total Edwards-Trinity pumping of 16,319 AF/yr. This total is less than the 28,400 AF/yr associated with the operating permit.

Ouput from the model was used in a post-processor named *gethds.exe* that writes groundwater elevation and drawdown for each of the Belding Farm wells and a summary file with the drawdown for each well at the end of the simulation (2070). The post processor, source code and all output files are also available from the above link.

7.2 Monthly Stress Periods, Constant Pumping

The model input files of the WPC Model were modified to run the simulation using monthly stress periods. However, for this base run, average annual rates of pumping and constant rates of recharge were maintained to demonstrate so that that the average drawdowns do not change using monthly stress periods or annual stress periods. All other input files were modified to handle the monthly stress periods. The output control file was modified to only write cell by cell output at the end of each year rather than the end of each month due to model file size constraints. All files associated with this base run of the monthly stress period alternative GAM can be accessed at:

https://drive.google.com/drive/folders/1fQ22hD-CUkt-g7YL-xaJ4JhDlfrr5Any?usp=sharing

A post-processor named *gethds.exe* extracted results from the model output files to obtain groundwater elevation and drawdown results for each of the Belding Farm wells and a summary file with the drawdown for each well at the end of the simulation (2070). In addition, the post processor calculates the difference between the maximum drawdown each year and the minimum drawdown each year for each well site. This “interannual variation” or “amplitude” is useful to understand the seasonal variation in groundwater elevations based on the assumptions of the particular analysis. The post processor, source code and all output files are also available from the above link.

7.3 Monthly Stress Periods, April to September Pumping

This simulation assumed that all pumping occurs from April to September. Thus, the rate of constant monthly pumping for each cell from April to September was doubled, and pumping from October to March was set to zero. Pumping for this simulation was developed with the pre-processor *ScenWel.exe*. All other input files for this simulation were the same as the constant monthly pumping scenario. The output control file was modified to only write cell by cell output at the end of each year rather than the end of each month due to model file constraints. All files associated with this base run of the monthly stress period alternative GAM can be accessed at:

https://drive.google.com/drive/folders/18IUjEl270vYY6S43-2Iv1MZBx9iIN9jd?usp=sharing

A post-processor named *gethds.exe* extracted results from the model output files to obtain groundwater elevation and drawdown results for each of the Belding Farm wells and a summary file with the drawdown for each well at the end of the simulation (2070). In addition, the post processor calculates the difference between the maximum drawdown each year and the minimum drawdown each year for each well site. This "interannual variation" or "amplitude" is useful to understand the seasonal variation in groundwater elevations based on the assumptions of the particular analysis. The post processor, source code and all output files are also available from the above link.

7.4 Monthly Stress Periods, March to October Pumping

This simulation assumed that all pumping occurs from March to October. Thus, the rate of constant monthly pumping for each cell from March to October was multiplied by 1.5 and pumping from November to February was set to zero. Pumping for this simulation was developed with the pre-processor *ScenWel.exe*. All other input files for this simulation were the same as the constant monthly pumping scenario. The output control file was modified to only write cell by cell output at the end of each year rather than the end of each month due to model file constraints. All files associated with this base run of the monthly stress period alternative GAM can be accessed at:

https://drive.google.com/drive/folders/1KDzIMEb7O29iPsDIMEJ9lw8m-3lF3VzY?usp=sharing

A post-processor named *gethds.exe* extracted results from the model output files to obtain groundwater elevation and drawdown results for each of the Belding Farm wells and a summary file with the drawdown for each well at the end of the simulation (2070). In addition, the post processor calculates the difference between the maximum drawdown each year and the minimum drawdown each year for each well site. This "interannual variation" or "amplitude" is useful to understand the seasonal variation in groundwater elevations based on the assumptions of the particular analysis. The post processor, source code and all output files are also available from the above link.

7.5 Simulation Results

7.5.1 Hydrographs of Well B-7 Drawdown

Results from these simulations were focused on drawdown in individual Belding Farms wells. Results for each well were saved in individual files which are available at the links provided above. An example is Well B-7.

Figure 6 presents the drawdown results from the annual stress period simulation and the monthly stress period simulation using constant pumping. The black data points represent the annual stress period simulation results and the red line represents the results from the constant monthly pumping simulation. There is no discernable difference between these sets of results in the hydrograph.

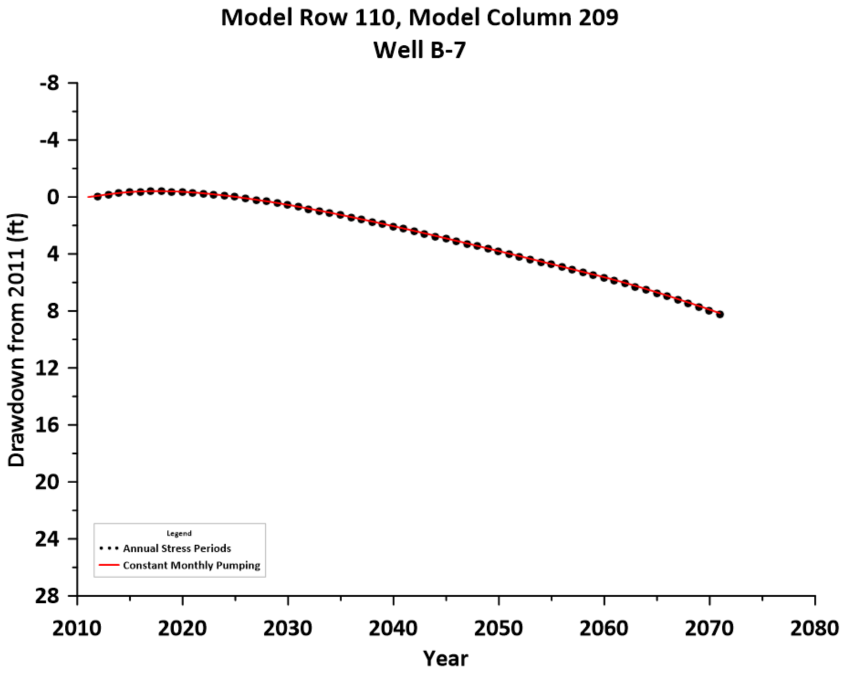


Figure 6. Well B-7 Drawdown Hydrograph - Annual Stress Period and Constant Monthly Pumping Simulations

Figure 7 presents the drawdown results from the annual stress period simulation and the monthly stress period simulation assuming pumping only from April to September. The red line represents the monthly stress period-constant pumping simulation results and the blue line represents the monthly stress period-April to September pumping simulation results. Please note that the simulation results show the seaasonal increase and decrease in groundwater elevation due to the seasonal cycle of pumping and recovery. The interannual variation or amplitude of the seasonal fluctuation exceeds 25 feet in this well. Also, please note that the model represents static groundwater levels, not pumping groundwater levels. Typcially, pumping water levels are lower than static groundwater levels as demonstrated in the Belding Farms data that was reviewed by Hutchison (2018).

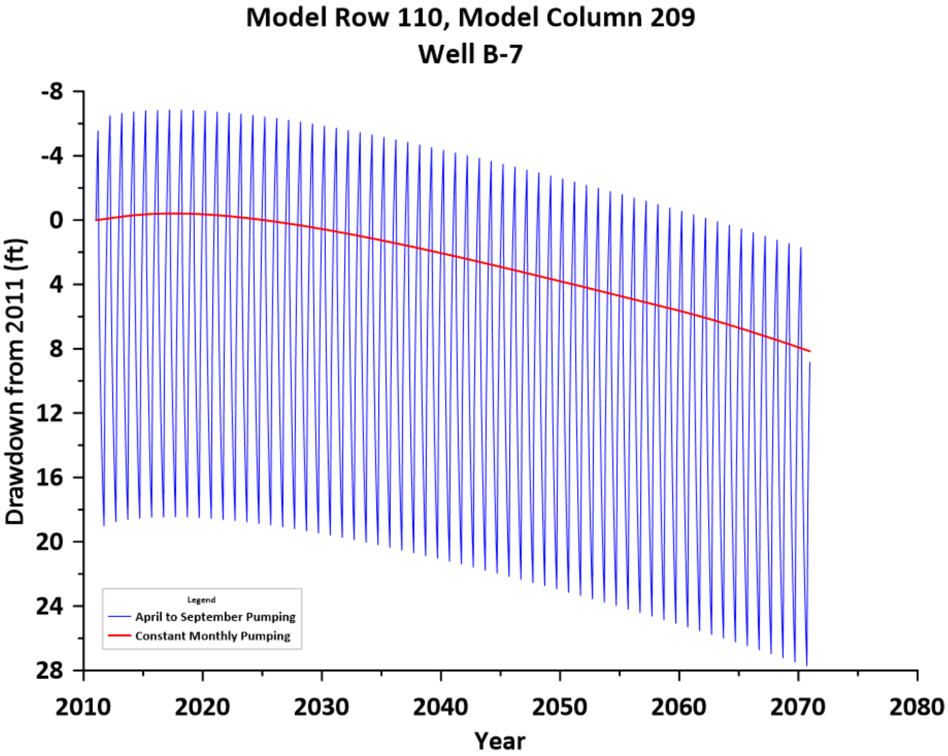


Figure 7. Well B-7 Drawdown Hydrograph - Annual Stress Period and April to September Pumping Simulations

Figure 8 presents the drawdown results from the annual stress period simulation and the monthly stress period simulation assuming pumping only from March to October. The red line represents the monthly stress period-constant pumping simulation results and the green line represents the monthly results of the March to October pumping simulation.

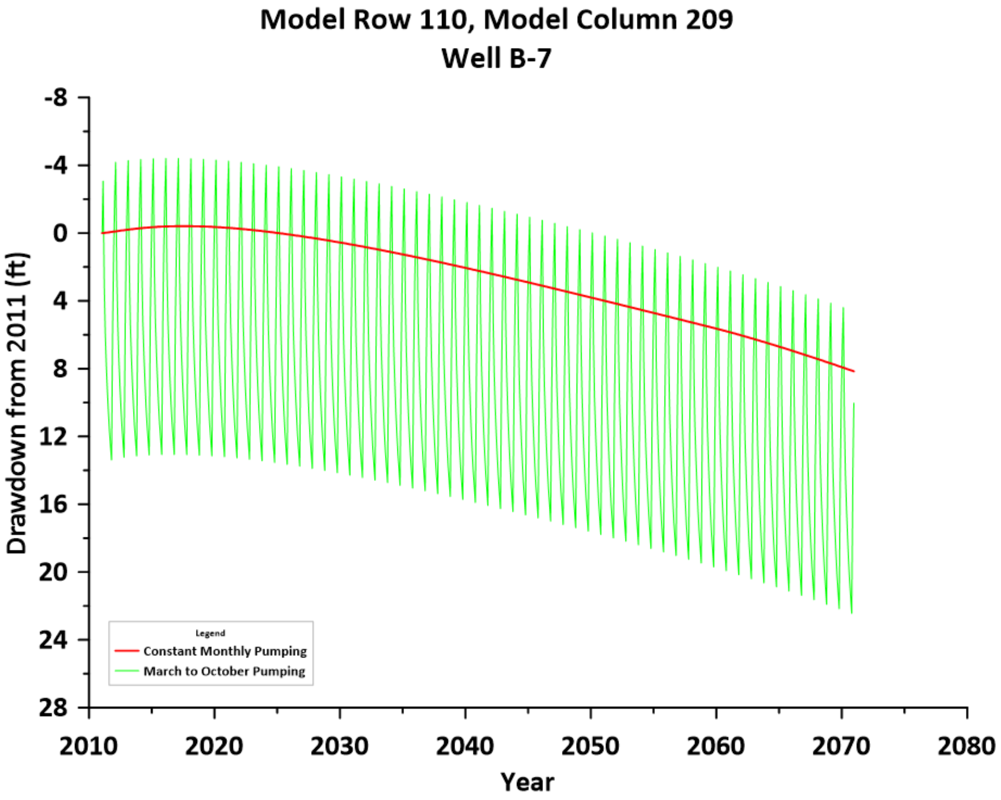


Figure 8. Well B-7 Drawdown Hydrograph - Annual Stress Period and March to April Pumping Simulations

Please note that the March to October results show a seasonal increase and decrease in groundwater elevation due to the cycle of pumping and recovery, but not to the extent as the April to September fluctuations. The interannual variation or amplitude of the seasonal fluctuation exceeds 15 feet in this well as compared to greater than 25 feet fluctuation in the April to September results previously shown in Figure 7. This is due to the higher rates of pumping in the April to September simulation (twice the average annual rate for six months) as compared to the March to October simulations (1.5 times the average annual rate for eight months).

Also, please note that the model represents static groundwater levels, not pumping groundwater levels. Typcially, pumping water levels are lower than static groundwater levels as demonstrated in the Belding Farms data that was reviewed by Hutchison (2018).

The example hydrographs are useful to visualize the differences in results between the simulations, but a more quantitative analysis of the results is provided below using all the Belding Farm well sites.

7.5.2 Summary of 2011 to 2070 Drawdown

Table 3 summarizes drawdown from 2011 to 2070 at 23 locations of Belding Farms wells. Please note that some of the three of the model cells contain two Belding Farms wells, and one cell contains three Belding Farms wells. Model row and column are provided for reference.
The fourth column is labeled "Annual Stress Period", and represents the drawdown from 2011 to 2070 for the base run of Hutchison (2017). The results of the monthly stress period simulations are presented in the next three columns. The final three columns are the difference between the annual stress period simulation drawdown and the individual monthly stress period simulations drawdown results. The final row represent the averages for each column, which are convenient to provide a basis for discussion.

Table 3. Summary of WPC Model Simulation Drawdowns in Belding Farms Wells

Well Number(s)	Model Row	Model Column	Drawdown - 2011 to 2070 (ft)				Monthly Stress Period Simulation Drawdown Difference from Annual Simulation (ft)		
			Annual Stress Period	Monthly Stress Periods					
				Constant	Apr-Sept	Mar-Oct	Constant	Apr-Sept	Mar-Oct
B1-B25	116	213	8.41	8.35	9.18	10.19	-0.06	0.77	1.78
B2	114	211	8.34	8.28	9.06	10.14	-0.06	0.72	1.80
B3	113	211	8.29	8.23	8.96	10.06	-0.06	0.67	1.77
B4	115	209	8.42	8.36	9.32	10.35	-0.06	0.90	1.93
B5	113	210	8.31	8.25	9.03	10.13	-0.06	0.72	1.82
B6	111	214	8.05	7.99	8.74	9.83	-0.06	0.69	1.78
B7	110	209	8.22	8.16	8.84	10.03	-0.06	0.62	1.81
B8-B17	110	210	8.17	8.11	8.76	9.95	-0.06	0.59	1.78
B9-B14	116	210	8.46	8.40	9.35	10.36	-0.06	0.89	1.90
B10	114	214	8.26	8.20	8.98	10.01	-0.06	0.72	1.75
B11	115	214	8.32	8.26	9.07	10.09	-0.06	0.75	1.77
B12	114	213	8.29	8.23	8.98	10.04	-0.06	0.69	1.75
B13	115	211	8.40	8.33	9.17	10.21	-0.07	0.77	1.81
B18	107	214	7.71	7.65	8.57	9.65	-0.06	0.86	1.94
B19	106	215	7.54	7.47	8.59	9.58	-0.07	1.05	2.04
B20	118	212	8.53	8.46	9.44	10.40	-0.07	0.91	1.87
B21	117	213	8.47	8.41	9.28	10.27	-0.06	0.81	1.80
B22	111	213	8.10	8.03	8.73	9.85	-0.07	0.63	1.75
B23	115	212	8.37	8.31	9.11	10.16	-0.06	0.74	1.79
B24	113	214	8.20	8.14	8.89	9.94	-0.06	0.69	1.74
B26	112	212	8.20	8.14	8.82	9.95	-0.06	0.62	1.75
B27	116	209	8.47	8.41	9.43	10.43	-0.06	0.96	1.96
B28-B29-B30	105	207	8.11	8.04	8.72	9.95	-0.07	0.61	1.84
Average			**8.25**	**8.18**	**9.00**	**10.07**	**-0.06**	**0.76**	**1.82**

Please note average drawdown for these 23 sites for the annual simulation and constant monthly simulation are within 0.1 feet (8.25 ft vs. 8.18 ft). However, the April to September simulation has a drawdown that is almost a foot less than the annual stress period simulation. The March to October drawdown is almost 2 feet lower than the annual stress period simulation. These differences are due to the timing of the "end of the year" drawdown calculation and the length of recovery from the seasonal pumping.

The April to September pumping recovers from October to March, but the drawdown in this table is calculated at the end of December, only four months into the six month recovery period. The

March to October pumping recovers from November to February. This means that the "end of the year" drawdown is calculated only two months into a four month recovery period.

The FSH operating permit thresholds do not consider "end of year" as winter groundwater elevations, but the winter maximum (whenever it occurs). The winter maximum groundwater elevations and the end of the year groundwater elevations were evaluated in Hutchison (2018) for this reason. Consequently, the differences between the drawdowns in Table 3 are not considered significant.

Also please recall from the example hydrograph of Well B-7 that the groundwater levels will rise above the annual average groundwater level in non-pumping periods and then fall below the annual average groundwater level during pumping periods. This fluctuation is well documented in the monitoring data in wells monitored by MPGCD. This fluctuation is analyzed below.

7.5.3 Interannual Variation in Groundwater Levels

Table 4 summarizes the interannual variation in 2011 and 2070 for the three monthly stress period simulations. For each well, the interannual variation is calculated as the maximum drawdown in a specific year minus the minimum drawdown in that same year. The results for 2011 are presented in the fourth, fifth, and sixth columns. The results for 2070 are presented in the seventh, eighth, and ninth columns. The final row represent the averages for each column, which are convenient to provide a basis for discussion.

Table 4. Summary of Interannual Variation in Groundwater Levels in Belding Farms Wells

Well Number(s)	Model Row	Model Column	Annual Maximum Drawdown minus Annual Minimum Drawdown (ft)					
			2011			2070		
			Constant	Apr-Sept	Mar-Oct	Constant	Apr-Sept	Mar-Oct
B1-B25	116	213	0.07	22.08	14.88	0.23	23.35	16.22
B2	114	211	0.08	22.66	15.22	0.23	23.96	16.63
B3	113	211	0.08	23.06	15.47	0.23	24.39	16.93
B4	115	209	0.08	21.20	14.17	0.23	22.42	15.50
B5	113	210	0.08	22.90	15.35	0.23	24.22	16.79
B6	111	214	0.08	22.40	15.02	0.23	23.70	16.45
B7	110	209	0.09	24.58	16.46	0.23	26.02	18.05
B8-B17	110	210	0.08	24.04	16.08	0.23	25.45	17.65
B9-B14	116	210	0.07	21.21	14.21	0.23	22.43	15.52
B10	114	214	0.07	22.60	15.23	0.23	23.90	16.62
B11	115	214	0.07	22.14	14.91	0.23	23.41	16.27
B12	114	213	0.07	22.58	15.19	0.23	23.88	16.59
B13	115	211	0.07	22.19	14.91	0.23	23.46	16.28
B18	107	214	0.09	20.19	13.41	0.23	21.39	14.76
B19	106	215	0.09	18.25	12.08	0.23	19.32	13.29
B20	118	212	0.07	20.30	13.62	0.23	21.49	14.87
B21	117	213	0.07	22.28	15.05	0.23	23.56	16.39
B22	111	213	0.08	22.86	15.32	0.23	24.19	16.79
B23	115	212	0.07	22.39	15.06	0.23	23.68	16.44
B24	113	214	0.08	23.06	15.54	0.23	24.38	16.96
B26	112	212	0.08	23.18	15.54	0.23	24.52	17.02
B27	116	209	0.08	20.59	13.76	0.23	21.78	15.03
B28-B29-B30	105	207	0.10	25.83	17.30	0.24	27.38	19.01
Average			**0.08**	**22.29**	**14.95**	**0.23**	**23.58**	**16.35**

Please note that the interannual variation in the constant monthly pumping columns for 2011 and 2070 are 0.08 ft and 0.23 ft, respectively. The annual drawdown average from Table 3 above is 8.25 feet, which is about 0.12 ft/yr. Thus, the 2011 value is below the annual average rate of decline and the 2070 value is above the annual average rate of decline. Thus, the constant pumping scenario results represent the long-term rate of decline since there is no seasonal variation associated with this simulation.

The April to September simulation fluctuation is greater than the March to October fluctuation:

- In 2011, April to September is about 22 ft and March to October is about 15 ft
- in 2070, April to September is about 24 ft and March to October is about 16 ft

This is because the pumping rate in the April to September simulation is double the average annual rate and the pumping rate in the March to October is 1.5 times the average annual rate. Pumping is more concentrated in the six month period (April to September) than it is in the eight month period (March to October). Thus, the higher seasonal variation would be expected in the scenario with the shorter pumping period.

These interannual simulation results are analogous to the results in Hutchison (2018) in evaluating the Belding Farms well drawdown data. Hutchison (2018) evaluated drawdown two ways based on the way Belding Farms records their data: 1) the difference between the static groundwater elevation and pumping groundwater elevation in the same month (informally called monthly drawdown) and 2) the difference between the winter maximum groundwater elevation and the pumping groundwater elevation for each month that year (informally called annual drawdown).

The results in Table 4 represent the difference between the winter maximum static groundwater elevation and the summer minimum static groundwater elevation in each year. The groundwater model only considers static groundwater levels, not pumping groundwater levels. It is expected, therefore, that these results would be less than the “annual” drawdowns in each well in Appendix D of Hutchison (2017). For convenient reference Appendix D of Hutchison (2018) is presented in this Technical Memorandum as Appendix A.

Please note that “annual drawdown” in hydrographs of Appendix A generally ranges between 20 and 50 feet, which, given the different definitions used in this analysis (static groundwater levels versus pumping groundwater levels) suggests that the WPC groundwater model is providing reasonable seasonal fluctuation results, despite the approximate way these simulations simulate monthly conditions (i.e. not a calibrated monthly model).

8.0 WPC Model Simulations with Alternative FSH Operating Permit Pumping Schedules

The simulations in the previous section demonstrated that the WPC Model can be used to analyze seasonal groundwater variations in the Bedling Farms wells resulting from seasonal pumping changes despite the limitations associated with converting a model that was developed and calibrated using annual stress periods. This conclusion is based on comparing the annual variation results with actual data from Belding Farms wells presented in Appendix A.

The simulations summarized in this section include:

- Four simulations that establish baselines (two with no pumping in the FSH Operating Permit wells and two with pumping in the FSH Operating Permit wells on an irrigation schedule), and
- Eight simulations that implent alternative "municipal" pumping schedules for the FSH Operating Permit wells while keeping all other wells in the model domain on an irrigation schedule (alternatively April to September or March to October).

The objective of these scenarios was to provide a basis for comparison to assess the potential for impacts to the Belding Farms wells as a result of changing the pattern of pumping by comparing the results to the results of the baseline scenarios.

All files associated with these simulations can be accessed at this link:

https://drive.google.com/drive/folders/1pmbxVpXcAUqqD_oxWzk56x76rxs9v3g9?usp=sharing

Based on the results of the WPC simulations presented above, it is evident that there is no need to simulate 60 years to obtain meaningful results relative to the objectives of this effort. Interannual variation changed only slightly between the first year and 65th year of the simulations. Thus, these simulation were run for a 10-year period using monthly stress periods.

8.1 Scenario Summary

A total of 12 scenarios were developed. Scenarios 1 to 4 were used to establish baseline conditions, and Scenarios 5 to 12 evaluated alternatives "municipal" pumping schedules for the FSH Operating Permit wells while keeping all other wells in the model domain on an irrigation schedule:

- Scenarios 1 and 2 assumed that the FSH Operating Permit wells are not pumped, and all other wells in the model domain are pumped on an irrigation schedule. Scenario 1 assumed that the irrigation season runs from April to September. Scenario 2 assumed that the irrigation season runs from March to October.
- Scenarios 3 and 4 assumed that all wells within the model domain (including the FSH Operating Permit wells) are pumped on an irrigation schedule. Scenario 3 assumed that

the irrigation season runs from April to September. Scenario 4 assumed that the irrigation season runs from March to October. Additonal details of assumptions in the specification of the pumping rate of the FSH Operating Permit wells are provided below.

- Scenarios 5 and 6 assumed that the FSH Operating Permit wells are pumped at a constant rate from January to December, simulating a municipal base supply. Scenario 5 assumed that all other pumping in the model domain occurs from April to September. Scenario 6 assumed that all other pumping in the model domain occurs from March to October. Additonal details of assumptions in the specification of the pumping rate of the FSH Operating Permit wells are provided below.
- Scenarios 7 and 8 assumed that the FSH Operating Permit wells are pumped based on a schedule that was constrained by the installed pump capacity and the annual permit limit for each well. Consequently, some wells were operated for less than four months, and some were operated for more than six months, but all pumping from these wells occurred from February to September. Details are provided below. All other pumping in the model domain occurred in April to September (Scenario 7) and March to October (Scenario 8).
- Scenarios 9 and 10 assumed that the FSH Operating Permit wells are pumped based on a schedule that was constrained by the installed pump capacity and the annual permit limit for each well. Consequently, some wells were operated for less than four months, and some were operated for more than six months, but all pumping from these wells occurred from March to October. Details are provided below. All other pumping in the model domain occurred from April to September (Scenario 9) and March to October (Scenario 10).
- Scenario 11 assumed that there was a relaxation of the permit limits associated with per well installed capacity limits to the point that all FSH Operating Permit pumping could occur in four months (June to September). All other pumping in the model domain occurred from April to September.
- Scenario 12 assumed that there was a relaxation of the permit limits associated with per well installed capacity limits to the point that all FSH Operating Permit pumping could occur in three months (July to September). All other pumping in the model domain occurred from April to September.

Groundwater pumping input for use in the simulations were developed using a pre-processor written for this effort (*ScenWelMuni.exe*). The source code, input files and output files for this pre-processor are included in the link provided above. As noted in the scenario summary above, the treatment of FSH Operating Permit wells and all other wells in the model domain were developed differently. Documentation of the development is provided below.

8.2 Development of non-FSH Operating Permit Well Pumping Input

Annual pumping for all non-FSH Operating Permit wells in the model domain was assumed equal to the 2010 pumping from the calibrated WPC Model as discussed in the previous section of this Technical Memorandum. A total of 1,364 non-FSH Operating Permit wells in the model domain were simulated in these scenarios.

As described in the previous section, pumping rates were doubled for all scenarios that assumed all non-FSH Operating Permit wells were pumped from April to September (Scenarios 1, 3, 5, 7, 9, 11 and 12), and pumping rates were multipled by 1.5 for all scenarios that assumed that all non FSH Operating Permit wells were pumped from March to October (Scenarios 2, 4, 6, 8, and 10).

8.3 Development of FSH Operating Permit Well Pumping Input

8.3.1 Scenarios with No FSH Operating Permit Well Pumping (1 and 2)

Scenarios 1 and 2 were developed to provide a baseline, and pumping for the FSH Operating Permit wells was set to zero for these scenarios.

8.3.2 Scenarios based on Average Annual Rates (3 to 6 and 11 to 12)

The pumping rates associated with the WPC Model in 2010 (Hutchison, 2017) that were used in the previous set of simulations described above were removed for these simulations. For the FSH Operating Permit wells, pumping rates for Scenarios 3 to 6 and Scenarios 11 and 12 were based on the annual operating permit limits for the 25 individual wells previosuly presented in Table 1. This annual total in AF/yr was converted to an average annual rate expressed in cubic feet per day (the units used in MODFLOW input files). This represents an average annual rate of pumping. Use of this average annual rate for these scenarios was as follows:

- For Scenario 3: the average annual rate was doubled to simulate pumping over 6 months (April to September).
- For Scenario 4, the average annual rate was multiplied by 1.5 to simulate pumping over 8 months (March to October).
- Scenarios 5 and 6: the average annual rate was used because the to simulate a constant rate of pumping from January to December.
- Scenario 11: the average annual rate was multiplied by 3 to simulate pumping over 4 months (June to September).
- Scenario 12: the average annual rate was multiplied by 4 to simulated pumping over 3 months (July to September).

These assumed rates are not entirely consistent with the permit conditions related to both installed capacity and annual permit production limits. Strict adherence to both of the conditions was simulated in Scenarios 7 to 10 as developed below.

8.3.3 Scenarios Constrained by Intalled Pump Capacity and Annual Limits (7 to 10)

Based on the insalled pump capacity and the production limits associated with each well (previously presented in Table 1), two sets of municipal pumping scnenarios were developed: one set with pumping from February to September (Scenarios 7 and 8), and one set with pumping from March to October (Scenarios 9 and 10). The development of these scenarios was completed using

Excel spreasheets that can be accessed in the link provided above (*FSHOperatingPermitWells-FebtoSep.xlsx* and *FSHOperatingPemitWells-MartoOct.xlsx*).

The last column in Table 1 (previously presented) is the number of days of pumping to reach the maximum limit based on the installed pump capacity, assuming continuous operation. This is Column K in the spreadsheet labeled The tab named *"Timing"* in the spreadsheets. Table 5 summarizes the number of days of pumping in each well for Scenarios 7 and 8 for each month to reach the annual production limit based on installed pump capacity. For this simulation, all pumps are turned on with the intention of reaching the annual limit on September 30. The companion table for Scenarios 9 and 10 assumes that the maximum limit would be reached on October 31.

For example, based on the installed capacity of Well C-1, continuous pumping would result in reaching the annual permit limit in about 96 days. In order to evaluate the maximum impact on end of September groundwater elevations, it was assumed that the well would operate for a little over 4 days in June, and then operate continuously in July, August, and September. The total in the right hand column can then be compared to verify that the number of days of pumping matches the calcuated days in the second column of the table.

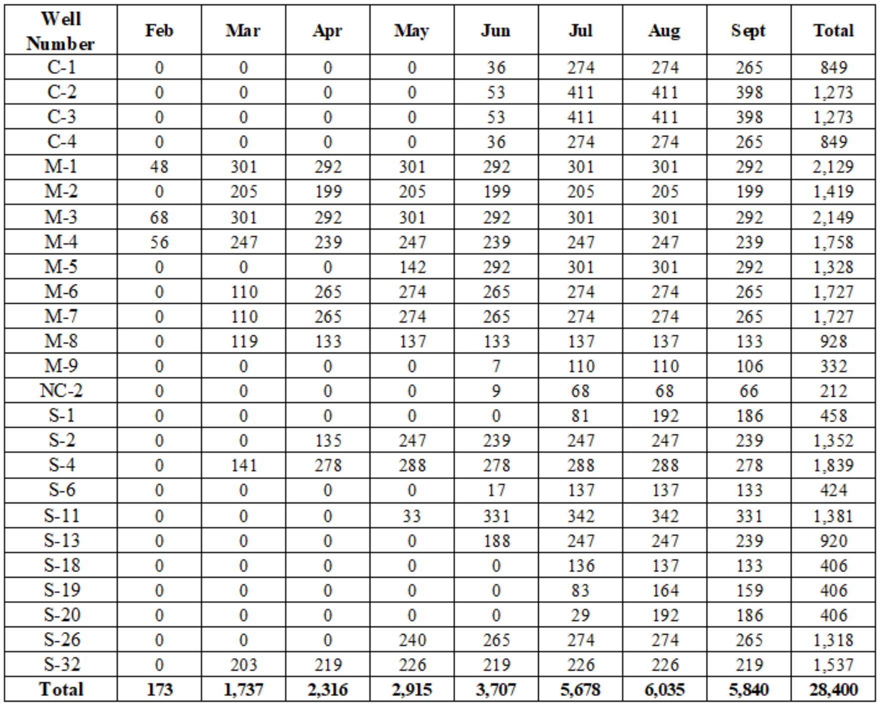
Another example is M-1. Based on the installed capacity of this well, continuous pumping would result in reaching the annual permit limit in about 219 days. In order to evaluate the maximum impact on end of September groundwater elevations, it was assumed that the well would operate for just under 5 days in February, and then operate continuously from March to September.

Table 5. Scenario 7 - Number of Days of Pumping in Each FSH Well

Well Number	Days at Max Rate to Reach Annual Limit	Days Each month at Maximum Pumping								
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
C-1	96.06					4.06	31.00	31.00	30.00	96.06
C-2	96.02					4.02	31.00	31.00	30.00	96.02
C-3	96.02					4.02	31.00	31.00	30.00	96.02
C-4	96.06					4.06	31.00	31.00	30.00	96.06
M-1	218.98	4.98	31.00	30.00	31.00	30.00	31.00	31.00	30.00	218.98
M-2	214.07	0.07	31.00	30.00	31.00	30.00	31.00	31.00	30.00	214.07
M-3	221.04	7.04	31.00	30.00	31.00	30.00	31.00	31.00	30.00	221.04
M-4	221.01	7.01	31.00	30.00	31.00	30.00	31.00	31.00	30.00	221.01
M-5	136.59				14.59	30.00	31.00	31.00	30.00	136.59
M-6	195.40		12.40	30.00	31.00	30.00	31.00	31.00	30.00	195.40
M-7	195.40		12.40	30.00	31.00	30.00	31.00	31.00	30.00	195.40
M-8	209.99		26.99	30.00	31.00	30.00	31.00	31.00	30.00	209.99
M-9	93.91					1.91	31.00	31.00	30.00	93.91
NC-2	95.95					3.95	31.00	31.00	30.00	95.95
S-1	74.03						13.03	31.00	30.00	74.03
S-2	169.97			16.97	31.00	30.00	31.00	31.00	30.00	169.97
S-4	198.16		15.16	30.00	31.00	30.00	31.00	31.00	30.00	198.16
S-6	95.95					3.95	31.00	31.00	30.00	95.95
S-11	125.00				3.00	30.00	31.00	31.00	30.00	125.00
S-13	115.66					23.66	31.00	31.00	30.00	115.66
S-18	91.87						30.87	31.00	30.00	91.87
S-19	76.56						15.56	31.00	30.00	76.56
S-20	65.62						4.62	31.00	30.00	65.62
S-26	149.12				27.12	30.00	31.00	31.00	30.00	149.12
S-32	210.79		27.79	30.00	31.00	30.00	31.00	31.00	30.00	210.79

Using the number of days shown in Table 5 and the installed capacity pumping rate, the actual pumping for each month for Scenarios 7 and 8 is presented in Table 6 in acre-feet per month. This is found in the "*AF mo*" tab in the spreadsheets. Please note that for this scenario, the highest monthly total is in August, because August has 31 days and September has 30 days, even though pumping in both months is at the maximum rates for each well. Maximum pumping occurs in July, August and September. Less than maximum pumping occurs from February to June as noted in Table 6. A similar "*AF mo*" tab is in the spreasheet associated with Scenarios 9 and 10.

Table 6. Scenario 7 - Pumping (AF/month)

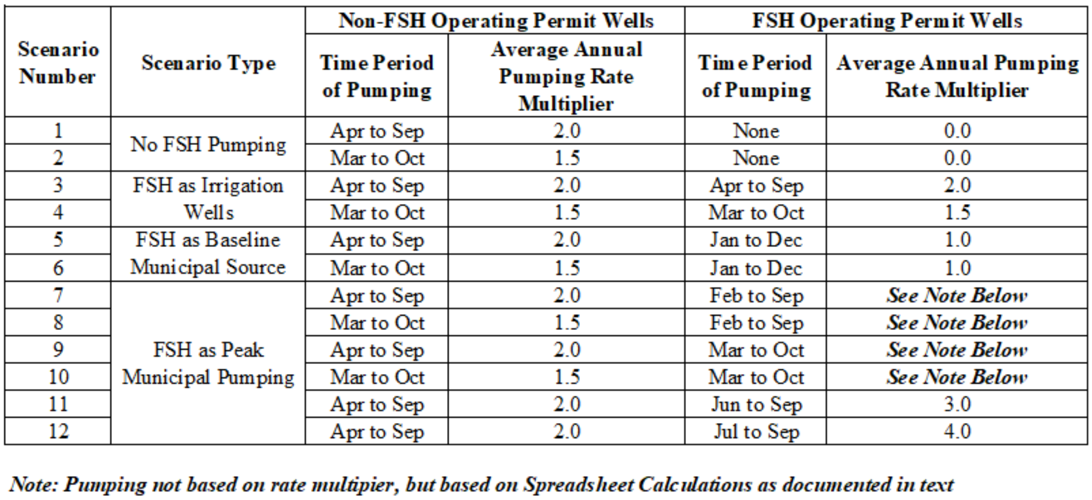


Well Number	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
C-1	0	0	0	0	36	274	274	265	849
C-2	0	0	0	0	53	411	411	398	1,273
C-3	0	0	0	0	53	411	411	398	1,273
C-4	0	0	0	0	36	274	274	265	849
M-1	48	301	292	301	292	301	301	292	2,129
M-2	0	205	199	205	199	205	205	199	1,419
M-3	68	301	292	301	292	301	301	292	2,149
M-4	56	247	239	247	239	247	247	239	1,758
M-5	0	0	0	142	292	301	301	292	1,328
M-6	0	110	265	274	265	274	274	265	1,727
M-7	0	110	265	274	265	274	274	265	1,727
M-8	0	119	133	137	133	137	137	133	928
M-9	0	0	0	0	7	110	110	106	332
NC-2	0	0	0	0	9	68	68	66	212
S-1	0	0	0	0	0	81	192	186	458
S-2	0	0	135	247	239	247	247	239	1,352
S-4	0	141	278	288	278	288	288	278	1,839
S-6	0	0	0	0	17	137	137	133	424
S-11	0	0	0	33	331	342	342	331	1,381
S-13	0	0	0	0	188	247	247	239	920
S-18	0	0	0	0	0	136	137	133	406
S-19	0	0	0	0	0	83	164	159	406
S-20	0	0	0	0	0	29	192	186	406
S-26	0	0	0	240	265	274	274	265	1,318
S-32	0	203	219	226	219	226	226	219	1,537
Total	**173**	**1,737**	**2,316**	**2,915**	**3,707**	**5,678**	**6,035**	**5,840**	**28,400**

The final step in developing the pumping input files is to convert the input pumping to cubic feet per day. The spreadsheet tab labeled "*cfd*" contains the calculations for these conversions.

Table 7 summarizes the input pumping assumptions associated with each scenario.

Table 7. Summary of Scenario Pumping Input



Scenario Number	Scenario Type	Non-FSH Operating Permit Wells		FSH Operating Permit Wells	
		Time Period of Pumping	Average Annual Pumping Rate Multiplier	Time Period of Pumping	Average Annual Pumping Rate Multiplier
1	No FSH Pumping	Apr to Sep	2.0	None	0.0
2		Mar to Oct	1.5	None	0.0
3	FSH as Irrigation Wells	Apr to Sep	2.0	Apr to Sep	2.0
4		Mar to Oct	1.5	Mar to Oct	1.5
5	FSH as Baseline Municipal Source	Apr to Sep	2.0	Jan to Dec	1.0
6		Mar to Oct	1.5	Jan to Dec	1.0
7	FSH as Peak Municipal Pumping	Apr to Sep	2.0	Feb to Sep	*See Note Below*
8		Mar to Oct	1.5	Feb to Sep	*See Note Below*
9		Apr to Sep	2.0	Mar to Oct	*See Note Below*
10		Mar to Oct	1.5	Mar to Oct	*See Note Below*
11		Apr to Sep	2.0	Jun to Sep	3.0
12		Apr to Sep	2.0	Jul to Sep	4.0

Note: Pumping not based on rate multipier, but based on Spreadsheet Calculations as documented in text

8.4 Simulation Results

Results from these simulations were focused on drawdown in individual Belding Farms wells. Results for each well were saved in individual files which are accessible at the links provided above. Results for drawdown, interannual variation in groundwater elevation, and pumping are also accessible at the links provided above.

8.4.1 Output Pumping Results

Total pumping in Management Zone 1 and pumping from the FSH Operating Permit wells was extracted from the cell by cell model output to verify the proper input pumping values as outlined above.

FSH Operating permit pumping was zero in Scenarios 1 and 2, and about 28,400 AF/yr in Scenarios 3 to 12. Small variations attributed to round error were present, but deemed insignifcant for purposes of this analysis.

Total pumping in Management Zone 1 included all FSH Operating Permit wells. The total pumping was about 60,000 AF/yr in Scenarios 1 and 2 (FSH Operating Permit wells were off), and about 88,000 AF/yr in Scenarios 3 to 12. Along with the small variations attributable to rounding error, there was also some decline in Management Zone 1 pumping that appears to be due to reduction in pumping due to dry cells. The reduction was about 600 AF for the 10-year simulation in all scenarios, and was not considered significant.

Files associated with the extraction of pumping were written by the post-proccessor *getpumpmuni.exe*. The source code, executables and output files are accessible in the link provided earlier.

8.4.2 Hydrographs of Well B-7 Drawdown

Results for each well are accessible in the link provided above, and the results are all similar. Hydrographs of Well B-7 for three of the scenarios are provided below to illustrate the interpretation of the results.

Figure 9 presents a comparison of the drawdown in Well B-7 for Scenarios 3 and 7. Please recall that Scenario 3 represents all wells pumping on an irrigation schedule that runs from April to September, and Scenario 7 represents the scenario where non-Operating Permit wells pump on an April to September irrigation schedule and FSH Operating Permit wells pumping on a schedule that is constrained by the pumping capacity and annual limits on each well as noted in Table 6 previously presented.

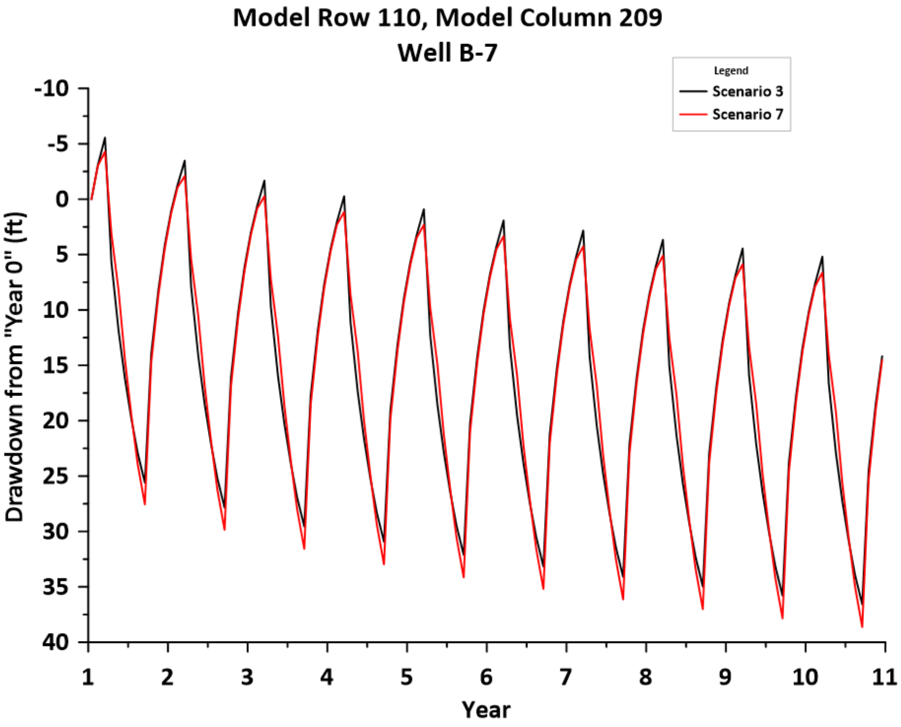


Figure 9. Well B-7 Drawdown Hydrograph - Scenarios 3 and 7

The general trend of reduced drawdown over time is evident, as well as an interannual cycle of drawdown and recovery. The drawdown trend is more pronounced in these simulations as compared to the earlier simulations because the overall pumping in higher. Please recall that the FSH Operating Permit wells in 2010 (the final year for the calibration period of the WPC Model) was about 16,300 AF/yr. Because the pumping for these simulations assumed pumping of 28,400 AF/yr, and there was no reduction in the pumping in the rest of Management Zone 1 to achieve a total of about 77,000 AF/yr, total pumping for Management Zone 1 was assumed to be about 88,000 AF/yr for these simulations, with the exception of Scenarios 1 and 2 that assumed no pumping from the FSH Operating Permit wells.

Please note that the interannual variationin groundwater elevation due to seasonal pumping is evident. The winter recovery in Scenario 3 is slightly higher than in Scenario 7 due to the nine wells that pumping in February and March in Scenario 7 that are off in Scenario 3. The maximum drawdown at the end of September is slightly higher in Scenario 7 than it is in Scenario 3 due to the higher rate of pumping in Scenario 7 associated with the nine wells that start operating in later June and are at full pumping during July, August and Septmber in Scenario 7. Scenario 3 has constant pumping in all months from April to September. However, the differences in the winter recovery levels between the two scenarios and the differences in the end-of-September groundwater levels are not signficant.

Based on this comparison, there is no significant difference between the groundwater levels in this well between the two scenarios where FSH Operating Permit wells are alternatively operated on an irrigation schedule and on an aggressive municipal schedule that maximizes production in July, August, and September consistent with the current permit conditions related to installed pump capacity and annual production limits for each well.

While Scenario 7 was constrained by current well capacities as listed in the permit, Scenario 12 represents a hypothetical assumption that the all FSH Operating Permit wells could produce their full annual permit limit in 3 months. This hypothetical assumption is inconsistent with the permit conditions, but the results are instructive to gain a better understanding of the potential impacts of concentrating pumping over a relatively short period of time. Comparison hydrographs of Scenario 3 and Scenario 12 is presented in Figure 10.

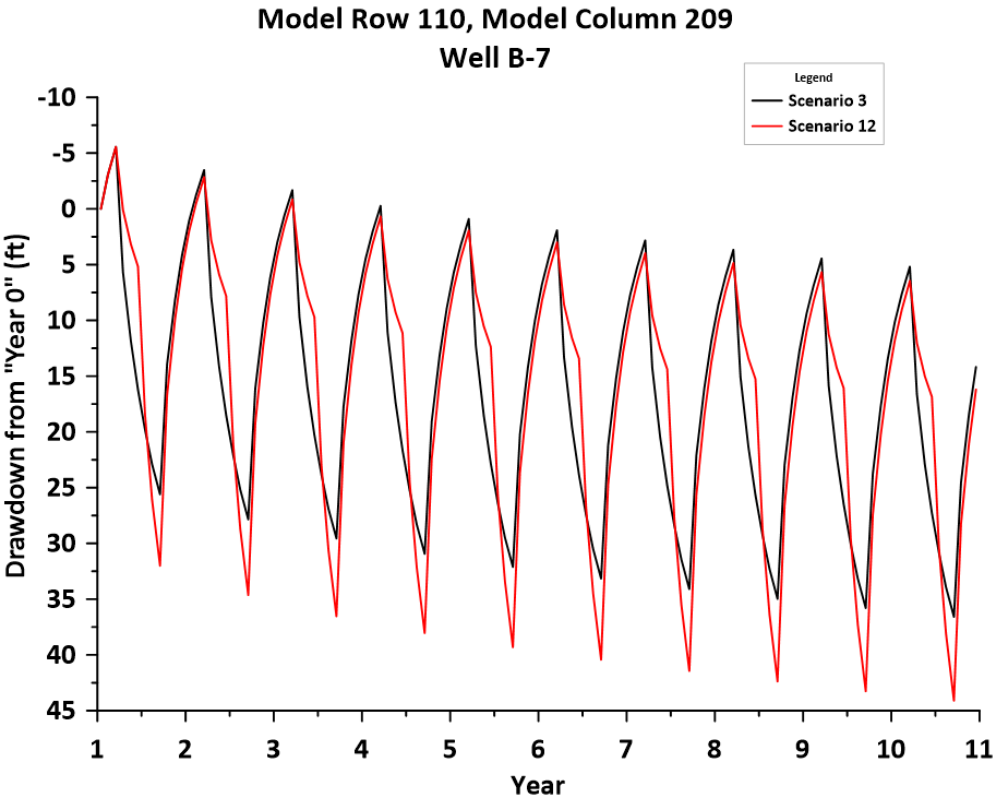


Figure 10. Well B-7 Drawdown Hydrograph - Scenarios 3 and 12

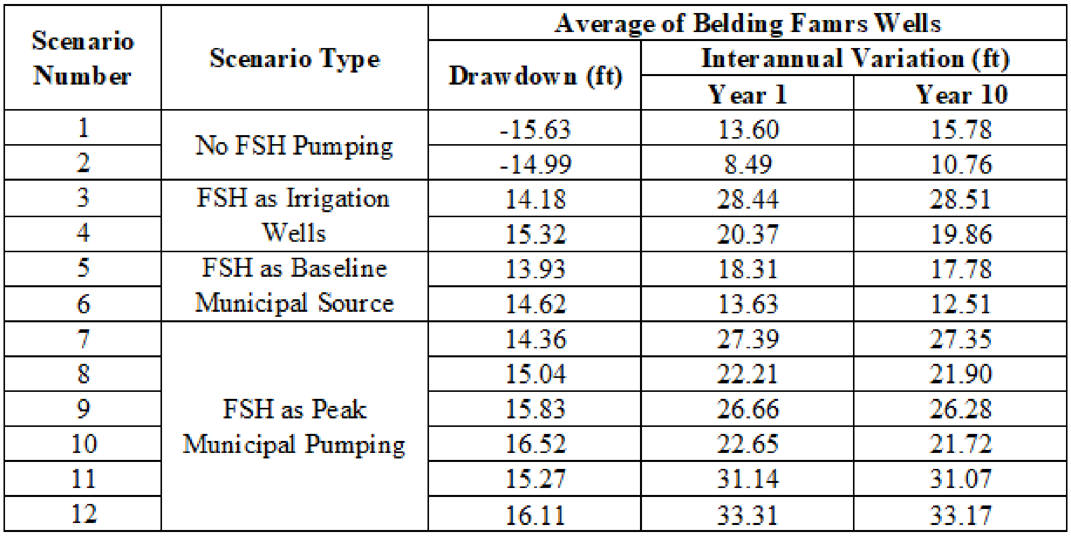
Please note the distinctive increase in Scenario 12 drawdown each July when the FSH Operating Permit wells start the three-month pumping cycle. Also, please note that the Scenario 12 end-of-September maximum drawdown is nearly 10 feet greater than the Scenario 3 end-of-September maximum drawdown. This is slightly greater than the difference between Scenario 3 and Scenario 12 end-of-September maximum drawdown.

8.4.3 Summary Results of Drawdown and Interannual Variation

The results were extracted from the model head save file using a post-processor *gethdsmuni.exe.* The source code, executable, and output files associated with this post-processor are accessible at the link provided above.

Table 8 summarizes the average simulated drawdown, simulated average interannual variation in Year 1, and the simulated average interannual vairation in Year 10 for the Belding Farms wells for each scenario.

Table 8. Summary of Simulated Average Drawdown and Interannual Variation for Belding Farms Wells



Scenario Number	Scenario Type	Average of Belding Famrs Wells		
		Drawdown (ft)	Interannual Variation (ft)	
			Year 1	Year 10
1	No FSH Pumping	-15.63	13.60	15.78
2		-14.99	8.49	10.76
3	FSH as Irrigation Wells	14.18	28.44	28.51
4		15.32	20.37	19.86
5	FSH as Baseline Municipal Source	13.93	18.31	17.78
6		14.62	13.63	12.51
7	FSH as Peak Municipal Pumping	14.36	27.39	27.35
8		15.04	22.21	21.90
9		15.83	26.66	26.28
10		16.52	22.65	21.72
11		15.27	31.14	31.07
12		16.11	33.31	33.17

Please note that in Scenarios 1 and 2 (no FSH Operating Permit well pumping), there is a overall recovery in groundwater elevations during the simulation period and interannual variation is relatively small. This is due to an overall reduction in pumping because FSH Operating Permit wells are off. Total pumping in Management Zone 1 in the scenario is about 60,000 AF/yr as compared to all other scenarios where the total pumping in Management Zone 1 is about 88,000 AF/yr.

The results of Scenario 3 and 4 represent a baseline because all pumping in the model domain is on an irrigation schedule (April to September in Scenario 3 and March to October in Scenario 4). Please note that the interannual variation is lower in the Scenario 4 than in Scenario 3 because the pumping in Scenario 4 is spread out over 8 months rather than 6 months in Scenario 3.

The simulated average interannual variation in Scenarios 5 and 6 is less than the irrigation pumping season baselines (Scenarios 3 and 4) because FSH Operating Permit well pumping is spread out over a 12 month period, thus reducing the drawdown and recovery associated with seasonal pumping for a significant portion of the total pumping in the model domain (about 28,000 AF/yr out of a total of about 88,000 AF/yr).

The simulated average interannual variation in Scenarios 7 and 9 are similar because the FSH Operating Permit well pumping is over the same time period (February to September), while all other pumping in Scenario 7 is between April and September (6 months) and other pumping in Scenario 9 is between March and October (8 months). Similarly, the simulated interannual variation in Scenarios 8 and 10 are simillar because the FSH Operating well pumping is over the same time period (March to October).

The simulated average interannual variation in Scenarios 11 and 12 is highest of all the scenarios because the FSH Operating Permit wells pumping in concentrated over a four month period

(Scenario 11) and a three month period (Scenario 12). As discussed above, this scenario is not consistent with the terms of the permit, but was completed to gain a better understanding of the potential impacts of concentrating pumping over a relatively short period of time.

8.5 Discussion of Results

Under current installed capacity and annual production limits of each well in the FSH Operating Permit, the results of simulating pumping on a municipal schedule demonstrate that impacts to the Belding Wells are nearly identical to simulated impacts to the Belding Wells when FSH Operating Permit wells are operated on an irrigation schedule. The current permit conditions require adherence to the current pump capacity and annual production limits of each well. Simulations that assumed relaxation of these limits (i.e. all FSH Operating Permit pumping over a three- or four-month period) did result in higher impacts to Belding Farms wells, but did not impact long-term drawdown, which is a groundwater planning issue.

The significance of the additional impacts associated with concentrated pumping of FSH Operating Permit wells over a three- or four-month period are unknown. However, understanding the significance is more properly groundwater management and groundwater regulation issues, not groundwater planning process issues. Additional data and a more robust analytical exercise with a more appropriate model would be needed to assess the significance of these simulated impacts. Currently, there are no plans to modify the installed pump capacity and/or the annual limits of individual wells, so there is no urgent need to evaluate the significance further. However, this analysis does provide some background if such a request is made in the future. Any such request would be made to the Middle Pecos Groundwater Conservation District (not Groundwater Management Area 7). Such a request would be analyzed by and would be approved by the Middle Pecos Groundwater Conservation District as part of its groundwater management and groundwater regulation activities.

9.0 References

R.W. Harden & Associates, Inc., LBG-Guyton Associates, and Thornhill Group, Inc., 2011. Hydrogeologic, Geochemical and Groundwater Model Evaluation of the Leon-Belding Area in Pecos County. Report prepared for Fort Stockton Holdings, L.P. April 14, 2011, 95p.

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. 2017. Review of Western Pecos County Groundwater Model (Draft 1). Report prepared for Middle Pecos Groundwater Conservation District. March 10, 2017, 55p.

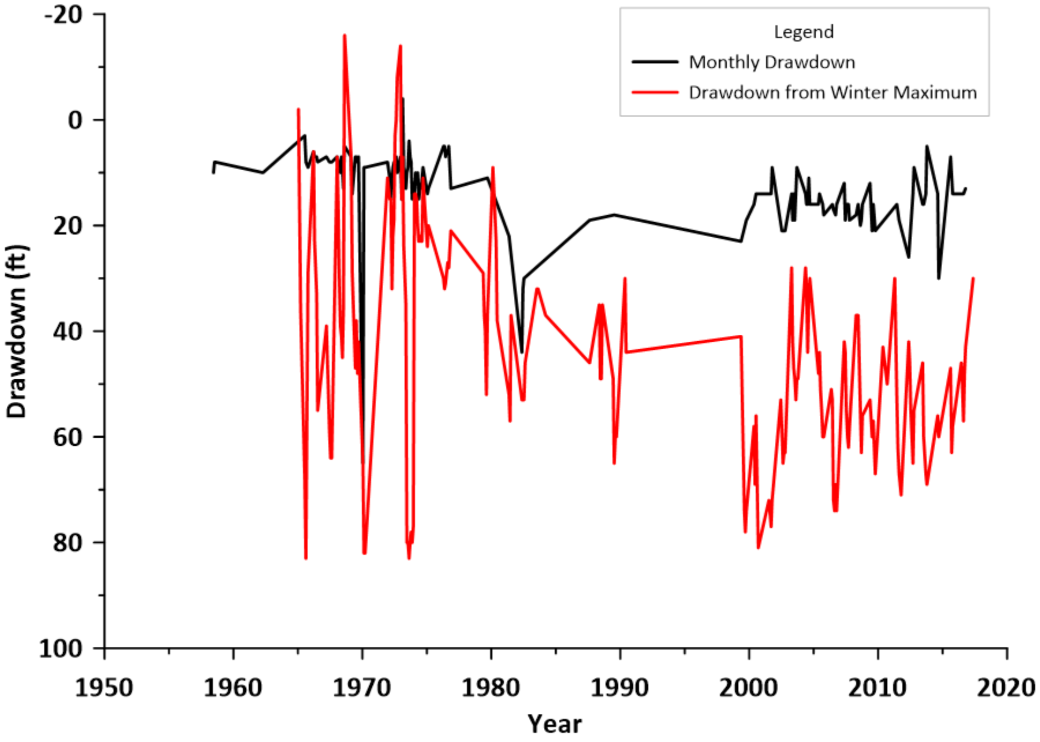
Hutchison, W.R., 2018. Review of Belding Farms Database (Draft). Report prepared for Middle Pecos Groundwater Conservation District. December 7, 2018, 94p.

Hutchison W.R., 2018b. Edwards-Trinity (Plateau), Pecos Valley and Trinity Aquifers: Nine Factor Documentation and Predictive Simulations. GMA 7 Technical Memorandum 15-06 (Final). Prepared for Groundwater Management Area 7. March 26, 2018, 61p.

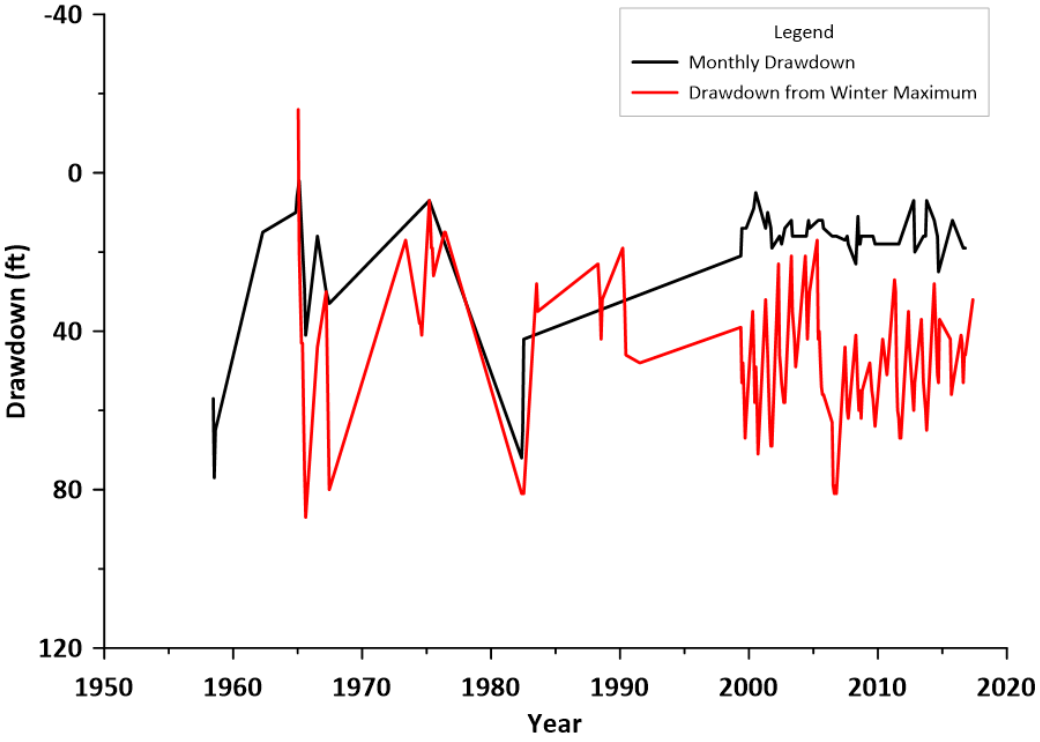
Hutchison, W.R., 2018c. Edwards-Trinity (Plateau), Pecos Valley, and Trinity Aquifers: Update of Average Drawdown Calculations. GMA 7 Technical Memorandum 18-01 (Final). Prepared for Groundwater Management Area 7., March 26, 2018, 11p.

Appendix A

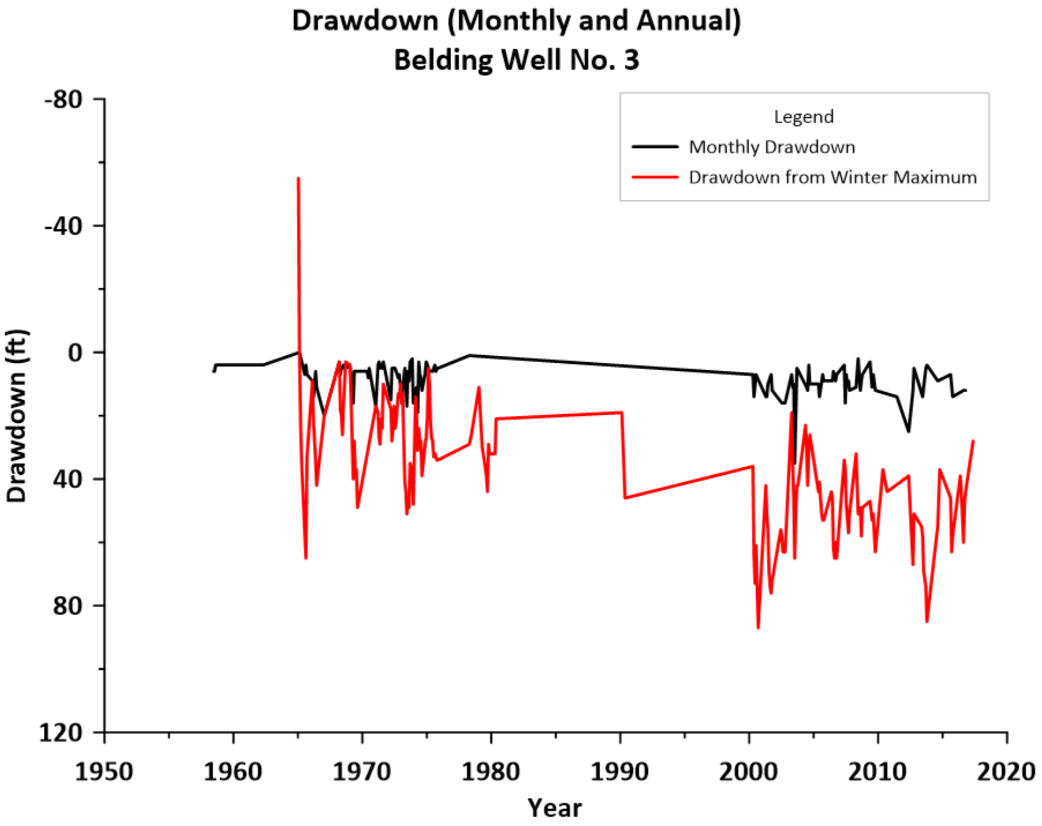
Belding Farms Drawdown Hydrographs

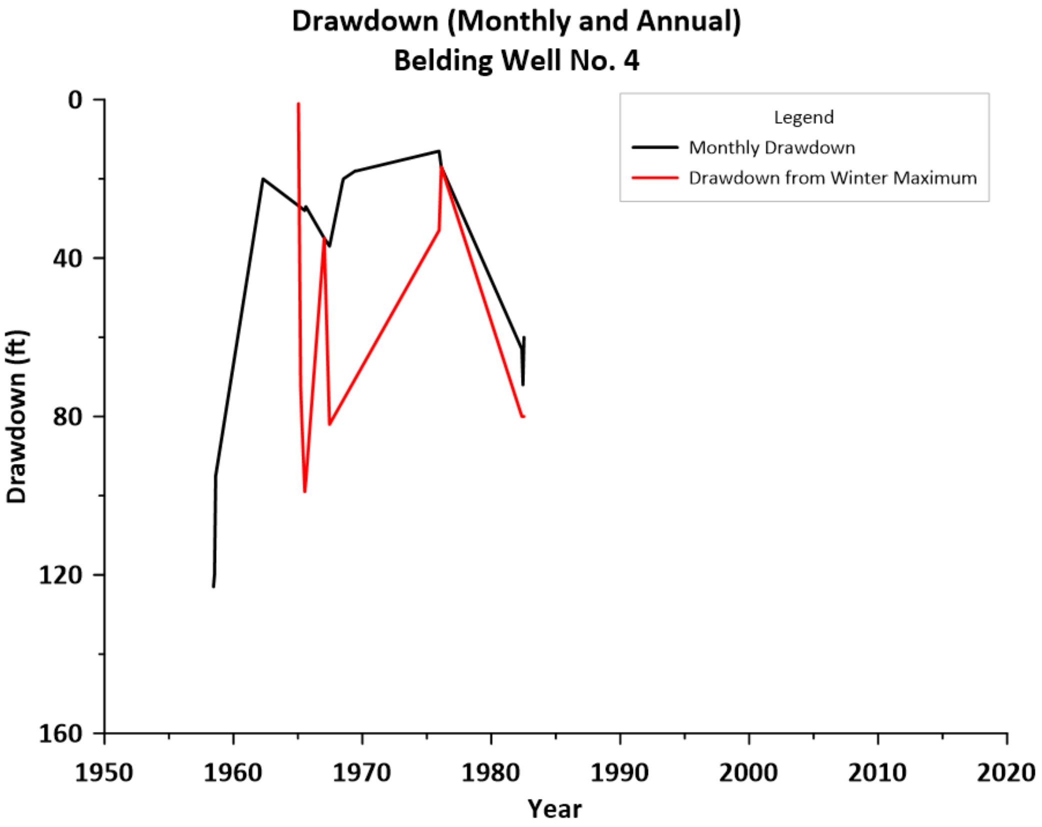


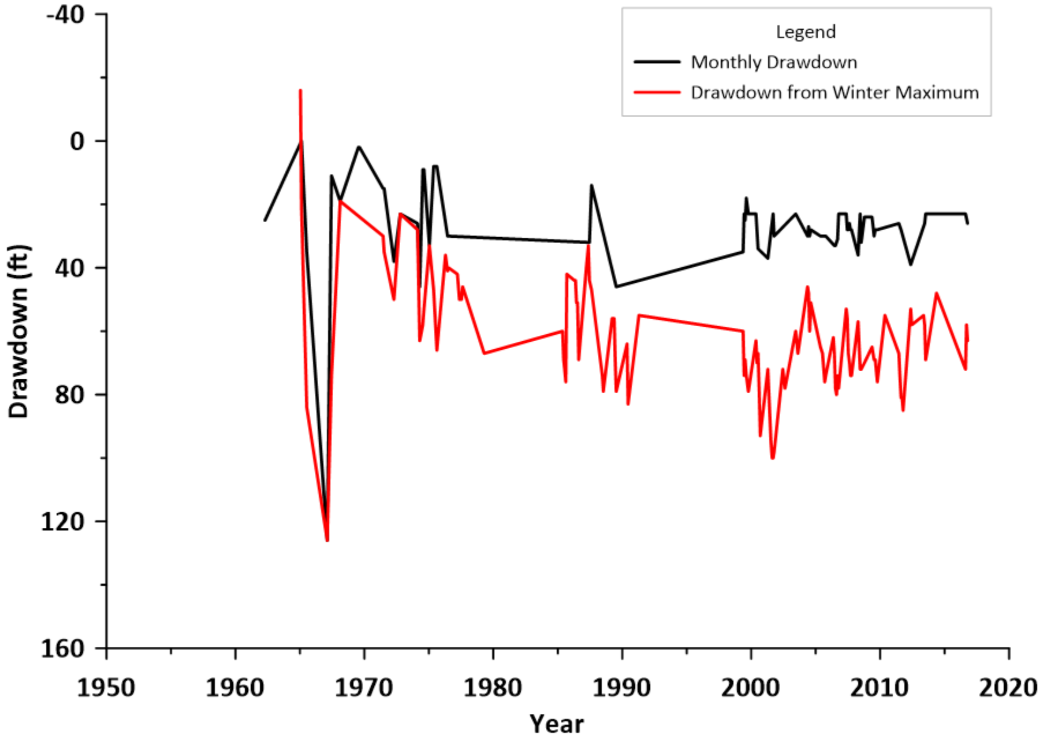
Drawdown (Monthly and Annual)
Belding Well No. 1



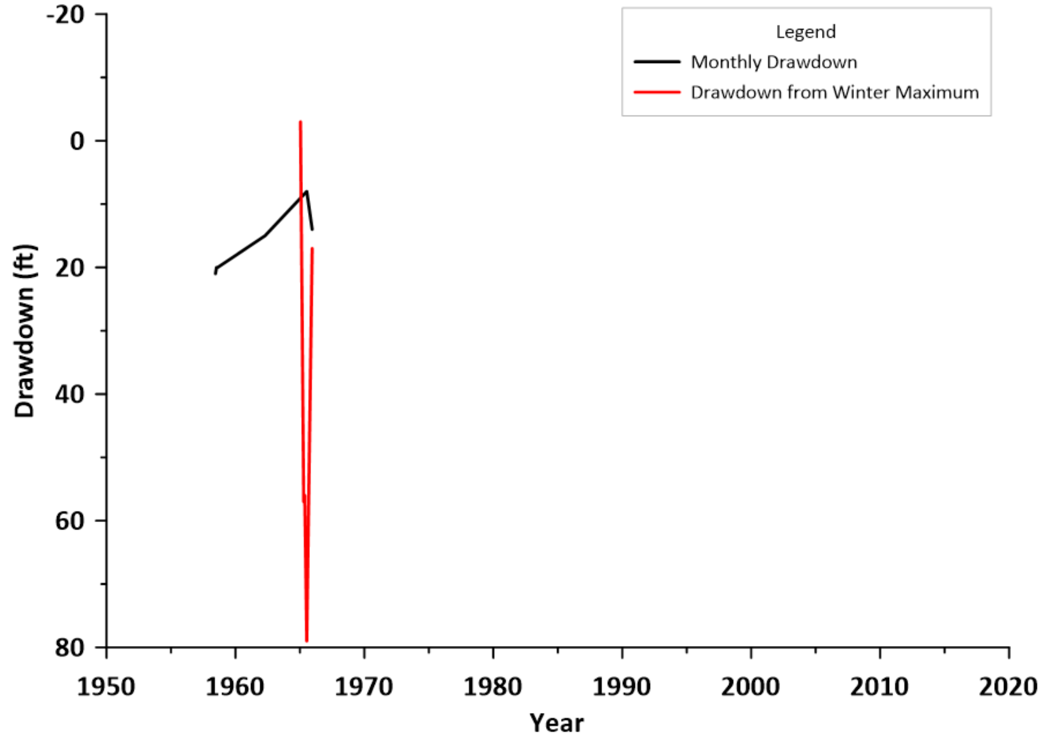
Drawdown (Monthly and Annual)
Belding Well No. 2


Drawdown (Monthly and Annual)
Belding Well No. 3
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
-80
-40
0
40
80
120
1950
1960
1970
1980
1990
2000
2010
2020
Year

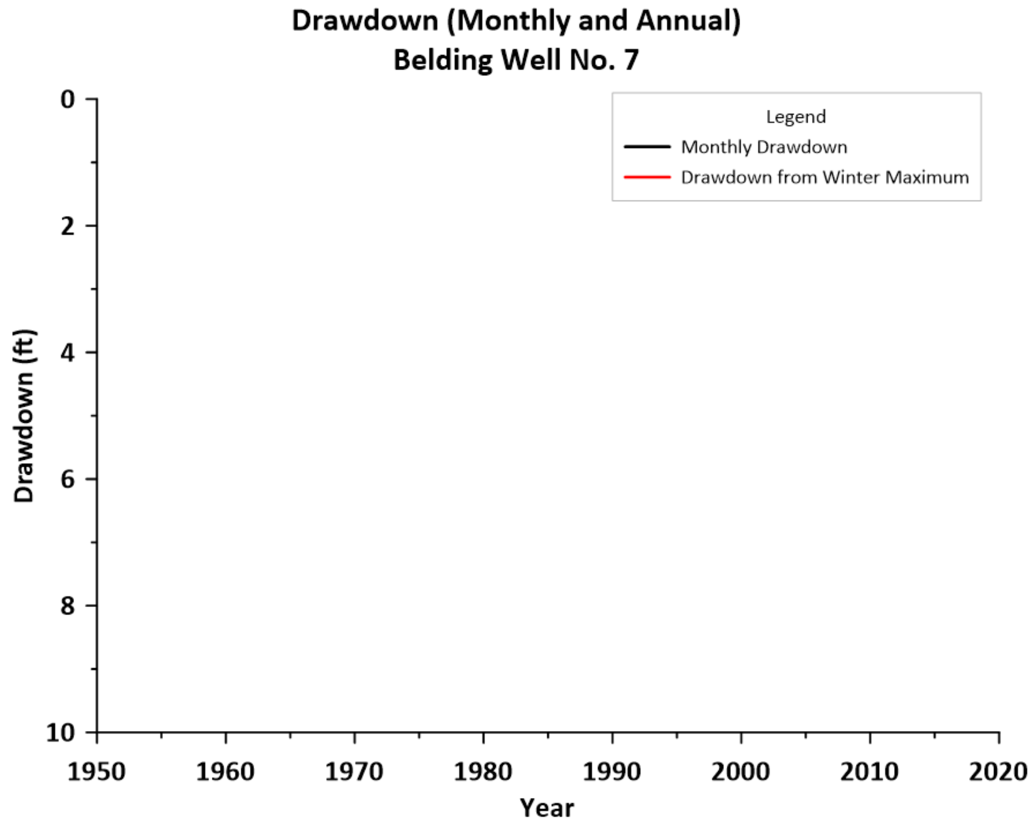

Drawdown (Monthly and Annual)
Belding Well No. 4
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
40
80
120
160
1950
1960
1970
1980
1990
2000
2010
2020
Year

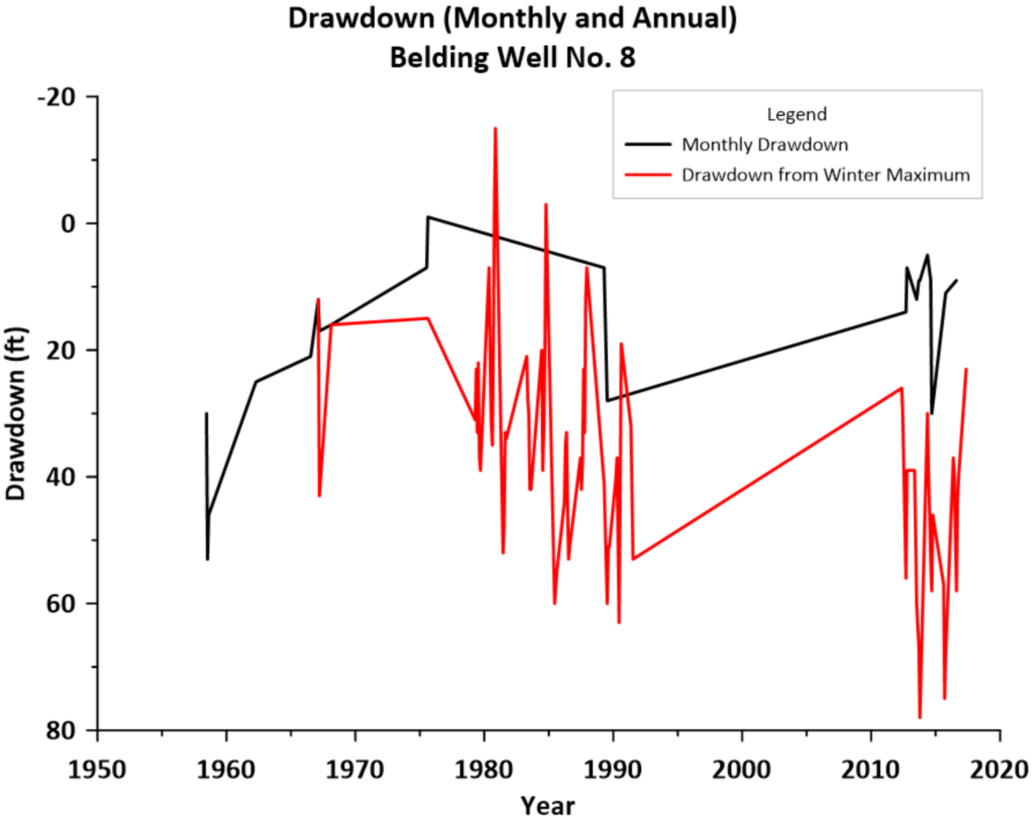


Drawdown (Monthly and Annual)
Belding Well No. 5



Drawdown (Monthly and Annual)
Belding Well No. 6


Drawdown (Monthly and Annual)
Belding Well No. 7
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
2
4
6
8
10
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 8
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
-20
0
20
40
60
80
1950
1960
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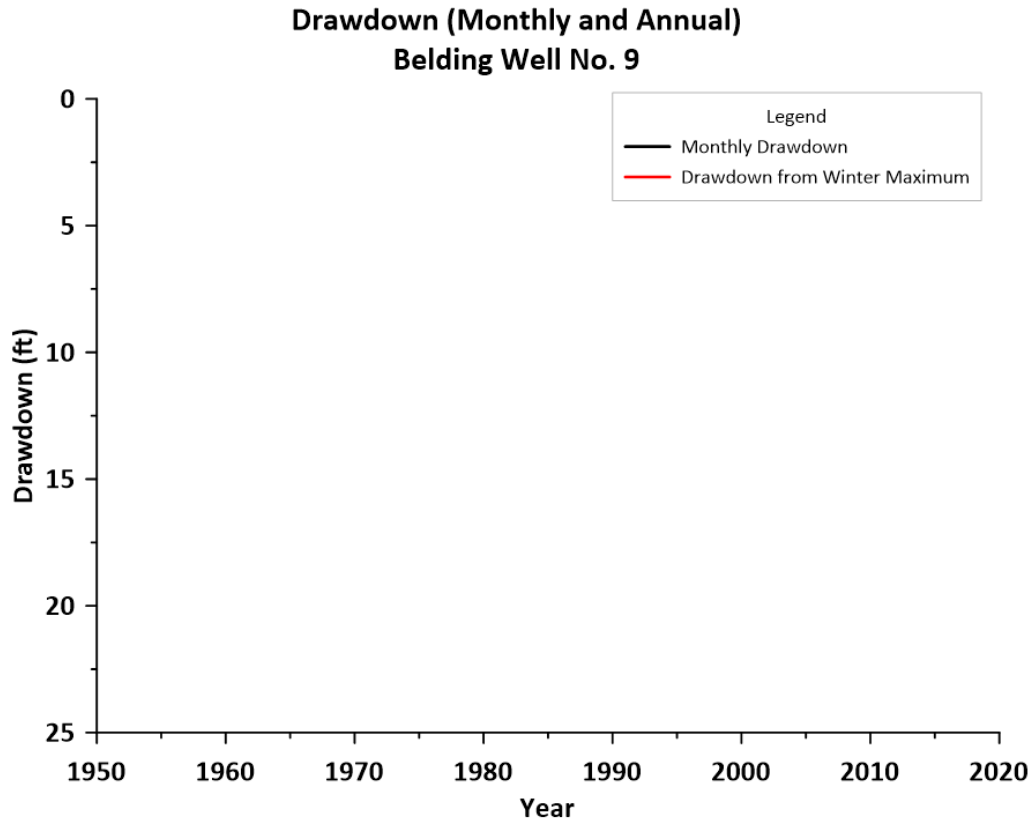
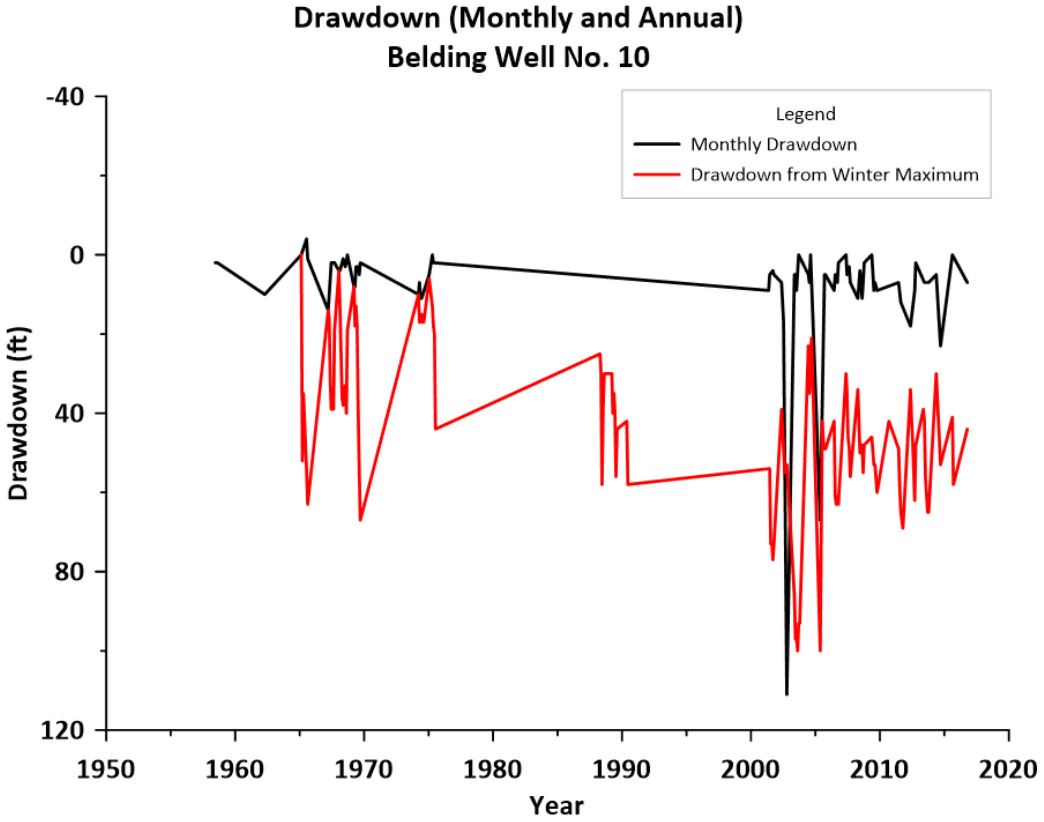
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 9
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
5
10
15
20
25
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 10
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
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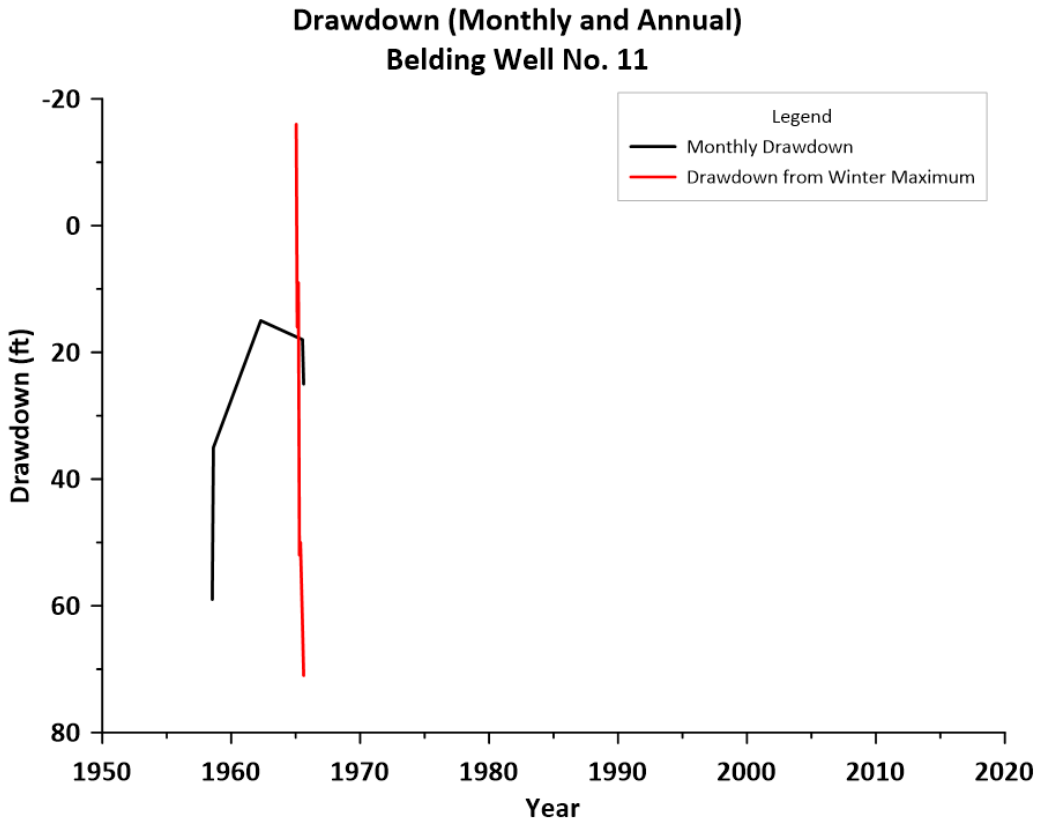
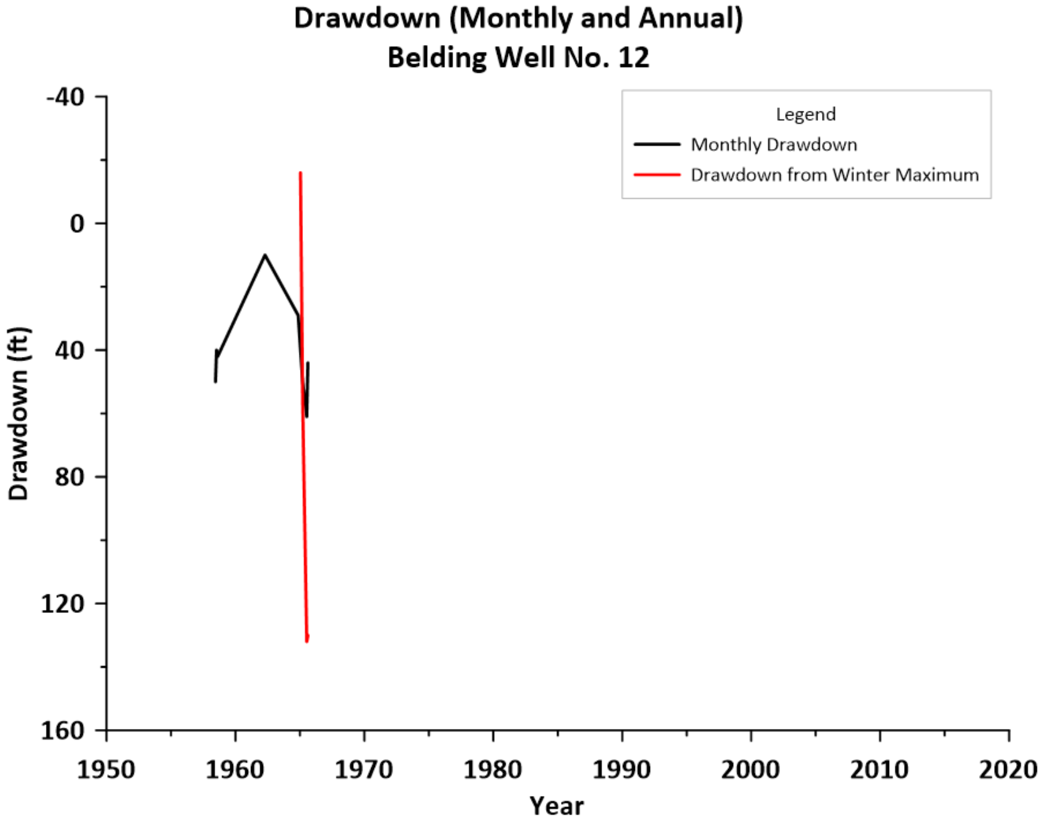
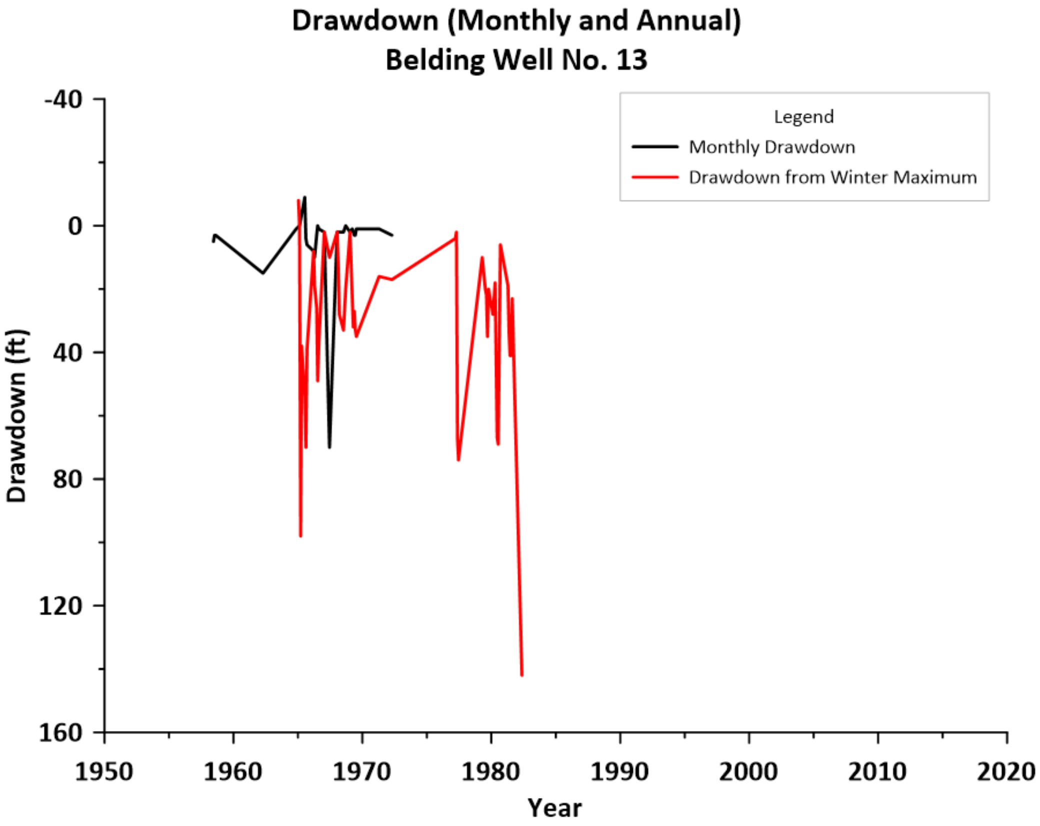
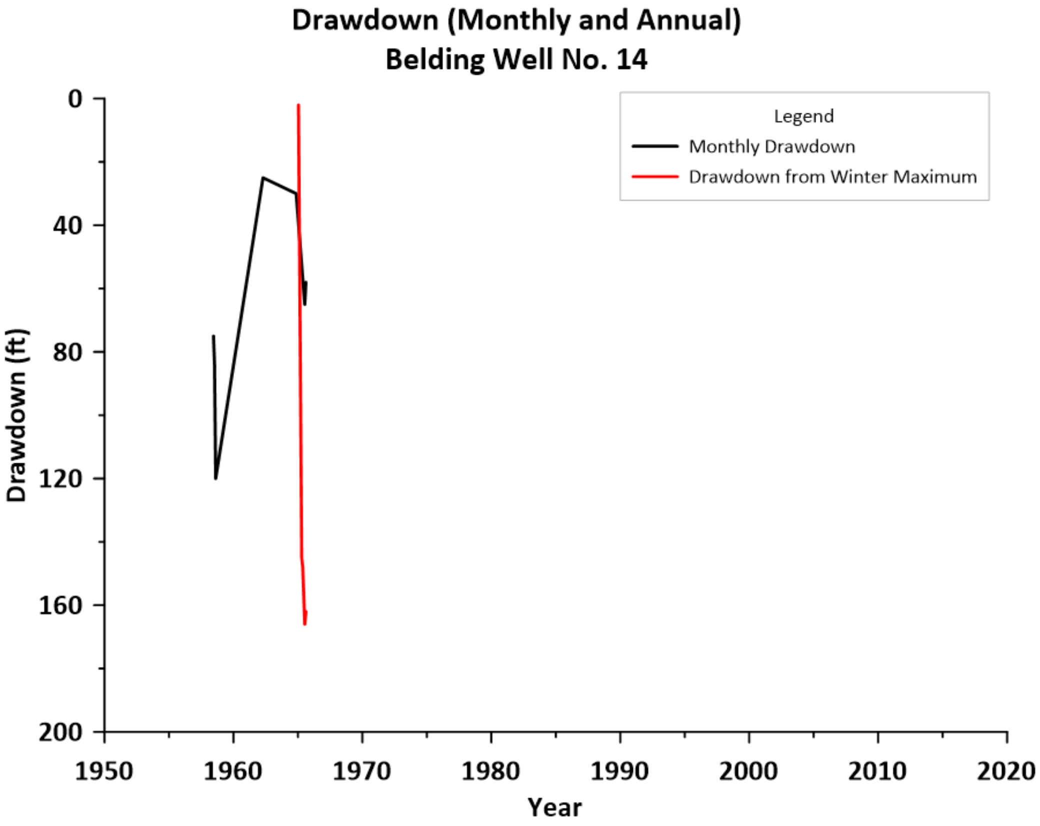
0
40
80
120
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 11


Drawdown (Monthly and Annual)
Belding Well No. 12


Drawdown (Monthly and Annual)
Belding Well No. 13
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
-40
0
40
80
120
160
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 14
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
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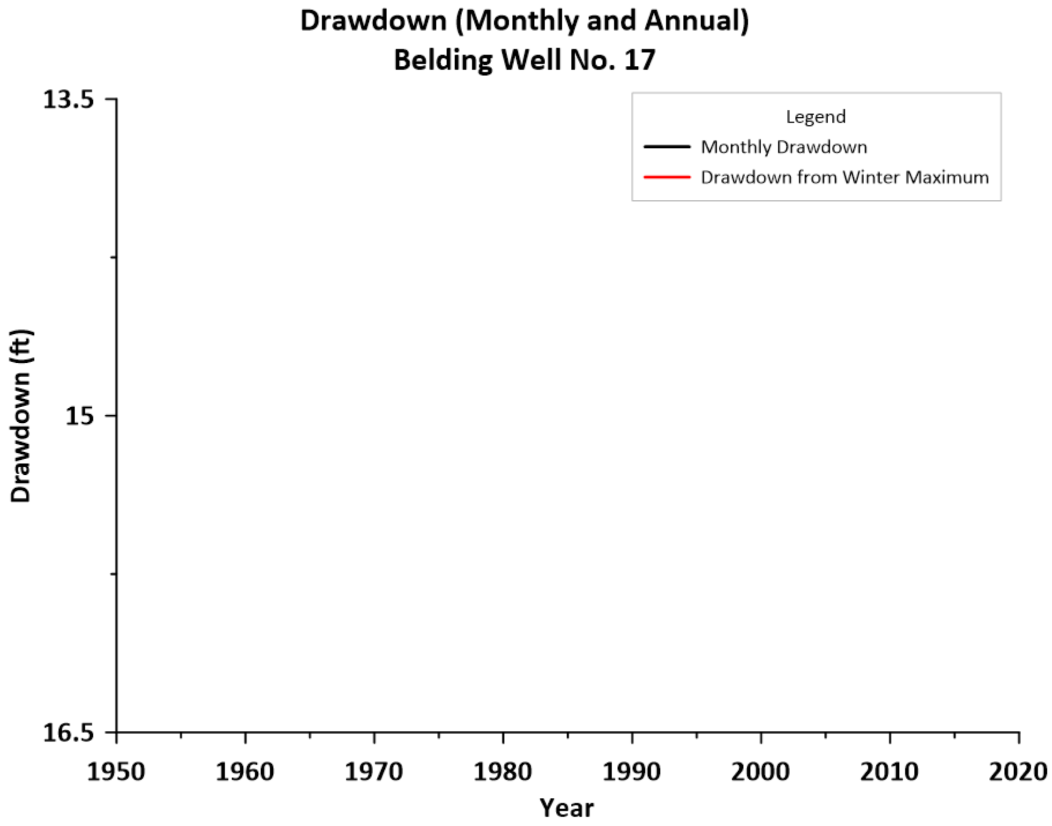
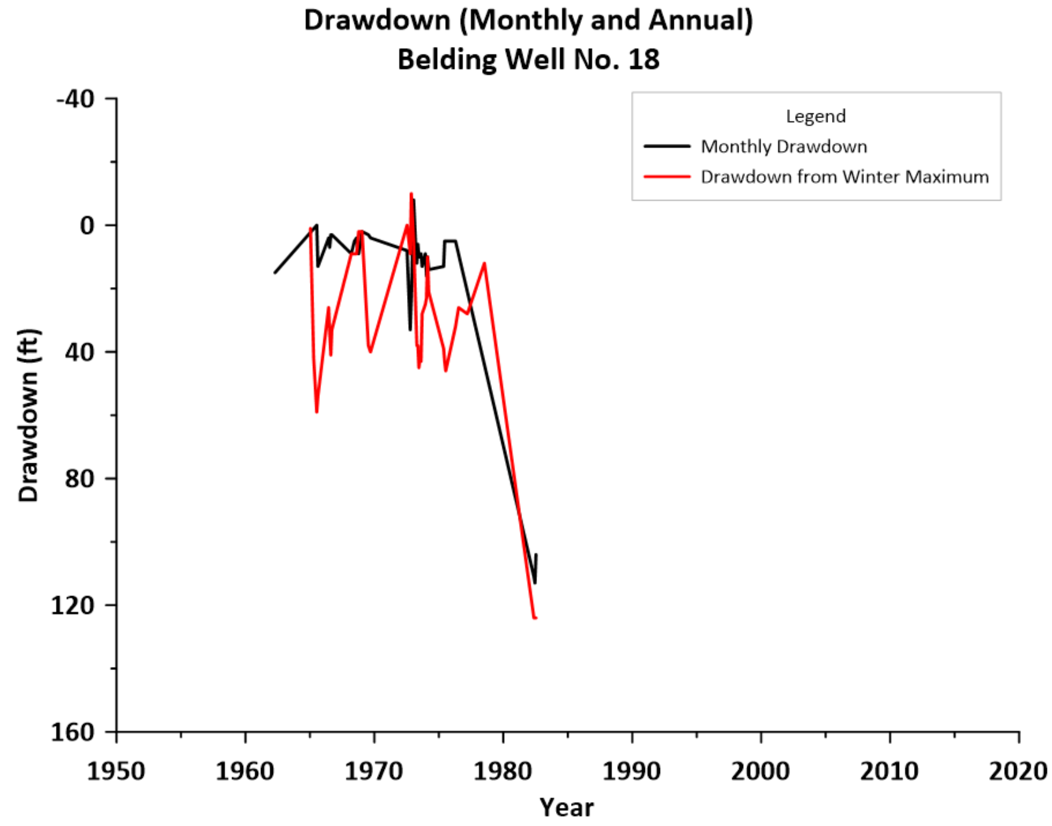
80
120
160
200
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 17
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
13.5
15
16.5
1950
1960
1970
1980
1990
2000
2010
2020
Year


Drawdown (Monthly and Annual)
Belding Well No. 18
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
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0
40
80
120
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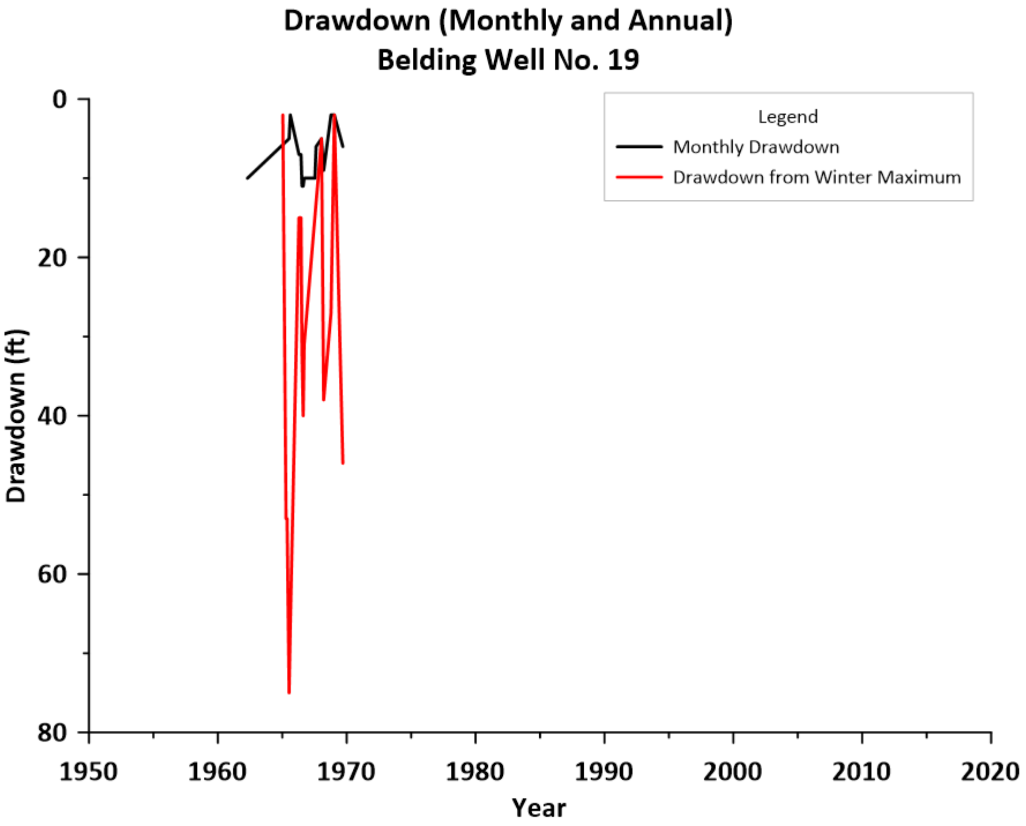
1980
1990
2000
2010
2020
Year



Drawdown (Monthly and Annual)
Belding Well No. 19
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
20
40
60
80
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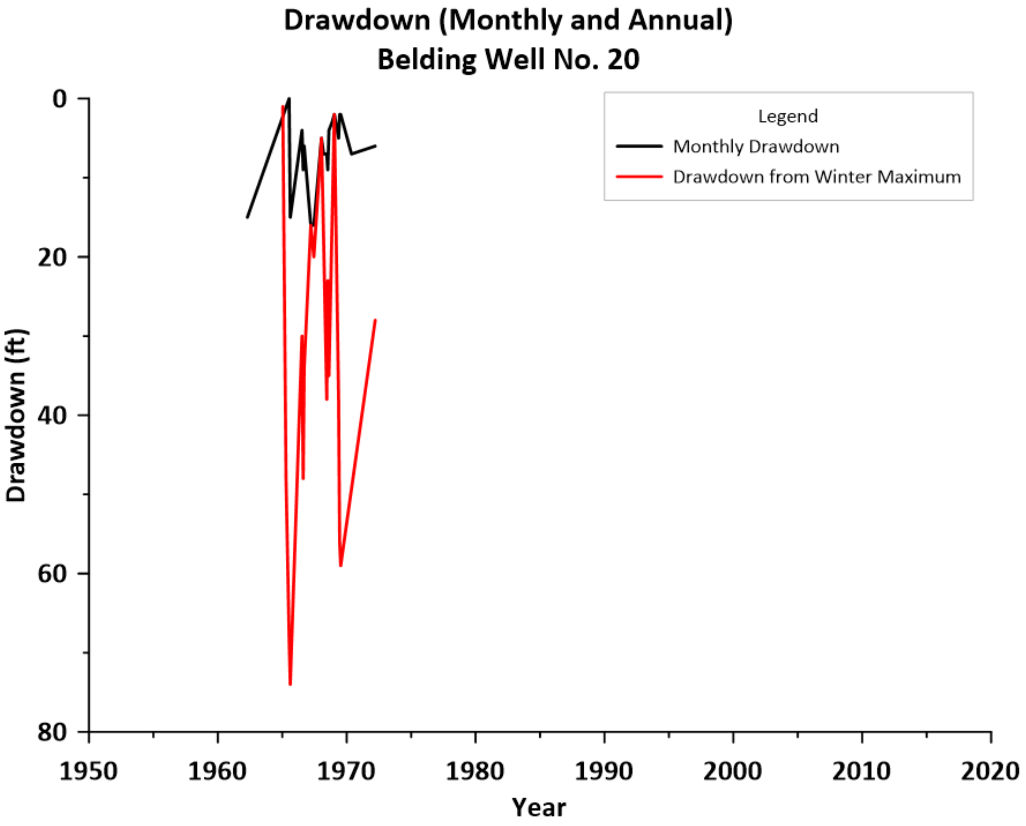
1990
2000
2010
2020
Year



Drawdown (Monthly and Annual)
Belding Well No. 20
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
20
40
60
80
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1960
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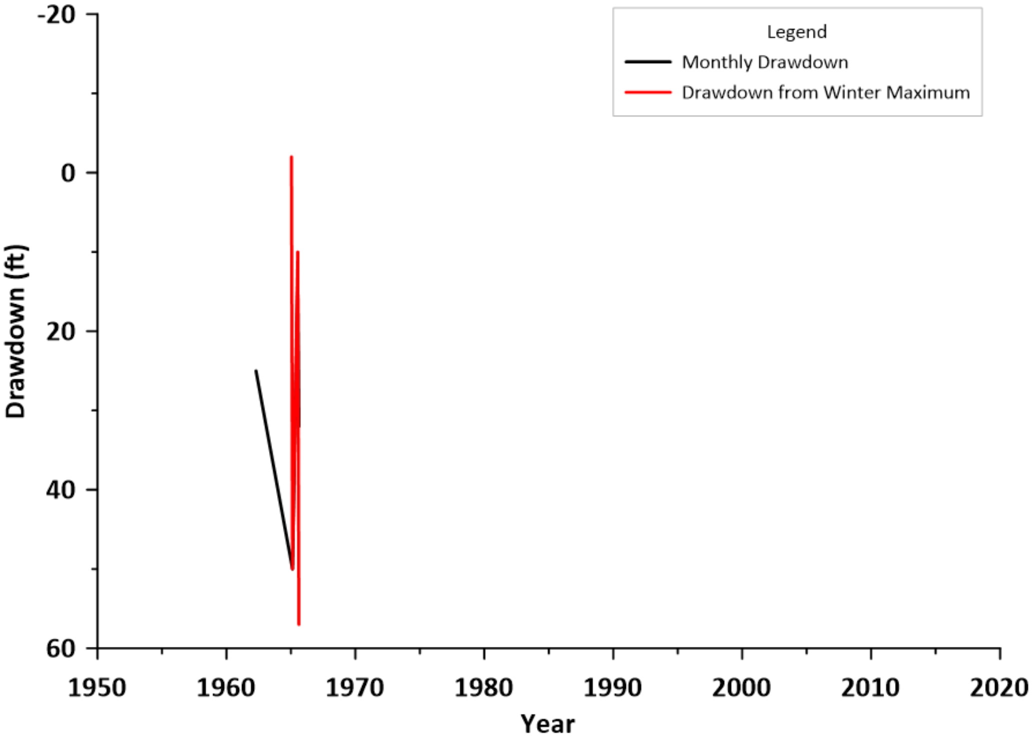
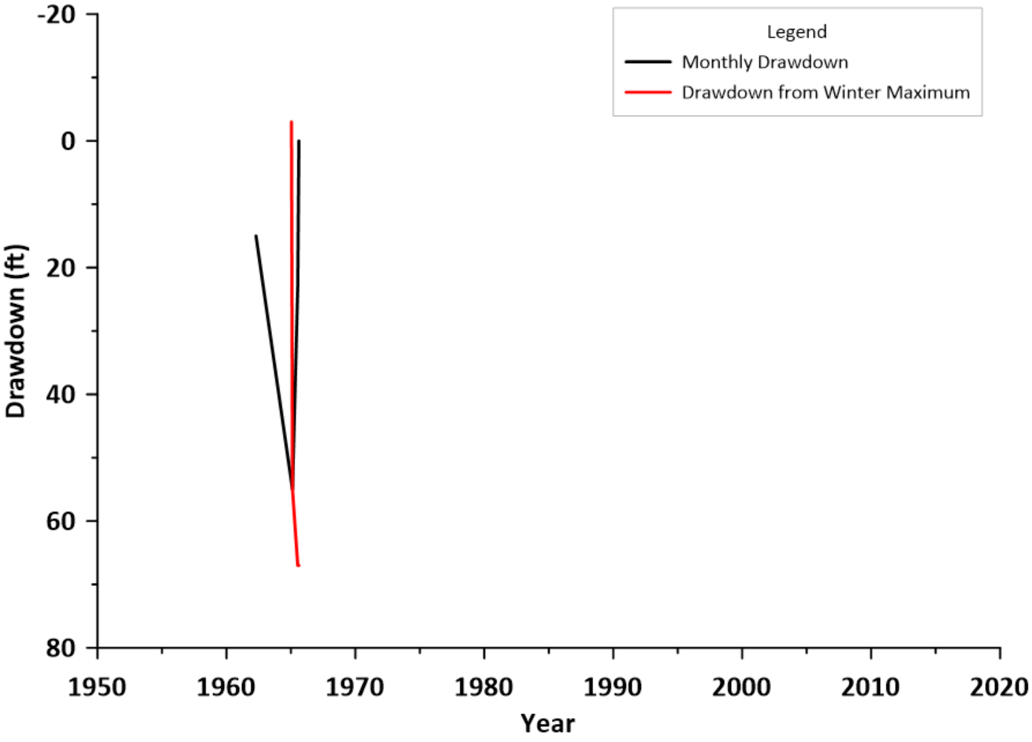
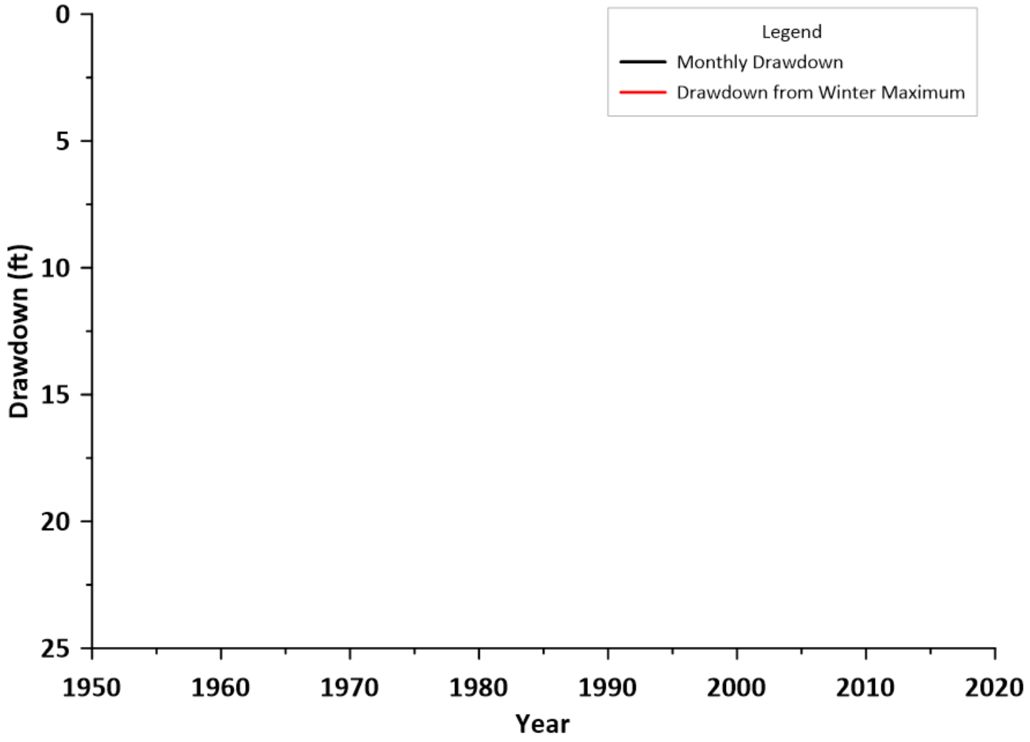
1980
1990
2000
2010
2020
Year

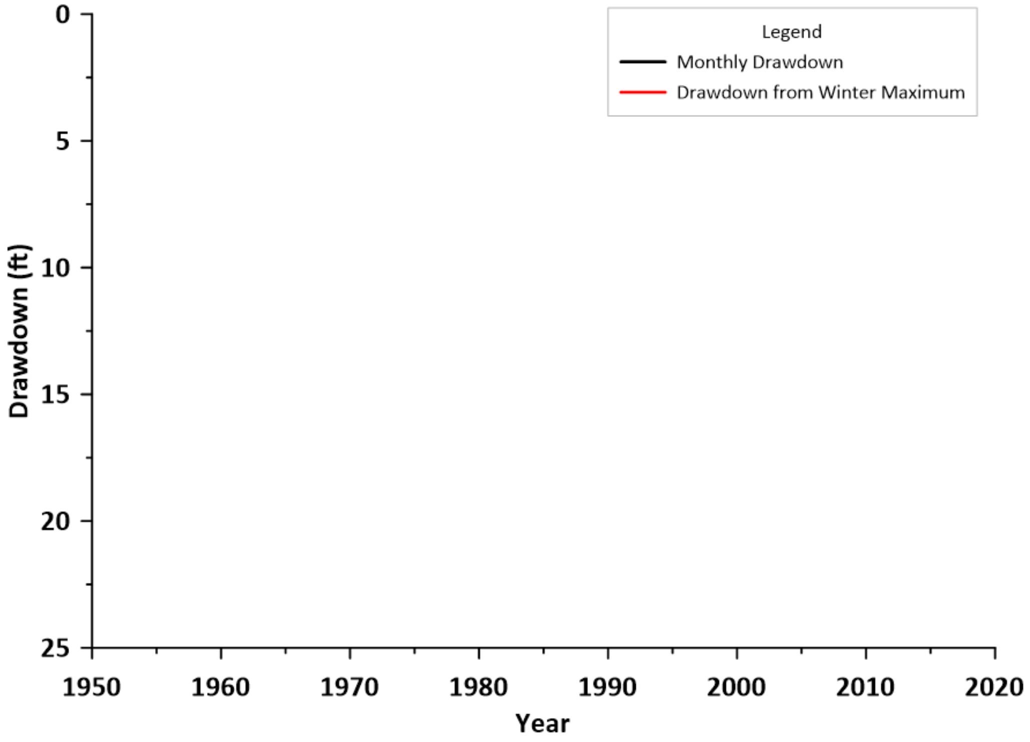


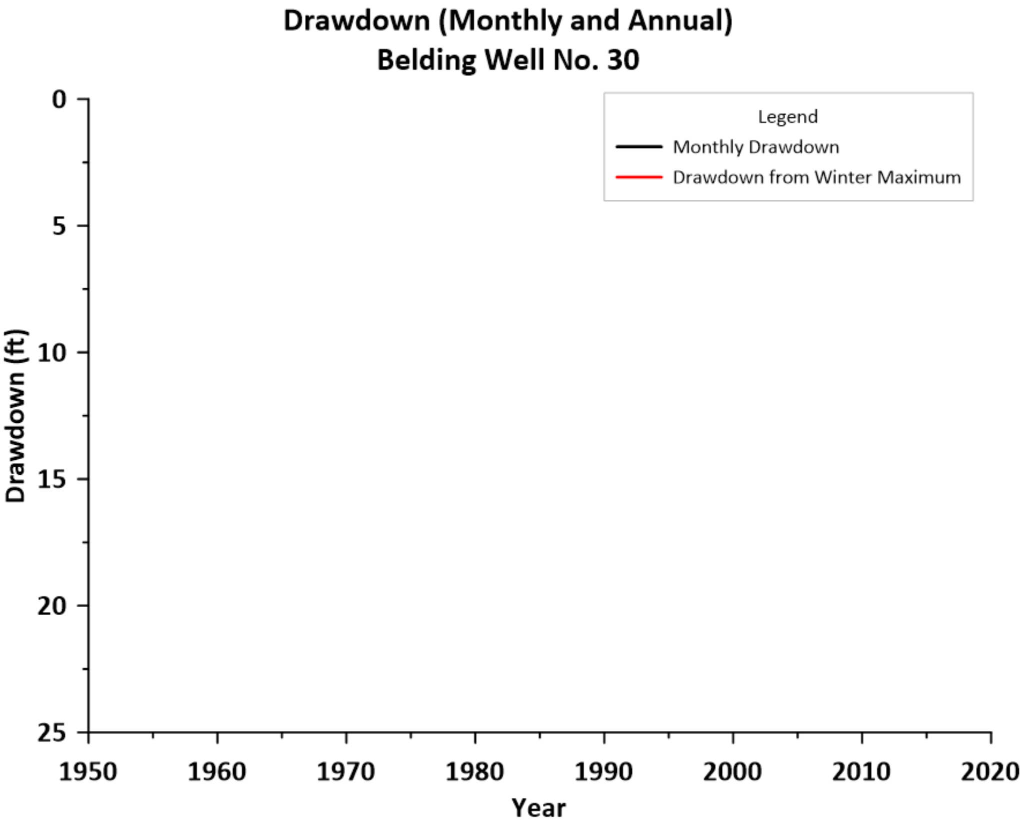
Drawdown (Monthly and Annual)
Belding Well No. 21



Drawdown (Monthly and Annual)
Belding Well No. 22


Drawdown (Monthly and Annual)
Belding Well No. 28


Drawdown (Monthly and Annual)
Belding Well No. 29


Drawdown (Monthly and Annual)
Belding Well No. 30
Legend
Monthly Drawdown
Drawdown from Winter Maximum
Drawdown (ft)
0
5
10
15
20
25
1950
1960
1970
1980
1990
2000
2010
2020
Year