Proposed Desired Future Conditions Explanatory Report

Austin Chalk and Buda Limestone Aquifers

Groundwater Management Area 10

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Abbreviations

DFC	Desired Future Conditions
GCD	Groundwater Conservation District
GMA	Groundwater Management Area
MAG	Modeled Available Groundwater
TWDB	Texas Water Development Board

1. Groundwater Management Area 10

Groundwater Management Areas (GMA) were created by the Texas Legislature to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence caused by withdrawal of water from those groundwater reservoirs or their subdivisions. Each GMA is charged with facilitating joint planning efforts in the GMAs within its jurisdiction.

GMA 10 was created to oversee the Edwards (Balcones Fault Zone) and Trinity aquifers. Other aquifers include the Leona Gravel, Buda Limestone, Austin Chalk, and the saline Edwards (Balcones Fault Zone) aquifers. The jurisdiction of GMA 10 includes all or parts of Bexar, Caldwell, Comal, Guadalupe, Hays, Kinney, Medina, Travis, and Uvalde counties (Figure 1). Groundwater Conservation Districts (GCD) in GMA 10 include Barton Springs/Edwards Aquifer Conservation District, Comal Trinity GCD, Edwards Aquifer Authority, Kinney County GCD, Medina County GCD, Plum Creek Conservation District, and Uvalde County Underground Water Conservation District (UWCD).

As mandated in Texas Water Code § 36.108, districts are required to submit DFCs of the groundwater resources in their GMA to the executive administrator of the Texas Water Development Board (TWDB), unless that aquifer is deemed to be non-relevant. According to Texas Water Code § 36.108 (d-3), the district representatives shall produce a DFCs Explanatory Report for the management area and submit to the TWDB a copy of the Explanatory Report.

The Austin Chalk and Buda Limestone aquifers are neither major nor minor aquifers, but have been determined to be locally relevant in Uvalde County for joint planning purposes. The Austin Chalk and Buda Limestone aquifers have been determined to be non-relevant in Medina County for joint planning purposes. This document is the Explanatory Report for the Austin Chalk and Buda Limestone aquifers where they is determined to be relevant within GMA 10.

2. Aquifer Description

For jurisdictional purposes, the Austin Chalk and Buda Limestone aquifers are defined as the Austin Chalk and Buda Limestone aquifers within Uvalde County. The boundaries of the Austin Chalk Aquifer and Buda Limestone Aquifer were determined using the Digital Geologic Atlas of Texas (U.S. Geological Survey and Texas Water Development Board, 2006), the Uvalde County boundary, and the GMA 10 boundary. The Buda Limestone Aquifer in Uvalde County is located entirely within the Regional Water Planning Area L, the Nueces River Basin, and the Uvalde County Underground Water Conservation District. The geographic extents of the Austin Chalk and Buda Limestone aquifers are presented in Figures 2 (Thorkildsen and Backhouse, 2011a) and 3 (Thorkildsen and Backhouse, 2011b), respectively. As illustrated, the jurisdiction is limited to Uvalde County.

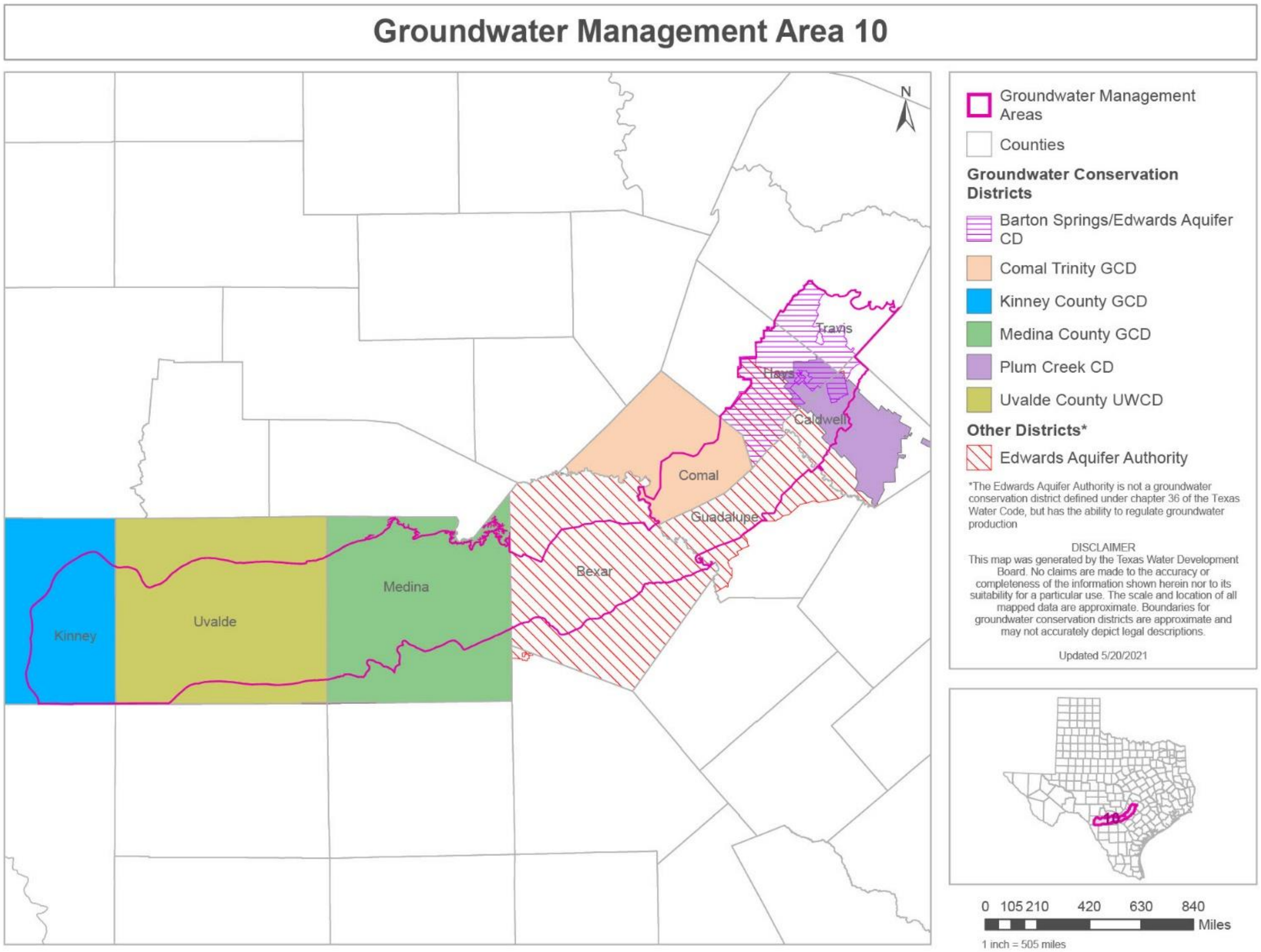


Figure 1. GCDs in GMA 10 (TWDB website)

3. Desired Future Conditions

The DFCs for the Austin Chalk and Buda Limestone aquifers in the Uvalde County part of GMA 10, as described in Resolution No. 2010-11 and adopted August 23, 2010 by the GCDs in GMA 10, are a regional average well drawdown of zero (0) feet (including exempt and non-exempt use) (Table 1). The second round DFCs were adopted at the GMA 10 meeting on March 14, 2016. The third round DFCs were adopted at the GMA 10 Meeting on October 26, 2021.

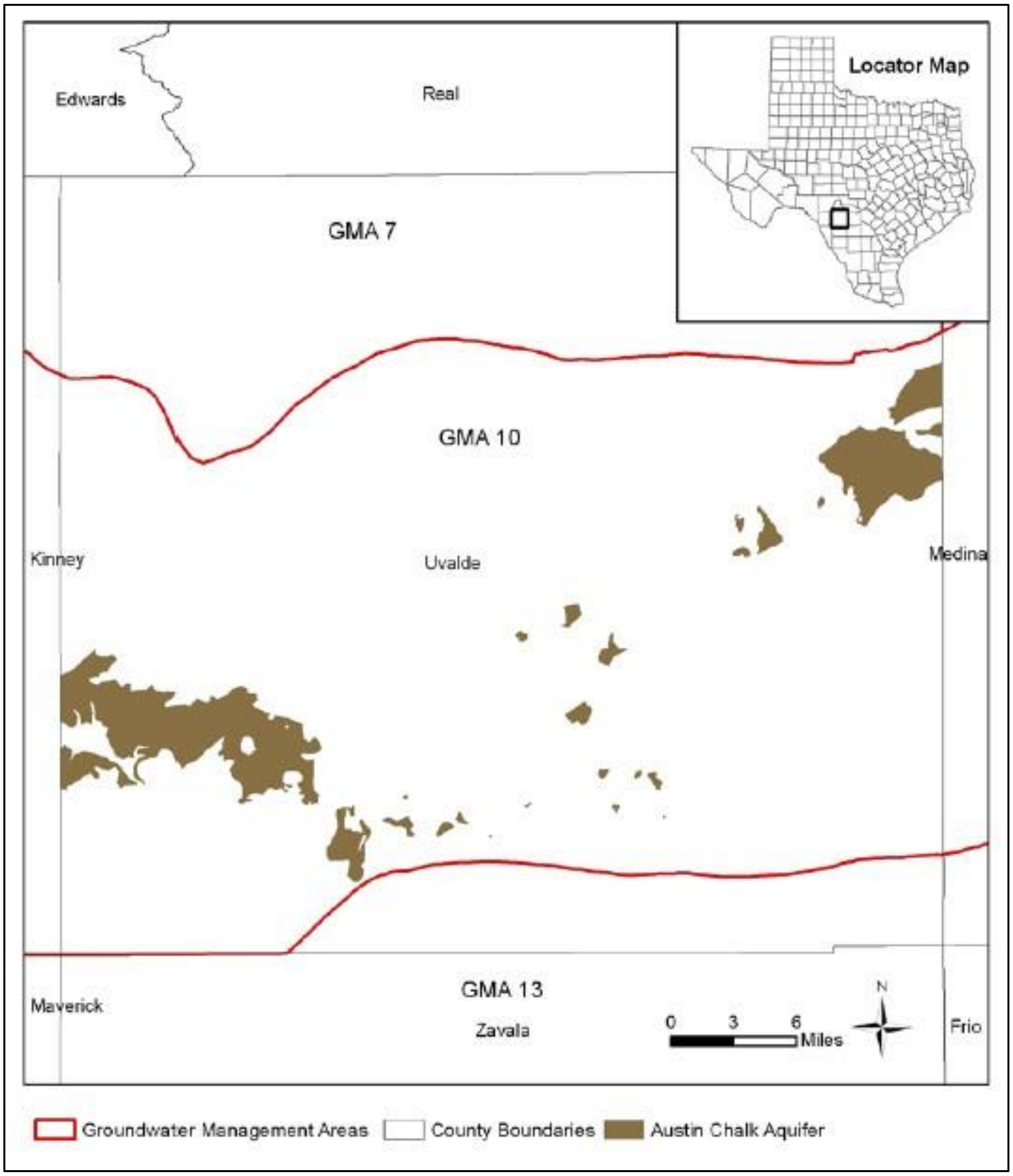


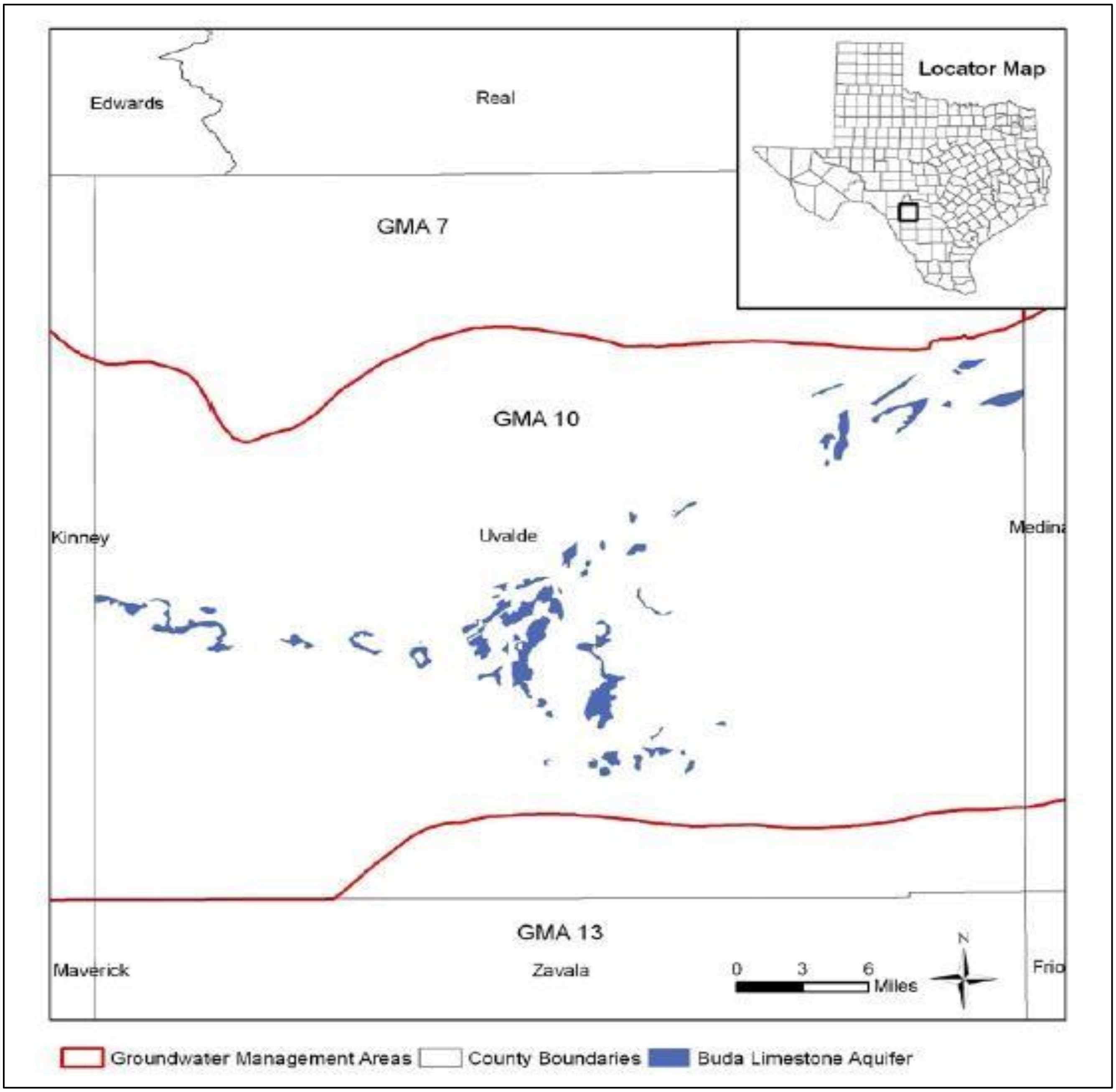
Figure 2. Map showing the outcrop extent of the Austin Chalk in Uvalde County in GMA 10 (from Thorkildsen and Blackhouse, 2011a)

Table 1. DFCs for the Austin Chalk and Buda Limestone aquifers within Uvalde County in GMA 10.

Aquifer	DFC Summary	Date DFC Adopted
Austin Chalk	No drawdown (including exempt and non-exempt use)	8/23/2010
Austin Chalk	No drawdown (including exempt and non-exempt use)	4/10/2016

Austin Chalk	No drawdown (including exempt and non-exempt use)	???
Buda Limestone	No drawdown (including exempt and non-exempt use)	8/23/2010
Buda Limestone	No drawdown (including exempt and non-exempt use)	4/10/2016
Buda Limestone	No drawdown (including exempt and non-exempt use)	???

Figure 3. Map showing the outcrop extent of the Buda Limestone in Uvalde County in GMA 10 Aquifers (From Thorkildsen and Blackhouse, 2011b).



4. Policy Justification

The DFCs for the Austin Chalk and Buda Limestone aquifers in Uvalde County were adopted after considering the following factors specified in Texas Water Code §36.108 (d):

A. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;

   i. for each aquifer, subdivision of an aquifer, or geologic strata; and
   ii. for each geographic area overlying an aquifer

B. The water supply needs and water management strategies included in the state water plan;

C. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator, and the average annual recharge, inflows, and discharge;

D. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water;

E. The impact on subsidence;

F. Socioeconomic impacts reasonably expected to occur;

G. 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;

H. The feasibility of achieving the DFC; and

I. Any other information relevant to the specific DFCs.

These factors are discussed in detail in appropriate sections in this Explanatory Report.

5. Technical Justification

There is no Groundwater Availability Model for either the Austin Chalk Aquifer or the Buda Limestone Aquifer in Uvalde County. Technical justification for selection of the DFCs for the Austin Chalk and Buda Limestone aquifers in Uvalde County was provided using alternative analyses.

Thorkildsen and Backhouse (2011a,b) noted that there are limited hydrogeologic data available for either the Austin Chalk Aquifer or the Buda Limestone Aquifer in Uvalde County, but that historical water-level data show significant variation in aquifer storage over time. Thorkildsen and Backhouse (2011a,b) cite measurements (2005-2006) for several Austin Chalk Aquifer wells and one Buda Limestone Aquifer well that show a degree of stabilization during that time period. Hydrographs of the Austin Chalk Aquifer wells and the Buda Limestone well are shown in Figures 4 and 5 (Thorkildsen and Backhouse (2011a,b).

Green et al, (2009b) estimated 2008 pumpage for the Austin Chalk Aquifer in Uvalde County was 2,935 acre-feet. For the Managed {modeled} Available Groundwater analysis of the Austin Chalk Aquifer in Uvalde County, Thorkildsen and Backhouse (2011a) assumed that the Austin Chalk Aquifer was under a state of dynamic equilibrium and the estimated pumpage of 2,935 acre-feet/year would achieve the adopted DFC for the Austin Chalk Aquifer in Uvalde County. Similarly, Thorkildsen and Backhouse (2011b) used the estimated 2008 pumpage for the Buda Limestone Aquifer in Uvalde County of 758 acre-feet (Green et al. 2009b) and with the same assumption of dynamic equilibrium, estimated that a Managed {modeled} Available Groundwater equivalent to the estimated 2008 pumpage of 758 acre-feet would achieve the adopted DFC for the Buda Limestone Aquifer in Uvalde County.

Since exempt uses are not available for permitting, it is necessary to account for them when determining the Modeled Available Groundwater (MAG). To do this, the TWDB developed a standardized method for estimating exempt use for domestic and livestock purposes based on projected changes in population and the ratio of domestic and livestock wells in an area to the total number of wells. Because other exempt uses can vary significantly from district to district and there is much higher uncertainty associated with estimating use due to oil and gas exploration, estimates of exempt pumping outside domestic and livestock uses have not been included. If a district believes it has a more appropriate estimate of exempt pumping, they may submit it, along with a description of how it was developed, to the TWDB for consideration. Once established, the estimates of exempt pumping are subtracted from the total pumping calculation to yield the estimated MAG for permitting purposes.

Exempt use in the Uvalde County Underground Water Conservation District was estimated for the period 2020 to 2070 by TWDB and accepted by the district (TWDB Projected Exempt Use Estimates, 2020). Table 2 contains the estimates of exempt pumping from the Austin Chalk Aquifer in the Uvalde County Underground Water Conservation District for domestic and livestock uses (TWDB Projected Exempt Use Estimates, 2020). There is negligible exempt use due to oil and gas exploration in Uvalde County.

Estimated total pumping from the Austin Chalk Aquifer within Uvalde County in GMA 10 that achieves the adopted DFC is approximately 2,935 acre-feet per year (Thorkildsen and Backhouse, 2011a). Table 3 shows the total pumping estimates by the lone river basin (i.e., Nueces River) for each decade between 2010 and 2060 for use in the regional water planning process. The MAG for the Uvalde County Underground Water Conservation District is the difference between the total pumping (Table 3) and the estimated exempt use (Table 2) and is shown in Table 4 (Thorkildsen and Backhouse, 2011a). Tables 5-7 contain the same information as Tables 2-4 for the Buda Limestone Aquifer in Uvalde County.

Table 2. Estimates of exempt use for the Austin Chalk Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2020 and 2080. Results are in acre-ft/yr. Estimated exempt use calculated by TWDB and accepted by the district (TWDB Projected Exempt Use Estimates, 2020).

Year	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**
Acre-ft	232	239	245	256	271	286	288

Table 3. Estimated total pumping for the Austin Chalk Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2010 and 2060. Results are in acre-ft/yr (Thorkildsen and Backhouse, 2011a).

Year	2010	2020	2030	2040	2050	2060
Acre-ft	2,935	2,935	2,935	2,935	2,935	2,935

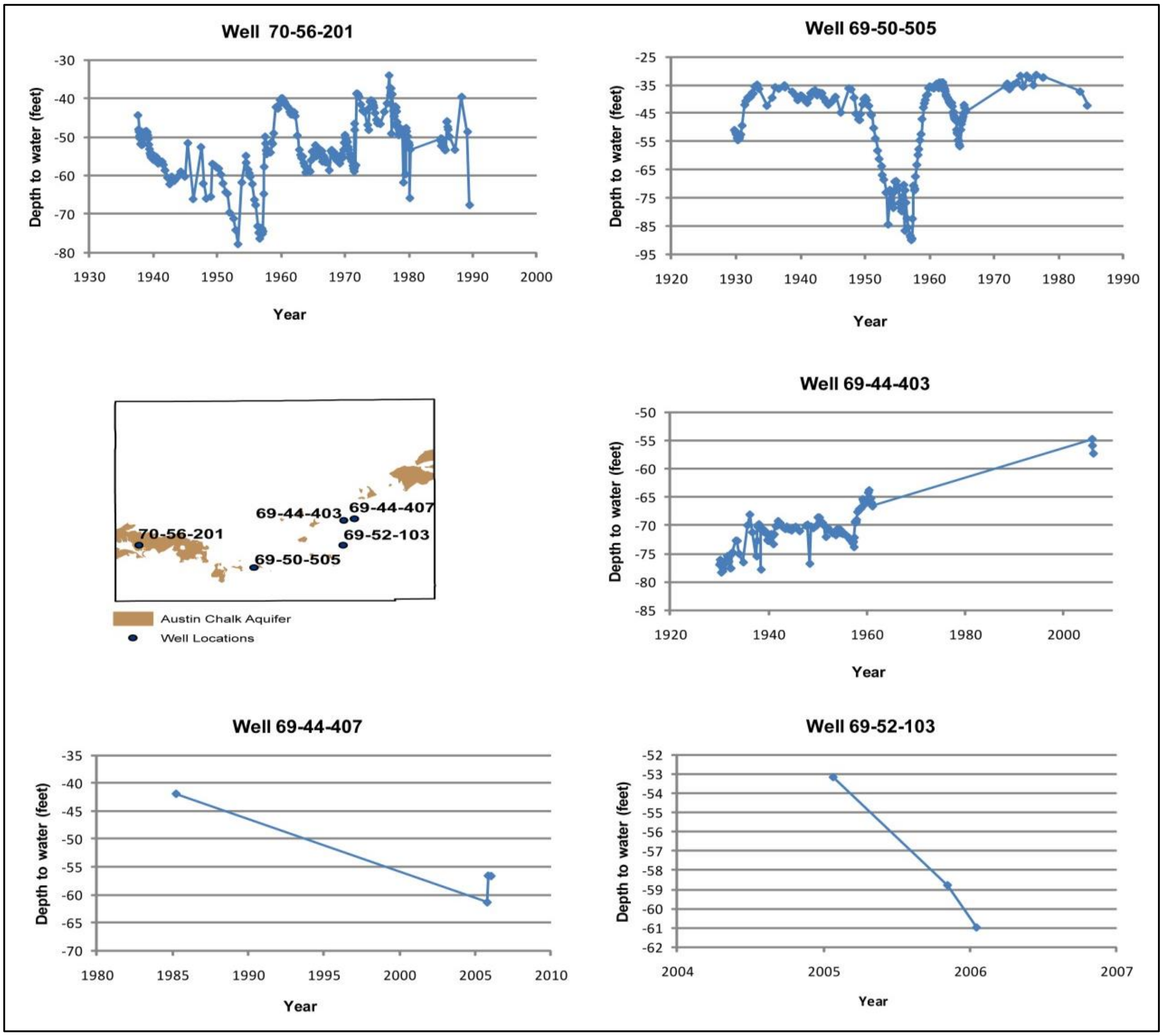


Figure 4. Water-level measurements for selected Austin Chalk wells in Uvalde County, Texas (Thorkildsen and Backhouse (2011a).

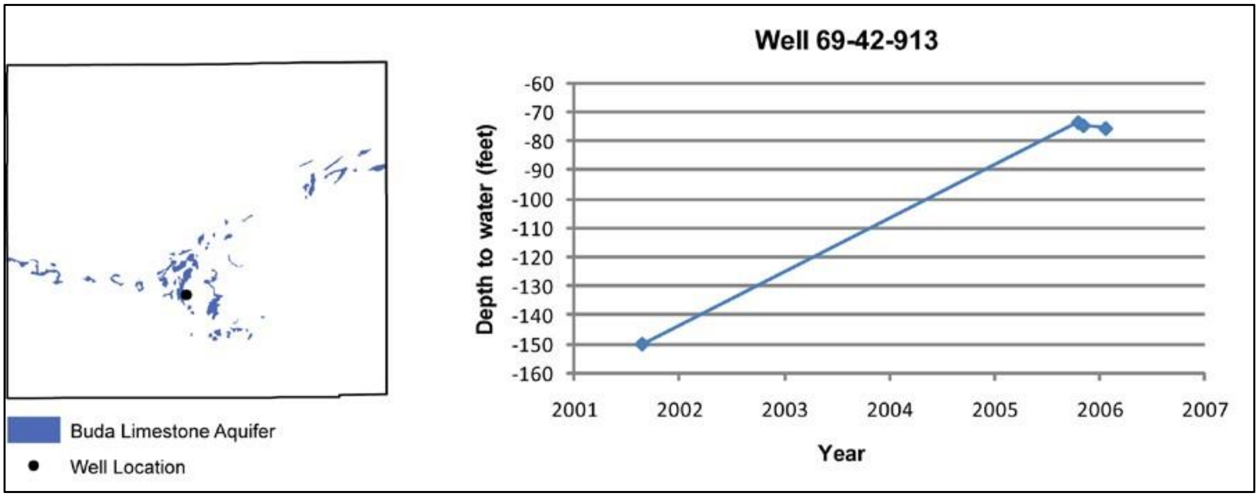


Figure 5. Water-level measurements for a selected Buda Limestone well in Uvalde County, Texas (Thorkildsen and Backhouse (2011b)

Table 4. Estimates of MAG for the Austin Chalk Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2020 and 2070. Results are in acre-ft/yr (Robert G. Bradley, P.G. and Radu Boghici, P.G. 2018.).

Year	2020	2030	2040	2050	2060	2070
Acre-ft	2,935	2,935	2,935	2,935	2,935	2,935

Table 5. Estimates of exempt use for the Buda Limestone Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2020 and 2080. Results are in acre-ft/yr. Estimated exempt use calculated by TWDB and accepted by the district (Thorkildsen and Backhouse, 2011b).

Year	2020	2030	2040	2050	2060	2070	2080
Acre-ft	232	239	245	256	271	286	288

Table 6. Estimated total pumping for the Buda Limestone Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2010 and 2060. Results are in acre-ft/yr (Thorkildsen and Backhouse, 2011b).

Year	2010	2020	2030	2040	2050	2060
Acre-ft	758	758	758	758	758	758

Table 7. Estimates of MAG for the Buda Limestone Aquifer in the Uvalde County Underground Water Conservation District for each decade between 2010 and 2060. Results are in acre-ft/yr (Robert G. Bradley, P.G. and Radu Boghici, P.G. 2018).

Year	2020	2030	2040	2050	2060	2070
Acre-ft	758	758	758	758	758	758

6. Consideration of Designated Factors

In accordance with Texas Water Code § 36.108 (d-3), the district representatives shall produce a Desired Future Condition Explanatory Report. The report must include documentation of how factors identified in Texas Water Code §36.108 (d) were considered prior to proposing a DFC, and how the proposed DFC impacts each factor. The following sections of the Explanatory Report summarizes the information that the GCDs used in its deliberations and discussions.

6.1 Aquifer Uses or Conditions

6.1.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

GMA 10 incorporated information from the Uvalde County Underground Water Conservation District Groundwater Management Plan and analyses from the TWDB during development of the proposed DFCs.

Surface water in Uvalde County comes primarily from the Nueces River and its tributaries. Groundwater is found in both major and local aquifers in Uvalde County. Although other rivers traverse Uvalde County, only reaches in the Nueces River exhibit significant baseflow. Major aquifers include the Edwards (Balcones Fault Zone), Edwards-Trinity (Plateau), Carrizo-Wilcox and Trinity aquifers. Minor or local aquifers include the Leona Gravel, Buda Limestone, Anacacho, Austin Chalk, and Glen Rose Formations. There is significant production from the Buda Limestone, Austin Chalk and Leona Formation aquifers in areas of Uvalde County west of the Knippa Gap (Green et al., 2006; 2009a.b). A report completed for the Uvalde County Underground Water Conservation District in 2009 concludes that the Edwards (Balcones Fault Zone) Aquifer is in hydraulic communication with these local aquifers, and that index well J-27, although completed in the Edwards (Balcones Fault Zone) Aquifer, can indicate declines in groundwater levels in the Buda Limestone, Austin Chalk and Leona Formation aquifers that adversely impact the water resource (Green et al., 2009b). When the level in index well J-27 drops below 860 feet msl, recharge to the Leona Gravel Aquifer and discharge to Soldiers Camp Springs and other related un-named springs in the Nueces River decline measurably (Green et al., 2009a.b).

Aquifer use in Uvalde County divided between surface water and groundwater and among industry sector for the years 2000–2019 is summarized in Table 8.

6.1.2 DFC Considerations

The dominant use of the Austin Chalk and Buda Limestone aquifers in Uvalde County by pumping is domestic use and irrigation, and the sustainability of that supply, especially for users who have no alternative supply physically or economically available and/or who are in vulnerable locations, must be protected to the extent feasible (Texas Water Code §36). The primary concern with sustainability of these karst aquifer groundwater supplies is drought, notably extreme drought that stresses both aquifers. The DFCs support and are, in fact, the primary concern with sustainability of these karst aquifer groundwater supplies is drought, notably extreme drought that stresses both aquifers. The DFCs support and are, in fact, the linchpin of a drought management program to promote long-term sustainability of water supplies.

Table 8. Uvalde County use divided between surface water (SW) and groundwater (GW) among industry sectors (Texas Water Development Board Historical Water Use TWDB) (acre-ft).

Year	Source	Municipal	Manufac turing	Steam Electric	Irriga tion	Mining	Livestock	Total
2000	GW	7,846	378	0	56,967	250	642	66,083
	SW	0	0	0	1,094	0	642	1,736
Total		7,846	378	0	58,061	250	1,284	67,819
2001	GW	5,472	1,110	0	83,276	250	592	90,700
	SW	67	13	0	1,700	0	592	2,372
Total		5,539	1,123	0	84,976	250	1,184	93,072
2002	GW	4,777	751	0	88,392	717	579	95,216
	SW	59	9	0	1,804	0	579	2,451
Total		4,836	760	0	90,196	717	1,158	97,667
2003	GW	5,207	152	0	67,820	239	557	73,975
	SW	64	2	0	425	0	557	1,048
Total		5,271	154	0	68,245	239	1,114	75,023
2004	GW	4,083	3	0	66,399	239	522	71,246
	SW	50	0	0	377	0	522	949
Total		4,133	3	0	66,776	239	1,044	72,195
2005	GW	5,121	3	0	58,087	147	1,837	65,195
	SW	0	0	0	400	0	339	739
Total		5,121	3	0	58,487	147	2,176	65,934
2006	GW	6,114	3	0	72,872	147	0	79,136
	SW	0	0	0	0	0	950	950
Total		6,114	3	0	72,872	147	950	80,086
2007	GW	4,425	3	0	36,649	112	2,727	43,916
	SW	0	0	0	358	0	336	694
Total		4,425	3	0	37,007	112	3,063	44,610
2008	GW	5,339	0	0	75,016	1,125	2,282	83,762
	SW	0	0	0	1,103	1,051	294	2,448
Total		5,339	0	0	76,119	2,176	2,576	86,210
2009	GW	5,578	3	0	96,802	1,092	2,207	105,682
	SW	0	0	0	698	1,090	248	2,036
Total		5,578	3	0	97,500	2,182	2,455	107,718
2010	GW	5,162	0	0	52,156	1,146	2,141	60,605
	SW	0	3	0	390	1,129	261	1,783
Total		5,162	3	0	52,546	2,275	2,402	62,388
2011	GW	6,112	0	0	82,968	74	2,205	91,359
	SW	0	3	0	491	0	270	764
Total		6,112	3	0	83,459	74	2,475	92,123
2012	GW	5,380	3	0	72,263	86	2,007	79,739
	SW	0	0	0	368	0	236	604
Total		5,380	3	0	72,631	86	2,243	80,343
2013	GW	4,901	3	0	49,494	49	1,728	56,175
	SW	0	0	0	462	0	245	707
Total		4,901	3	0	49,956	49	1,973	56,882

2014	GW	4,742	0	0	52,877	49	1,624	59,292
	SW	0	0	0	572	0	273	845
Total		4,742	0	0	53,449	49	1,897	60,137
2015	GW	4,472	0	0	36,243	0	1,478	42,193
	SW	0	0	0	357	49	247	653
Total		4,472	0	0	36,600	49	1,725	43,499
2016	GW	4,477	0	0	47,886	44	1,726	54,133
	SW	0	0	0	150	0	251	401
Total		4,477	0	0	48,036	44	1,977	54,534
2017	GW	4,337	0	0	33,387	44	1,712	39,480
	SW	0	0	0	441	0	226	667
Total		4,337	0	0	33,828	44	1,938	40,147
2018	GW	4,118	0	0	42,829	61	1,648	48,656
	SW	0	0	0	514	0	234	748
Total		4,118	0	0	43,343	0	1,882	49,404
2019	GW	4,157	0	0	52,735	54	1631	58,577
	SW	0	0	0	110	0	239	349
Total		4,157	0	0	52,845	54	1,870	58,926
GW = groundwater; SW = surface water								
Source: TWDB Water Use Survey Database 1/5/2010								

6.2 Water-Supply Needs

6.2.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

Water use in Uvalde County is divided between surface water and groundwater and among industry sector (Table 10) (Uvalde County Underground Water Conservation District Groundwater Management Plan). Water use is not delineated by aquifer; thus, water use of the Austin Chalk and Buda Limestone aquifers is not known.

6.2.2 DFC Considerations

The population growth of Uvalde County is projected by the Office of the State Demographer for State of Texas, Texas State Data Center Texas A&M University System to grow from 26,260 in 2020 to 35,650 in 2040, an increase of 26.33 percent (https://demographics.texas.gov/data/TPEPP/Estimates/). The DFCs maximize the amount of water that can be provided during non-drought periods that is consistent with the implementation of a drought management program that protects the supply for existing uses during drought, especially extreme drought. The drought program response to the DFCs indexes the amount of aquifer water available to meet the needs with the severity of drought.

6.3 Water-Management Strategies

6.3.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

The following information is from the South Central Texas Region Water Plan (South Central Texas Region Water Planning Group, 2021). A major component of the South Central Texas Region Initially Prepared Water Plan is to identify municipalities and water-use categories that may, in times of severe drought, be unable to meet expected water-supply needs based on today's ability to access, treat, and distribute the supply. A goal of the South Central Texas Region Water Plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. Recreation activities involve human interaction with the outdoor environment and are often directly dependent on water resources. It is recognized that the maintenance of the regional environmental community's water supply needs serves to enhance the lives of citizens of the South Central Texas Region as well as the tens of thousands of annual visitors to this Region. The implementation of water-management strategies recommended in the South Central Texas Region Water Plan is not expected to have any impact on native-water quality. In particular, primary and secondary safe drinking water standards, which are the key parameters of water quality identified by the South Central Texas Region Water Planning Group as important to the use of the water resource, are not compromised by the implementation of the strategies. Also, no recommended strategies involve moving water from a rural location for use in an urban area.

The data presented in this section are provided by the South Central Texas Region Water Planning Group Plan (South Central Texas Region Water Planning Group, 2021). Recommended alternatives, or water-management strategies, to meet anticipated drought-induced shortages are presented in the South Central Texas Region Water Plan for consideration. The projected water supply and demand estimates for Uvalde County indicate that projected demands exceed projected supplies within the City of Sabinal, City of Uvalde, and Irrigation (Table 9). Source water available after known demands are subtracted are presented in Table 10. Table 11 identifies water-use categories where no water supply is available to meet its total need. As noted, these data are not currently available in the South Central Texas Region Water Planning Group Plan (South Central Region Water Planning Group, 2021).

To meet the needs of water-user groups in the Uvalde County Underground Water Conservation District, Region L recommended water-management strategies to address the identified shortages. Water-management strategies are projects or procedures that if implemented will produce additional water to meet the identified needs of water-user groups. The total amount of groundwater and surface water resulting from implementation of the water-management strategies recommended for Uvalde County in the 2022 State Water Plan is anticipated to provide 2,771 acre-feet in 2020, increasing to 4,738 acre-feet in 2070. Transfers from the Edwards (Balcones Fault Zone) Aquifer and municipal water conservation are the primary strategies identified (Table 12).

Table 9. Projected water-supply and demand estimates for Uvalde County in the 2022 State Water Plan

Water User Group	Supply/Shortage 2020 (acft/yr)	Supply/Shortage 2070 (acft/yr)	Comment
City of Sabinal	151	-4	Projected shortage 2070
City of Uvalde	-483	-2021	Projected shortage (2020 through 2070)
Rural Area Residential and Commercial	858	1,146	No projected shortage
Manufacturing	111	111	No projected shortage
Steam-Electric Power	0	0	No projected shortage
Mining	2,457	3,670	No projected shortage
Irrigation	-18,573	-20,999	Projected shortage (2020 through 2070)
Livestock	2,198	2,198	No projected shortage

Table 10. Source water available after known demands are subtracted (South Central Texas Initially Prepared Plan, 2021) (acre-ft/yr).

Groundwater	Basin	Salinity	2020	2030	2040	2050	2060	2070
Buda Limestone Aquifer	Nueces	Fresh	233	233	233	233	233	233
Carrizo-Wilcox Aquifer	Nueces	Fresh	0	0	0	0	0	0
Edwards-Trinity Aquifer	Nueces	Fresh	0	0	0	0	0	0
Leona Gravel Aquifer	Nueces	Fresh	256	262	283	78	0	0
Trinity Aquifer	Nueces	Fresh	0	0	0	0	0	0

Table 11. Water-use categories where no water supply is available to meet its total need. These data are not currently available in the South Central Texas Region Water Planning Group Plan (South Central Region Water Planning Group, 2021) (acre-ft/yr).

WUG/WWP	Basin	2020	2030	2040	2050	2060	2070
-	-	-	-	-	-	-	-

Water-management strategies for Uvalde County that are identified in the 2022 State Water Plan are summarized in Table 13. Water-management strategies that involve aquifer storage and recovery (ASR) comprise approximately 9 percent of recommended new supplies and include an Uvalde aquifer storage and recovery project (1,155 acre-ft/yr @ $2,803/acre-ft/yr) (South Central Region Water Planning Group, 2021).

Table 12. Water-management strategies in Uvalde County in the 2022 State Water Plan (acre-ft/yr).

WUG	River Basin	Water Management Strategy	Source Name	2020	2030	2040	2050	2060	2070
Sabinal	Nueces	Edwards Transfers	Edwards (Balcones Fault Zone) Aquifer	150	150	150	125	125	125
Sabinal	Nueces	Municipal Water Conservation	Conservation	20	57	96	141	182	203
Uvalde	Nueces	Edwards Transfers	Edwards (Balcones Fault Zone) Aquifer	2,138	2,195	2,074	1,947	1,911	2,030
County Other	Nueces	Municipal Water Conservation	Conservation	0	0	0	0	0	1
Uvalde	Nueces	Municipal Water Conservation	Conservation	193	552	945	1,384	1,744	1,942
TOTAL				**2,501**	**2,954**	**3,265**	**3,597**	**3,962**	**4,301**

6.3.2 DFC Considerations

The DFCs under consideration here are specific to the Austin Chalk and Buda Limestone Aquifers in Uvalde County. The Edwards Aquifer in Uvalde County has a different DFC and is the subject of a separate groundwater management zone, designed to promote protection of the downgradient springs in the Edwards Aquifer and the endangered species impacted by spring discharge. The DFCs for the Austin Chalk and Buda Limestone Aquifers, as described above, underpin an aquifer-responsive drought management program that encourages both full-time water conservation and further temporary curtailments in pumping during drought periods that increase with drought severity.

6.4 Hydrological Conditions

6.4.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

6.4.1.1 Total Estimated Recoverable Storage

Texas statute requires that the total estimated recoverable storage of relevant aquifers be determined. Total estimated recoverable storage is a calculation provided by the TWDB. Texas Administrative Code Rule §356.10 (Texas Administrative Code, 2011) defines the total estimated recoverable storage as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity- adjusted aquifer volume. As described in Aquifer Assessment 16-01 (Bradley, 2016), the total recoverable storage was estimated for the portion of the Austin Chalk Aquifer and the Buda Limestone Aquifer within

GMA 10 (Tables 13 and 14). The official lateral aquifer boundaries were delineated in Bradley (2016).Total estimated recoverable storage values may include a mixture of water quality types, including fresh, brackish, and saline groundwater, because the available data and the existing Groundwater Availability Models do not permit the differentiation between different water quality types. The total estimated recoverable storage values do not take into account the effects of land surface subsidence, degradation of water quality, or any changes to surface water-groundwater interaction that may occur due to pumping.

Table 13. Total estimated recoverable storage for the Austin Chalk Aquifer within Uvalde County Underground Water Conservation District in GMA 10. Estimates are rounded within two significant numbers (Bradley, 2016).

Total Storage (acre-ft)	**25 percent of Total Storage (acre-ft)**	**75 percent of Total Storage (acre-ft)**
280,000	70,000	210,000

Table 14. Total estimated recoverable storage for the Buda Limestone Aquifer within Uvalde County Underground Water Conservation District in GMA 10. Estimates are rounded within two significant numbers (Bradley, 2016).

Total Storage (acre-ft)	**25 percent of Total Storage (acre-ft)**	**75 percent of Total Storage (acre-ft)**
76,000	19,000	57,000

6.4.1.2 Average Annual Recharge

Using results from TWDB GAM Run 15-006 (Bahaya, 2015), the estimated recharge from the Carrizo-Wilcox Aquifer in Uvalde County is 3,003 acre-ft/yr and the estimated recharge from the Edwards-Trinity Aquifer in Uvalde County is 8,436 acre-ft/yr (Uvalde County Underground Water Conservation District Groundwater Management Plan). The Uvalde County Underground Water Conservation District Groundwater Management Plan does not include an estimate for average annual recharge from the Austin Chalk Aquifer and the Buda Limestone Aquifer.

6.4.1.3 Inflows

The Austin Chalk and Buda Limestone aquifers are recharged by distributed recharge where they crop out. In addition, the intense faulting and significant offset inherent to the Balcones Fault Zone within the confines of the Uvalde pool has sufficiently juxtaposed the Edwards, Austin Chalk, and Buda Limestone aquifers that all three aquifers are in hydraulic communication. Because of this hydraulic communication, the Austin Chalk and the Buda Limestone aquifers are readily recharged by the Edwards (Balcones Fault Zone) Aquifer, however, the Austin Chalk and the Buda Limestone can just as easily discharge to the Edwards (Balcones Fault Zone) Aquifer. The direction of flow is a function of local hydraulic gradient. Whether recharge to the Austin Chalk and Buda Limestone aquifers is from autogenic recharge or by discharge from the Edwards (Balcones Fault Zone) Aquifer is complex due to the structure and not easily quantified.

6.4.1.4 Discharge

The Uvalde County Underground Water Conservation District has only partial estimation of discharge from the Austin Chalk Aquifer and the Buda Limestone Aquifer in Uvalde County. The source for the Soldiers Camp Spring and related un-named springs on the Nueces River appears to be the Austin Chalk Aquifer where it crops out at the Nueces River. These springs are at the downdip boundary of where the Austin Chalk crops out in Uvalde County. The U.S. Geological Survey gage on the Nueces River downstream from Soldier Camp Springs and the other unnamed springs provides a measure of the discharge from all the springs in addition to surface runoff flow in the Nueces River. The baseflow component to flow measured at this gage could be separated out from total flow to provide the quantity of discharge from the Austin Chalk Aquifer. This separation has not yet been performed.

Similarly, the Buda Limestone Aquifer and possibly the Austin Chalk Aquifer crop out in the bed of the Leona River north of Ft Inge and south of the City of Uvalde. The Buda Limestone Aquifer and possibly the Austin Chalk Aquifer discharge to the Leona River and possibly to the Leona Gravel Aquifer near this location.

Analysis by Green et al. (2008) indicates that as much as 74,000 acre-ft/yr is recharged to the Leona Gravel Aquifer as inflow where the gravels abut with down gradient boundary of the Austin Chalk, Buda Limestone, and possibly the Edwards (Balcones Fault Zone) Aquifer in the Leona River floodplain in the reach from Highway 90 in the north to Ft. Inge in the south. The quantity of recharge to the Leona Gravel Aquifer is highly variable and is greatly affected by aquifer stage as measured at monitoring well J-27. This volume of water discharge by the Austin Chalk and Buda Limestone aquifers to the Leona Gravel Aquifer has not been quantified.

6.4.1.5 Other Environmental Impacts Including Springflow and Groundwater/Surface Water Interaction

Significant springs in Uvalde County include Soldiers Camp Spring and related un-named springs on the Nueces River and Leona Springs on the Leona River. Soldiers Camp Spring and related un-named springs on the Nueces River contribute to surface flow in the Nueces River Green et al., 2009a,b). The source for the Soldiers Camp Spring and related un-named springs on the Nueces River appears to be the Austin Chalk Aquifer where it crops out at the Nueces River. Baseflow in the Nueces River downstream from Soldiers Camp Spring and the related un- named springs is wholly derived from the Austin Chalk Aquifer. Storm surge and surface runoff are the only contribution to the Nueces River that flows from the north.

6.4.2 DFC Considerations

The DFCs are proposed on the basis that the Austin Chalk Aquifer and the Buda Limestone Aquifer in Uvalde County are in direct hydrologic communication with each other and with the Edwards Aquifer. The three aquifers are well-integrated hydrologically and have a common potentiometric surface throughout the subdivision. This hydrologic condition denotes that all three aquifers are jointly vulnerable to drought. The Austin Chalk Aquifer and the Buda Limestone Aquifer in Uvalde County are more vulnerable to drought than the Edwards Aquifer because they are above and have less saturated thickness that the Edwards Aquifer.

7. Subsidence Impacts

Subsidence has historically not been an issue with the Austin/Buda Aquifer in GMA 10. The aquifer matrix in the northern subdivision is well-indurated and the amount of pumping does not create compaction of the host rock and/or subsidence of the land surface. Hence, the proposed DFCs are not affected by and do not affect land-surface subsidence or compaction of the aquifer. Additionally, LRE Water LLC hydrologists have built a Subsidence Prediction Tool (SPT) that takes individual well characteristics and calculates a potential subsidence risk in a localized area. GMA 10 recognizes that the general reports from the SPT indicate that subsidence is not a concern for GMA 10 at this time.

8. Socioeconomic Impacts Reasonably Expected to Occur

8.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process, and rules direct TWDB staff to provide technical assistance [§357.7 (4)(A)]. Staff of the TWDB's Water Resources Planning Division designed and conducted a report in support of the South Central Texas Regional Water Planning Group (Region L). The report "Socioeconomic Impacts of Projected Water Shortages for the South Central Texas Regional Water Planning Area (Region L)" was prepared by the TWDB in support of the 2021 South Central Texas Regional Water Plan.

The report on socioeconomic impacts summarizes the results of the TWDB analysis and discusses the methodology used to generate the results for Region L. The report does not include the socioeconomic impact associated with only the Austin Chalk and Buda Limestone aquifers. The socioeconomic impact report for Water Planning Group L is included in Appendix A.

8.2 DFC Considerations

Because none of the water management strategies involve changes in the current use of the Austin Chalk and Buda Limestone aquifers in Uvalde County, as described in Section 6.3, the proposed DFCs do not have a differential socioeconomic impact. They are supportive of the status quo in this regard, which is considered positive.

9. Private Property Impacts

9.1 Description of Factors in the Austin Chalk and Buda Limestone Aquifers in Uvalde County

The impact on the interests and rights in private property, including ownership and the rights of GMA landowners and their lessees and assigns in groundwater is recognized under Texas Water Code Section 36.002. The legislature recognizes that a landowner owns the groundwater below the surface of the landowner's land as real property. Nothing in this code shall be construed as granting the authority to deprive or divest a landowner, including a landowner's lessees, heirs, or assigns, of the groundwater ownership and rights described by this section.

Texas Water Code Section 36.002 does not: (1) prohibit a district from limiting or prohibiting the drilling of a well by a landowner for failure or inability to comply with minimum well spacing or tract size requirements adopted by the district; (2) affect the ability of a district to regulate groundwater production as authorized under Section 36.113, 36.116, or 36.122 or otherwise under this chapter or a special law governing a district; or (3) require that a rule adopted by a district allocate to each landowner a proportionate share of available groundwater for production from the aquifer based on the number of acres owned by the landowner.

9.2 DFC Considerations

The DFCs are designed to protect the sustained use of the aquifer as a water supply for all users in aggregate. The DFCs do not prevent use of the groundwater by landowners either now or in the future, although ultimately total use of the groundwater in the aquifer is restricted by the aquifer condition, and that may affect the amount of water that any one landowner could use, either at particular times or all of the time.

10. Feasibility of Achieving the DFCs

The feasibility of achieving a DFC directly relates to the ability of the Uvalde County Underground Water Conservation District to manage the Austin Chalk and Buda Limestone aquifers toward that goal. The Uvalde County Underground Water Conservation District is limited by the hydrogeology of the resource (e.g. how it responds to drought) and the authority of the Uvalde County Underground Water Conservation District to regulate pumping (e.g. uses exempt from permitting and by virtue of the fact that the Edwards (Balcones Fault Zone) Aquifer, the principal aquifer within its jurisdictional boundaries, is regulated by the Edwards Aquifer Authority, not the Uvalde County Underground Water Conservation District. Because the Edwards (Balcones Fault Zone) Aquifer is the principal source of recharge to Austin Chalk and Buda Limestone aquifers, the feasibility of achieving the DFC of the Austin Chalk and Buda Limestone aquifers is dependent on the management and hydraulic condition of the Edwards (Balcones Fault Zone) Aquifer.

11. Discussion of Other DFCs Considered

No other DFC of the Austin Chalk and Buda Limestone aquifers in Uvalde County was considered.

12. Discussion of Other Recommendations

12.1 Advisory Committees

An Advisory Committee for GMA 10 has not been established.

12.2 Public Comments

GMA 10 approved its proposed DFCs on April 20, 2021. In accordance with requirements in Chapter 36.108(d-2), each GCD then had 90 days to hold a public meeting at which stakeholder input was documented. This input was submitted by the GCD to the GMA within this 90-day period. The dates on which each GCD held its public meeting is summarized in Table 16. Public comments for GMA 10 are included in Appendix B.

Table 16. Dates on which each GCD held a public meeting allowing for stakeholder input on the DFCs.

GCD	Date
Barton Springs/Edwards Aquifer Conservation District	June 10,2021
Comal Trinity GCD	May 17, 2021
Kinney County GCD	June 10, 2021
Medina County GCD	June 16, 2021
Plum Creek Conservation District	June 30, 2021
Uvalde County UWCD	May 19, 2021

Under Texas Water Code, Ch. 36.108(d-3)(5), GMA 10 is required to "discuss reasons why recommendations made by advisory committees and relevant public comments were or were not incorporated into the desired future conditions" in each DFC Explanatory Report.

Numerous comments on the GMA 10's proposed DFCs were received from stakeholders. All individual public comments and the detailed GMA 10 responses to each are included in Appendix B of this Explanatory Report and are incorporated into the discussion herein by reference. Some comments did not designate which aquifer's DFC was being addressed but were considered by the GMA, where possible and pertinent, to be applicable to all DFCs. And some comments were not DFC recommendations *per se*, rather general observations on joint groundwater planning.

However, there were no comments specifically addressing the Austin Chalk and Buda Limestone Aquifer DFC.

13. Any Other Information Relevant to the Specific DFCs

No additional information relevant to the specific DFCs has been identified.

14. 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

This DFC is designed to balance 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. This balance is demonstrated in (a) how GMA 10 has assessed and incorporated each of the nine factors used to establish the DFC, as described in Chapter 6 of this Explanatory Report, and (b) how GMA 10 responded to certain public comments and concerns expressed in timely public meetings that followed proposing the DFC, as described more specifically in Appendix B of this Explanatory Report. Further, this approved DFC will enable current and future Management Plans and regulations of those GMA 10 GCDs charged with achieving this DFC to balance specific local risks arising from protecting the aquifer while maximizing groundwater production.

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APPENDIX A

Socioeconomic Impacts of Projected Water Shortages

for the South Central Texas (Region L) Regional Water Planning Area

Prepared in Support of the 2021 Region L Regional Water Plan

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

November 2019

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Executive Summary

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

Based on projected water demands and existing water supplies, Region L 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 L generated close to $148 billion in GDP (2018 dollars) and supported roughly 1.6 million jobs in 2016. The Region L estimated total population was approximately 2.9 million in 2016.

It is estimated that not meeting the identified water needs in Region L would result in an annually combined lost income impact of approximately $16.6 billion in 2020, and $9.3 billion in 2070 (Table ES-1). It is also estimated that the region would lose approximately 100,500 jobs in 2020, and 95,000 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 L socioeconomic impact summary

Regional Economic Impacts	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$16,571	$17,246	$14,600	$11,679	$9,674	$9,384
Job losses	100,514	107,453	96,710	86,976	85,393	94,978
Financial Transfer Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Tax losses on production and imports ($ millions)*	$1,775	$1,794	$1,433	$1,032	$740	$663
Water trucking costs ($ millions)*	$3	$4	$6	$8	$9	$13
Utility revenue losses ($ millions)*	$70	$146	$268	$400	$560	$723
Utility tax revenue losses ($ millions)*	$1	$3	$5	$7	$10	$14
Social Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Consumer surplus losses ($ millions)*	$67	$80	$118	$184	$342	$651
Population losses	18,454	19,728	17,756	15,969	15,678	17,438
School enrollment losses	3,530	3,773	3,396	3,054	2,999	3,335

* 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 L, 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 L Regional Water Planning Area generated close to $148 billion in gross domestic product (2018 dollars) and supported roughly 1.6 million jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for 8.6 percent of the state's total gross domestic product 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 L. The real estate, finance, and manufacturing sectors generated more than 27 percent of the region's total value-added and were also significant sources of tax revenue. The top employers in the region were in the public administration, health care, and retail trade sectors. Region L's estimated total population was roughly 2.9 million in 2016, approximately 10 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.

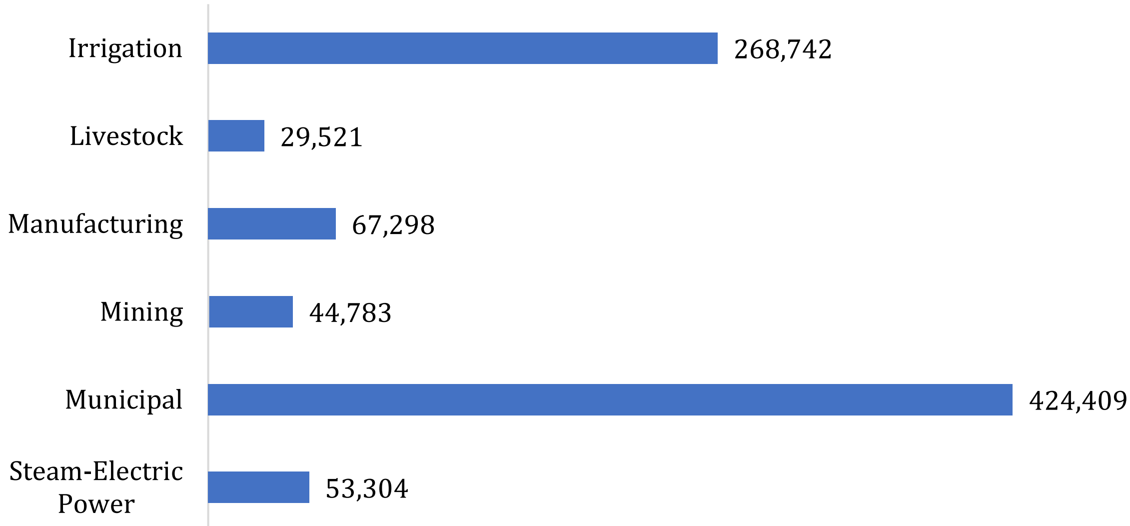
Table 1-1 Region L regional economy by economic sector*

Economic sector	Value-added ($ millions)	Tax ($ millions)	Jobs
Public Administration	$23,573.9	$(202.2)	233,720
Real Estate and Rental and Leasing	$15,515.7	$2,278.1	67,656
Finance and Insurance	$13,382.4	$1,120.4	109,447
Manufacturing	$11,484.3	$399.0	64,959
Health Care and Social Assistance	$10,396.6	$133.1	171,474
Retail Trade	$9,296.3	$2,156.9	158,939
Mining, Quarrying, and Oil and Gas Extraction	$8,492.5	$1,188.7	32,890
Professional, Scientific, and Technical Services	$8,348.1	$242.7	98,810
Wholesale Trade	$8,182.9	$1,400.0	47,605
Construction	$7,788.3	$122.6	110,766
Accommodation and Food Services	$6,028.2	$903.0	149,509
Transportation and Warehousing	$5,605.6	$194.9	52,917
Administrative and Support and Waste Management and Remediation Services	$5,103.9	$129.3	108,945
Information	$4,281.1	$953.1	25,718
Other Services (except Public Administration)	$4,150.0	$423.9	87,960
Utilities	$1,984.1	$247.7	4,421
Arts, Entertainment, and Recreation	$1,276.1	$264.1	29,315
Management of Companies and Enterprises	$1,259.6	$43.0	15,266
Educational Services	$991.2	$43.6	27,800
Agriculture, Forestry, Fishing and Hunting	$830.2	$29.7	33,150
Grand Total	$147,971.1	$12,071.5	1,631,267

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

Figure 1-1 illustrates Region L's breakdown of the 2016 water use estimates by TWDB water use category. The categories with the highest use in Region L in 2016 were municipal (48 percent) and irrigation (30 percent). Notably, more than 26 percent of the state's mining water use occurred within Region L.

Figure 1-1 Region L 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 L 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 L 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)	131,184	131,915	134,104	136,099	137,596	140,812
	% of the category's total water demand	37%	37%	37%	38%	38%	39%
Livestock	water needs (acre-feet per year)	1,674	1,668	1,757	1,852	1,930	1,930
	% of the category's total water demand	5%	5%	6%	6%	6%	6%
Manufacturing	water needs (acre-feet per year)	10,429	12,939	13,040	13,072	13,072	13,072
	% of the category's total water demand	14%	16%	16%	16%	16%	16%
Mining	water needs (acre-feet per year)	16,147	17,125	15,491	12,786	11,170	11,578
	% of the category's total water demand	33%	34%	32%	29%	27%	28%
Municipal*	water needs (acre-feet per year)	26,557	51,105	88,889	129,728	179,452	229,740
	% of the category's total water demand	6%	11%	17%	22%	28%	33%
Steam-electric power	water needs (acre-feet per year)	21,707	21,707	21,707	21,707	21,707	21,707
	% of the category's total water demand	20%	20%	20%	20%	20%	20%
Total water needs (acre-feet per year)		**207,698**	**236,459**	**274,988**	**315,244**	**364,927**	**418,839**

* 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.

[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.

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 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)

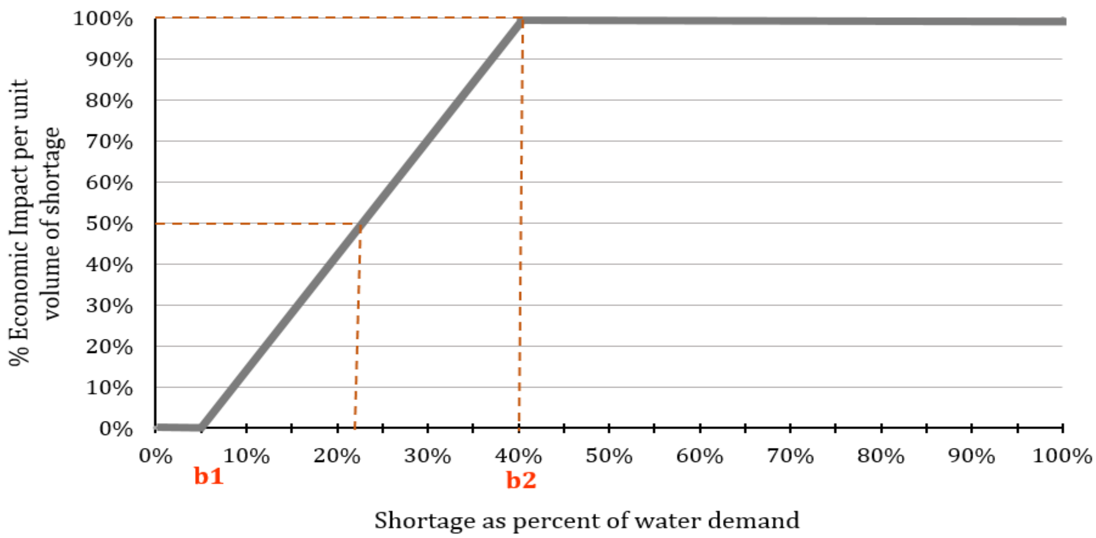

Table 3-1 Economic impact elasticity function lower and upper bounds

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

Fifteen of the 21 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 L

Impact measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$66	$66	$67	$67	$67	$68
Job losses	1,217	1,225	1,232	1,234	1,238	1,267

* 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

Eleven of the 21 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 L

Impact measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$18	$18	$20	$21	$23	$23
Jobs losses	664	660	731	772	820	820
Tax losses on production and imports ($ millions)*	$1	$1	$1	$1	$1	$1

* 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 five of the 21 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 L

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$3,349	$4,250	$4,283	$4,296	$4,296	$4,296
Job losses	21,100	27,846	28,069	28,155	28,155	28,155
Tax losses on production and Imports ($ millions)*	$221	$279	$281	$282	$282	$282

* 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 12 of the 21 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 L

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$11,992	$11,666	$8,617	$5,081	$2,229	$985
Job losses	70,538	68,993	51,650	31,445	15,269	8,466
Tax losses on production and Imports ($ millions)*	$1,514	$1,465	$1,067	$608	$235	$67

* 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

Sixteen of the 21 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 L

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses[1] ($ millions)*	$407	$507	$873	$1,474	$2,321	$3,273
Job losses[1]	6,995	8,729	15,028	25,370	39,911	56,270
Tax losses on production and imports[1] ($ millions)*	$39	$49	$84	$142	$223	$314
Trucking costs ($ millions)*	$3	$4	$6	$8	$9	$13
Utility revenue losses ($ millions)*	$70	$146	$268	$400	$560	$723
Utility tax revenue losses ($ millions)*	$1	$3	$5	$7	$10	$14

[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 two of the 21 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 L

Impacts measure	2020	2030	2040	2050	2060	2070
Income Losses ($ millions)*	$740	$740	$740	$740	$740	$740

* 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 L

Impacts measure	2020	2030	2040	2050	2060	2070
Consumer surplus losses ($ millions)*	$67	$80	$118	$184	$342	$651
Population losses	18,454	19,728	17,756	15,969	15,678	17,438
School enrollment losses	3,530	3,773	3,396	3,054	2,999	3,335

* 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 L

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
ATASCOSA	MUNICIPAL	$6.52	$8.70	$12.68	$16.54	$20.57	$24.16	112	150	218	285	354	416
ATASCOSA Total		**$6.52**	**$8.70**	**$12.68**	**$16.54**	**$20.57**	**$24.16**	**112**	**150**	**218**	**285**	**354**	**416**
BEXAR	IRRIGATION	$0.92	$0.92	$0.92	$0.92	$0.92	$0.92	19	19	19	19	19	19
BEXAR	MUNICIPAL	$102.48	$113.74	$254.91	$517.90	$907.12	$1,401.82	1,765	1,958	4,389	8,918	15,620	24,139
BEXAR	STEAM ELECTRIC POWER	$94.79	$94.79	$94.79	$94.79	$94.79	$94.79	-	-	-	-	-	-
BEXAR Total		**$198.18**	**$209.44**	**$350.62**	**$613.61**	**$1,002.83**	**$1,497.53**	**1,784**	**1,978**	**4,409**	**8,937**	**15,640**	**24,158**
CALDWELL	MUNICIPAL	$1.21	$1.61	$4.71	$10.35	$22.89	$38.76	20	26	77	174	389	662
CALDWELL Total		**$1.21**	**$1.61**	**$4.71**	**$10.35**	**$22.89**	**$38.76**	**20**	**26**	**77**	**174**	**389**	**662**
CALHOUN	IRRIGATION	$2.32	$2.32	$2.32	$2.32	$2.32	$2.32	54	54	54	54	54	54
CALHOUN	LIVESTOCK	$3.26	$3.26	$3.26	$3.26	$3.26	$3.26	147	147	147	147	147	147
CALHOUN	MINING	$13.51	$14.10	$10.57	$7.05	$2.68	$1.01	96	100	75	50	19	7
CALHOUN	MUNICIPAL	-	-	$0.00	$0.06	$0.15	$0.29	-	-	0	1	3	5
CALHOUN Total		**$19.09**	**$19.68**	**$16.15**	**$12.68**	**$8.41**	**$6.87**	**297**	**301**	**276**	**252**	**223**	**213**
COMAL	IRRIGATION	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	0	0	0	0	0	0
COMAL	MANUFACTURING	$1,900.96	$2,571.00	$2,571.00	$2,571.00	$2,571.00	$2,571.00	16,829	22,761	22,761	22,761	22,761	22,761
COMAL	MINING	$327.57	$440.34	$548.92	$643.67	$762.34	$895.31	2,907	3,908	4,872	5,713	6,766	7,946
COMAL	MUNICIPAL	$35.17	$74.22	$189.22	$350.61	$472.41	$587.96	606	1,278	3,258	6,037	8,135	10,125
COMAL Total		**$2,263.71**	**$3,085.57**	**$3,309.15**	**$3,565.30**	**$3,805.77**	**$4,054.28**	**20,342**	**27,947**	**30,891**	**34,511**	**37,662**	**40,832**
DEWITT	IRRIGATION	$0.26	$0.26	$0.19	$0.19	-	-	6	6	4	4	-	-
DEWITT	MANUFACTURING	-	$0.65	-	-	-	-	-	9	-	-	-	-
DEWITT	MINING	$1,674.17	$1,554.31	$115.83	-	-	-	9,704	9,010	671	-	-	-
DEWITT Total		**$1,674.44**	**$1,555.23**	**$116.02**	**$0.19**	**-**	**-**	**9,710**	**9,024**	**675**	**4**	**-**	**-**
DIMMIT	IRRIGATION	$3.97	$3.97	$3.97	$3.97	$3.97	$3.97	65	65	65	65	65	65
DIMMIT	MINING	$4,116.25	$4,202.00	$3,558.84	$2,089.31	$622.70	$18.57	23,860	24,357	20,629	12,111	3,609	108
DIMMIT Total		**$4,120.22**	**$4,205.97**	**$3,562.81**	**$2,093.27**	**$626.67**	**$22.54**	**23,925**	**24,422**	**20,694**	**12,176**	**3,674**	**173**

		Income losses (Million $)*						Job losses					
County	Water Use Category	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
FRIO	IRRIGATION	-	-	-	-	$0.30	$0.91	-	-	-	-	7	20
FRIO	MUNICIPAL	$10.81	$16.41	$21.97	$26.05	$29.61	$32.90	186	283	378	449	510	567
FRIO Total		**$10.81**	**$16.41**	**$21.97**	**$26.05**	**$29.91**	**$33.81**	**186**	**283**	**378**	**449**	**516**	**586**
GOLIAD	IRRIGATION	$0.03	$0.03	$0.03	$0.03	$0.03	$0.03	1	1	1	1	1	1
GOLIAD	MUNICIPAL	$0.18	$0.14	$0.11	$0.11	$0.10	$0.10	3	2	2	2	2	2
GOLIAD Total		**$0.21**	**$0.17**	**$0.15**	**$0.14**	**$0.13**	**$0.13**	**4**	**3**	**3**	**3**	**3**	**3**
GUADALUPE	MANUFACTURING	-	$17.48	$17.48	$17.48	$17.48	$17.48	-	179	179	179	179	179
GUADALUPE	MUNICIPAL	$0.03	$0.05	$8.19	$58.02	$144.05	$205.33	1	1	141	999	2,480	3,536
GUADALUPE Total		**$0.03**	**$17.53**	**$25.67**	**$75.50**	**$161.53**	**$222.81**	**1**	**179**	**320**	**1,178**	**2,659**	**3,714**
HAYS	LIVESTOCK	$8.58	$8.58	$8.58	$8.58	$8.58	$8.58	261	261	261	261	261	261
HAYS	MUNICIPAL	$2.56	$12.63	$73.92	$152.60	$322.83	$505.05	40	217	1,267	2,616	5,510	8,606
HAYS Total		**$11.14**	**$21.22**	**$82.51**	**$161.19**	**$331.41**	**$513.63**	**301**	**478**	**1,528**	**2,876**	**5,771**	**8,867**
KARNES	IRRIGATION	$0.13	$0.13	$0.68	$0.68	$0.68	$0.68	2	2	12	12	12	12
KARNES	MANUFACTURING	-	-	$34.37	$47.14	$47.14	$47.14	-	-	232	319	319	319
KARNES	MINING	$1,876.79	$1,319.99	$743.71	$109.72	$11.62	$0.97	10,879	7,651	4,311	636	67	6
KARNES	MUNICIPAL	$5.16	$5.08	$4.66	$4.57	$6.57	$6.40	89	88	80	79	113	110
KARNES Total		**$1,882.09**	**$1,325.20**	**$783.41**	**$162.10**	**$66.00**	**$55.19**	**10,970**	**7,741**	**4,635**	**1,045**	**511**	**446**
KENDALL	MUNICIPAL	-	$2.14	$4.91	$8.12	$31.23	$75.35	-	37	85	140	538	1,297
KENDALL Total		**-**	**$2.14**	**$4.91**	**$8.12**	**$31.23**	**$75.35**	**-**	**37**	**85**	**140**	**538**	**1,297**
LA SALLE	IRRIGATION	$0.19	$0.19	$0.20	$0.21	$0.22	$0.23	6	6	6	7	7	7
LA SALLE	MINING	$3,983.72	$4,134.76	$3,638.75	$2,231.58	$829.29	$68.54	23,092	23,967	21,092	12,935	4,807	397
LA SALLE Total		**$3,983.91**	**$4,134.96**	**$3,638.95**	**$2,231.80**	**$829.51**	**$68.77**	**23,098**	**23,973**	**21,099**	**12,942**	**4,814**	**405**
MEDINA	IRRIGATION	$18.46	$18.63	$18.60	$18.76	$18.85	$19.40	353	356	355	359	360	371
MEDINA	MINING	-	-	-	-	-	$0.25	-	-	-	-	-	2
MEDINA	MUNICIPAL	$16.32	$20.84	$25.35	$30.35	$34.73	$38.37	281	359	437	523	598	661
MEDINA Total		**$34.78**	**$39.48**	**$43.95**	**$49.11**	**$53.58**	**$58.02**	**634**	**715**	**792**	**881**	**958**	**1,034**
UVALDE	IRRIGATION	$25.48	$25.64	$25.72	$25.87	$26.05	$26.25	455	458	460	462	466	469
UVALDE	LIVESTOCK	$5.38	$5.28	$6.53	$8.19	$9.42	$9.42	207	203	251	315	362	362
UVALDE	MUNICIPAL	$60.80	$68.72	$75.60	$83.44	$91.59	$99.55	1,047	1,183	1,302	1,437	1,577	1,714
UVALDE Total		**$91.66**	**$99.65**	**$107.85**	**$117.51**	**$127.06**	**$135.23**	**1,709**	**1,845**	**2,013**	**2,214**	**2,405**	**2,546**
VICTORIA	IRRIGATION	$1.44	$1.44	$1.44	$1.44	$1.44	$1.44	33	33	33	33	33	33
VICTORIA	MANUFACTURING	$1,447.95	$1,660.38	$1,660.38	$1,660.38	$1,660.38	$1,660.38	4,270	4,897	4,897	4,897	4,897	4,897
VICTORIA	MUNICIPAL	$164.14	$179.88	$192.09	$204.46	$216.14	$226.15	2,826	3,097	3,308	3,521	3,722	3,894
VICTORIA	STEAM ELECTRIC POWER	$644.82	$644.82	$644.82	$644.82	$644.82	$644.82	-	-	-	-	-	-

County	Water Use Category	Income losses (Million $)* 2020	2030	2040	2050	2060	2070	Job losses 2020	2030	2040	2050	2060	2070
VICTORIA Total		**$2,258.36**	**$2,486.52**	**$2,498.74**	**$2,511.10**	**$2,522.79**	**$2,532.80**	**7,130**	**8,027**	**8,237**	**8,450**	**8,651**	**8,824**
WILSON	IRRIGATION	$0.82	$0.83	$0.84	$0.85	$0.93	$1.12	18	18	18	18	20	24
WILSON	LIVESTOCK	$1.25	$1.25	$1.80	$1.25	$1.25	$1.25	50	50	72	50	50	50
WILSON	MUNICIPAL	$1.13	$2.85	$4.96	$11.07	$20.87	$31.14	19	49	85	191	359	536
WILSON Total		**$3.20**	**$4.93**	**$7.60**	**$13.16**	**$23.06**	**$33.51**	**87**	**117**	**176**	**259**	**429**	**610**
ZAVALA	IRRIGATION	$11.74	$11.80	$11.67	$11.46	$11.14	$10.98	205	206	204	200	195	192
ZAVALA Total		**$11.74**	**$11.80**	**$11.67**	**$11.46**	**$11.14**	**$10.98**	**205**	**206**	**204**	**200**	**195**	**192**
REGION L Total		**$16,571.30**	**$17,246.20**	**$14,599.51**	**$11,679.18**	**$9,674.50**	**$9,384.38**	**100,514**	**107,453**	**96,710**	**86,976**	**85,393**	**94,978**

APPENDIX B

Summarization of Public Comments Received and Groundwater Management Area 10 Responses

Aquifer: Northern Fresh Edwards

Summary of Comment: 6.5 cfs is not adequate to sustain Salamander habitat and needs to be changed to 10 cfs

GMA 10 Response: As part of its approved Habitat Conservation Plan (HCP), BSEACD has spent considerable time, effort, and money over the past decade in analyzing the relationships between pumping of the aquifer, springflows within the aquifer and at Barton Springs, dissolved oxygen levels and regimes, and effects and impacts on the two endangered salamander species. In fact, much of the “best science available” that the Commenter refers to derives from BSEACD initiatives. In BSEACD’s view, it is infeasible to achieve a DOR springflow of 11 cfs on the basis of what is now known. That would be tantamount to complete cessation of pumping by all BSEACD permittees during a DOR. The District’s permittees have had to justify their normal pumpage levels as reasonable, non-speculative, and appropriate for the permitted use, and they are required to participate in a very stringent drought management program administered by BSEACD. The best they can currently and reasonably achieve is a DOR pumpage of 4.7 cfs. Using a well-documented water balance, that pumpage translates to 6.5 cfs of springflow during a DOR, which is the Extreme Drought DFC. This is a lower springflow than has been measured in recorded history, but it is very likely not the lowest springflow that ever existed at Barton Springs, considering the historical drought indices (e.g. dendrochronological record) of prolonged, more extreme droughts over the centuries. And yet the salamander populations persisted during those times. On the basis of the best science and other information available, the BSEACD Board considers a DOR springflow of 6.5 cfs as a reasonable balance of protection of private property rights and protection of the aquifer and salamander populations, and the US Fish and Wildlife Service - Austin Field Office has concurred with that determination.

Aquifer: Northern Fresh Edwards and Trinity

Summary of Comment: Increasing pumping in the Trinity threatens to decrease the flow in the Blanco River which in return could cause effects on recharge to the Northern Edwards

GMA 10 Response: GMA 10 agrees that the Blanco River is a critical resource which provides recharge to the northern segment of the Edwards Aquifer, especially during times of drought. However, it is still poorly understood to what extent pumping from the Trinity Aquifer in GMA 10 will affect upgradient springs which contribute to Blanco River flow, such as Pleasant Valley Spring and Jacobs Well Spring. This is why a consortium of GCDs, government agencies, and private firms are currently undertaking efforts to produce the Blanco River Aquifer Assessment Tool, a numerical groundwater model which, among other things, will be able to simulate potential impacts of pumping from the Trinity on these springs. Martin et al., 2019 presents the conceptual model, the first phase in creating the Blanco River Aquifer Assessment Tool numerical model. The second phase, creation of the numerical model, has been funded and is planned to begin in 2021 and be completed in 2022 or early 2023. Once the completed numerical groundwater model is available, we will be able to more accurately simulate pumping impacts on Blanco River flow to inform the DFC process.

Aquifer: Northern Fresh Edwards

Summary of Comment: Effects of Climate Change

GMA 10 Response: Climate modeling provides important high-level, long-term predictions for water planners. However, global climate models are less reliable at local scales, and have high level of uncertainty. Thus, they are less useful as a quantitative benchmark for DFC planning than historic droughts from which we have directly observed data, including springflow measurements at Barton Springs. Currently, the Texas 1950s drought of record (DOR) is the worst drought within the historical observation period; and is still widely accepted across the state as the benchmark for drought planning.

Furthermore, according to the best available groundwater models, achieving a DFC of 10 CFS at Barton Springs during a recurrence of the DOR event would require complete cessation of pumping within the northern segment of the Edwards Aquifer. Achieving a DFC of 10 CFS at Barton Springs during a drought worse than the DOR may be impossible, as spring flow may still drop below 10 CFS even with complete cessation of pumping. Enforcing a complete cessation of pumping would not be in accordance with the District’s mandate to balance beneficial use with conservation.

Aquifer: Trinity

Summary of Comment: Zero Region Well Drawdown

GMA 10 Response: The Trinity Aquifer condition is a confined aquifer that is isolated from the surface in GMA 10. It can produce fairly substantial amounts of groundwater, especially a mile or two downdip of the Trinity outcrop area (which coincides generally with the western boundary of GMA 10), without affecting other water supplies and without dewatering the aquifer. The demand for Trinity water in the area is growing, and there is little in the way of other alternative supplies to meet that demand. Zero-drawdown technically connotes no groundwater use, as drawdown is required to withdraw water from an individual well and from all wells in a given area. Sustainability, which is a more rational concept for management of groundwater in an area that depends on it for water supplies, connotes that total groundwater discharge, both natural (springs and seeps) and man-made (water wells), is balanced over the long term by the amount of recharge that may exist naturally or be induced by groundwater withdrawals, taking into consideration a time period required for achieving such a balance. The proposed DFCs are intended to provide such a balance, but a DFC based on zero-drawdown doesn’t pass that balancing test for any of its aquifers, in the judgment of GMA-10.

Aquifer: Trinity

Summary of Comment: Differentiating the Middle and Lower Trinity Aquifers and measuring methods

GMA 10 Response: GMA 10 has visited this concept and will continue to discuss during the next planning cycle on how to separate the Trinity and what would be the best way to measure DFC compliance. Currently, BSEACD is exploring the feasibility of a sustainable yield project that would allow the District to potentially establish a DFC for the Middle and a DFC for the Lower Trinity.

Aquifer: Trinity

Summary of Comment: Pumping in the Trinity would have effects to ecological and socioeconomic impacts and private property rights

GMA 10 Response: GMA 10 understands that maintaining a balance between needs, ecological and socioeconomic impacts, and private property rights is important to all users. However, adjusting the DFC would cause the balance test to start tipping in one favor or the other. For example, if the DFC was moved to a more conservative DFC, it would effect the socioeconomic and ecological impacts in a positive way, but, would cause the needs and private property rights to be impacted in a negative way. GMA 10 has determined that the DFCs provide the best balance to accomplish the balance test. GMA 10 will revisit comment next cycle once more data is obtained from current models being developed.

Aquifer: Undesignated/Multiple

Summary of Comment: DFC established around spring flow where necessary and DFC established for managed depletion where necessary

GMA 10 Response: Commenter do not provide guidance or additional information on what ***"is appropriate***" means or involves to them. So even if GMA 10 did know the specific aquifer(s) involved, it still would not know under what circumstances or rules to which ***"around spring flow"*** of these aquifers refer or apply.
The term "managed depletion" has not been defined within Chapter 36 of the Texas Water Code. Groundwater depletion has been described by the U.S. Geological Survey in concept as similar to money kept in a bank account:

> "If you withdraw money at a faster rate than you deposit new money you will eventually start having account-supply problems. Pumping water out of the ground faster than it is replenished over the long-term causes similar problems. The volume of groundwater in storage is decreasing in many areas of the United States in response to pumping. Groundwater depletion is primarily caused by sustained groundwater pumping." *Groundwater depletion*, USGS, https://water.usgs.gov/edu/gwdepletion.html

Such a condition is not a permanent condition within GMA 10. In GMA 10, there is substantial recharge, from both surface and subsurface sources, and the aquifers are able to induce additional recharge with additional drawdown until stability is reached.

Aquifer: Undesignated/Multiple

Summary of Comment: DFC Does not consider Subsidence

GMA 10 Response: Commenter does not assert nor provide evidence that there has been actual subsidence in GMA 10 caused by groundwater withdrawals. The Groundwater Conservation District representatives of GMA 10 are not aware of any subsidence, and would not expect any on the basis of all these aquifers' lithologic characteristics (dominantly competent carbonate formations), regardless of the DFC approved.

Aquifer: Trinity

Summary of Comment: Adopt a more conservative DFC even if Water Management Strategies (WMS) are affected

GMA 10 Response: GMA 10 complies with all laws governing joint groundwater planning, with its being included in the regional planning for all water resources in Texas, which coordinates groundwater and surface water supplies, needs, and water management strategies. GMA 10 does not have the authority to change this approach. A DFC has a statutory requirement to balance aquifer protection and the maximum groundwater production feasible. This means that GMA 10 has to consider all 9 Factors which includes WMS

Aquifer: General Comment

Summary of Comment: BSEACD should work with Hays Trinity GCD to establish a DFC based on spring flow from Jacobs Well

GMA 10 Response: Jacobs Well is not located in GMA 10 and the DFC should be established by GMA 9. However, GMA 10 is not opposed to local GCDs that benefit from Jacobs Well to work together across GMA boundaries to establish management tools for the future of Jacobs Well.

Aquifer: General Comment

Summary of Comment: Public comment/involvement process for DFCs

GMA 10 Response: GMA 10 understands the amount of information to be digested by the public in this process can be daunting. However, to a considerable extent, the deadlines for various actions are not controllable by the GMA, and GMA 10 has adhered to the required schedule for developing, proposing, and seeking public comment before adopting DFCs.

There have been several public meetings and hearings by both the GMA and individual GCDs where both written and oral comments were solicited and received. At this point, the GMA sees no reason to further delay considering the proposed DFC for adoption and completing this round. It should be noted that this is a recurring process on a five-year cycle, and the GMA and the public will be able to consider new information and use any new tools that might become available in the next five years.

Aquifer: General Comment

Summary of Comment: Release of an Explanatory Report before the 90 day public comment period begins

GMA 10 Response: The Explanatory Report is one of the last steps in the DFC process. The report has several components that have to be completed before the report can be viewed and finalized by GMA 10 for public dispersal, such as, public hearing meetings held by individual GCDs and public comment.

Aquifer: General Comment

Summary of Comment: Requiring less technical comments from the public

GMA 10 Response: State Law requires the use of scientific data to determine the DFC for each aquifer. Any public comment input that provides data will more likely have an affect on the DFC process.

Aquifer: General Comment

Summary of Comment: More funding for the DFC process

GMA 10 Response: Currently, there is no funding mechanism to provide funds to GCDs to complete the DFC process. Each GCD has to provide funds its own funds to complete the DFC process.