Explanatory Report for Proposed Desired Future Conditions of the Fresh Edwards (Balcones Fault Zone) Aquifer in Northern Subdivision, 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. Description of Groundwater Management Area 10 and its Northern Subdivision

Groundwater Conservation Districts (GCDs, or districts) were created, typically by legislative action, 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. The individual GCDs overlying each of the major aquifers or, for some aquifers, their geographic subdivisions were aggregated by the Texas Water Development Board (TWDB) acting under legislative mandate to form Groundwater Management Areas (GMAs). Each GMA is charged with facilitating joint planning efforts for all aquifers wholly or partially within its GMA boundaries that are considered relevant to joint regional planning. .

GMA 10 was created to coordinate planning primarily for the San Antonio and Barton Springs segments of the Fresh Edwards (Balcones Fault Zone) Aquifer, but it also includes the underlying down-dip Trinity Aquifer. Other aquifers in GMA 10 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 in a GMA are required to submit Desired Future Conditions (DFCs) of the groundwater resources in their GMA to the executive administrator of the TWDB, unless that aquifer is deemed to be non-relevant for the purposes of joint planning. According to Texas Water Code § 36.108 (d-3), the district representatives shall produce a Desired Future Conditions Explanatory Report for the management area and submit to the TWDB Board a copy of the Explanatory Report.

GMA 10 has designated the fresh Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of the GMA as a major aquifer for purposes of joint planning of. The extent of this aquifer-based subdivision corresponds to the Barton Springs segment of the fresh Edwards (Balcones Fault Zone) Aquifer, a TWDB-designated major aquifer system in Texas. This document is the Explanatory Report for the fresh Edwards (Balcones Fault Zone) Aquifer in the northern subdivision within GMA 10.

2. Aquifer Description

For jurisdictional purposes, the northern subdivision of GMA 10 for the fresh Edwards (Balcones Fault Zone) Aquifer is coincident with the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Figure 2). The boundaries of the northern subdivision, fresh Edwards (Balcones Fault Zone) Aquifer were determined using the Digital Geologic Atlas of Texas (U.S. Geological Survey and Texas Water Development Board, 2006) and the GMA 10 boundary. The northern subdivision of GMA 10 for the Edwards (Balcones Fault Zone) Aquifer is located within the Regional Water Planning Areas K and L, and is almost entirely within the Barton

Springs/Edwards Aquifer Conservation District. The geographic extent of the northern fresh Edwards (Balcones Fault Zone) Aquifer in the Barton Springs/Edwards Aquifer Conservation District is presented in Figure 3 (Barton Springs/Edwards Aquifer Conservation District website). As illustrated, the jurisdictional area for this aquifer subdivision includes substantial portions of Hays and Travis Counties and a small portion of Caldwell County.

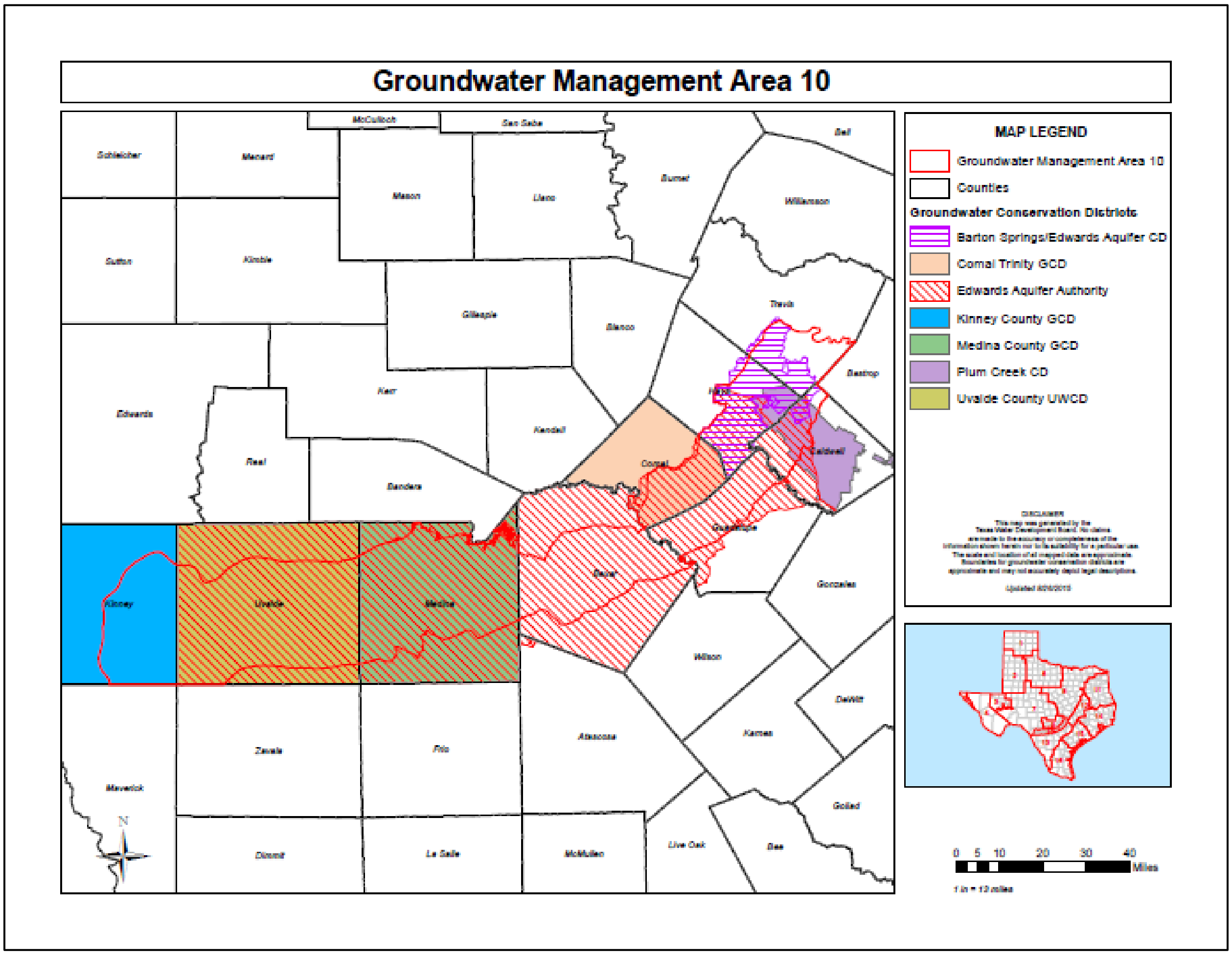

Figure 1. Map of the administrative boundaries of GMA10 designated for joint-planning purposes and the GCDs in the GMA (From Texas Water Development Board website)

3. Desired Future Conditions

GMA10 incorporated information from the Barton Springs/Edwards Aquifer Conservation District Management Plan and analyses from the TWDB during development of the proposed DFCs. The DFCs in the first round of joint planning for the northern fresh Edwards (Balcones Fault Zone) Aquifer in Hays and Travis counties in GMA10, were described in Resolution No. 2010-11 and adopted August 23, 2010, by the GCDs in GMA 10.

This subdivision of the aquifer had two DFCs in the first round:

(1) springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and

(2) springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 cfs averaged on a monthly basis.

The expression of the All Conditions DFC was initially adopted with the intent of providing a limit on the acceleration of the change from non-drought to drought conditions in the aquifer by no more than one month. The expression of the Extreme Drought DFC was initially adopted to preserve a minimum amount of springflow during a recurrence of drought of record conditions.

The second round of DFCs was adopted at the GMA10 meeting on March 14, 2016. GMA 10 has resolved to maintain the same DFCs in the second round as in the first round for this aquifer, and to continue to have two DFCs, related to different water level conditions in the aquifer (Table 1).

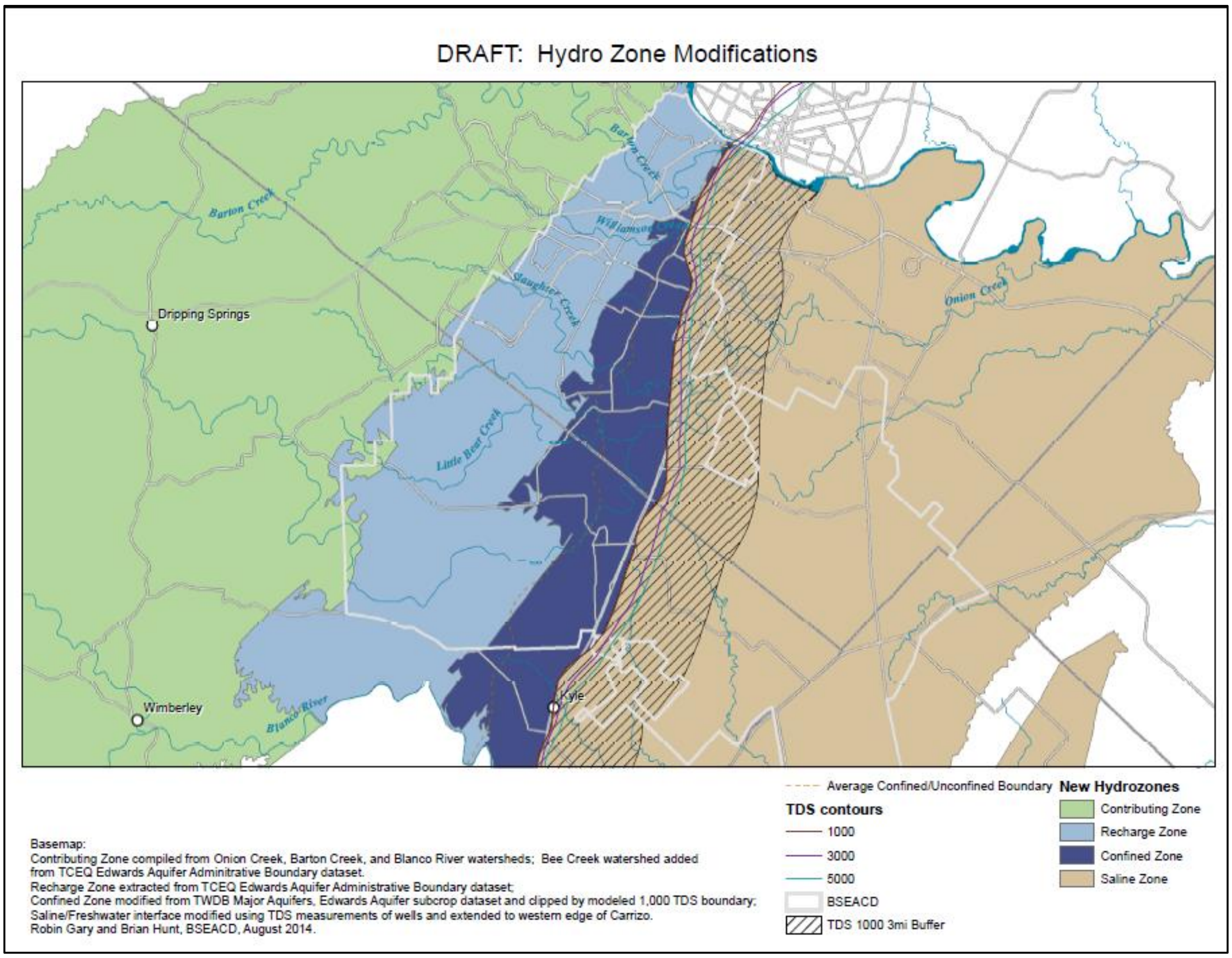

Figure 2. Map showing the extent and hydrologic zones of the Edwards (Balcones Fault Zone) Aquifer in the Barton Springs segment in Hays and Travis counties in Groundwater Management Area 10 (from Barton Springs/Edwards Aquifer Conservation District)

Table 1. Desired Future Conditions for the fresh Edwards (Balcones Fault Zone) Aquifer in northern subdivision, Groundwater Management Area 10

Aquifer	Desired Future Condition Summary	Date Desired Future Condition Adopted
Northern subdivision's fresh Edwards (Balcones Fault Zone) Aquifer	Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, springflow of Barton Springs shall be no less than 6.5 cfs average on a monthly basis.	First Round: 8/4/2010
Northern subdivision's fresh Edwards (Balcones Fault Zone) Aquifer	Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 cfs average on a monthly basis.	Second Round: 3/14/2016

4. Policy Justification

The DFCs in the northern subdivision of GMA 10 for the fresh Edwards (Balcones Fault Zone) Aquifer in Hays and Travis Counties were adopted after considering the following factors specified in Texas Water Code §36.108 (d):

1. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;
   a. for each aquifer, subdivision of an aquifer, or geologic strata; and
   b. for each geographic area overlying an aquifer

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

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

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

5. The impact on subsidence;

6. Socioeconomic impacts reasonably expected to occur;

7. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002;

8. The feasibility of achieving the DFC; and,

9. Any other information relevant to the specific DFCs.

GCDs are required to comply with all federal and state statutes and laws as a matter of law and policy. Two endangered species of salamander have habitat at the Barton Springs outlets of the aquifer; the preservation and health of that habitat depends on maintaining a certain amount of springflow, which is demonstrably affected by groundwater withdrawals by wells. Federal law requires that positive steps be taken to have an approved habitat conservation plan that avoids jeopardy (inability for the endangered species populations to recover) and to minimize take (harm to individuals in the population). The Barton Springs/Edwards Aquifer Conservation District is in the process of finalizing a habitat conservation plan and acquiring a federal Incidental Take Permit that, once issued, will legally allow District-permitted pumping from the federal prohibition on take on an exception basis.

These factors and their relevance to establishing the DFCs are discussed in appropriate detail in corresponding subsections within Section 6 of this Explanatory Report.

5. Technical Justification

Technical justification for the DFCsand the subsequent Modeled Available Groundwater in both the first and second rounds of DFCs is summarized in a technical note by Hunt et al. (2011). There are several numerical models of the Barton Springs segment of the Edwards Aquifer available for simulating aquifer performance and spring discharge. The TWDB-approved Groundwater Availability Model (GAM) for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer was developed by Scanlon et al. in 2001, which incorporated concepts and modeling approaches by earlier researchers (Slade et al., 1986; Barrett and Charbeneau, 1996). This model was calibrated on data from 1989 to 1998 and did not include the historic drought-of-record that lasted from 1950 through 1956, when the estimated minimum monthly discharge of 11 cfs occurred at Barton Springs. Since 2001, there have been several modeling studies to re-calibrate the model to include the drought of record (Smith and Hunt, 2004; Winterle et al., 2009; Hutchison and Hill, 2011) for more confident use in aquifer management and as a Groundwater Availability Model in joint planning. Each of these is described below.

The first Groundwater Availability Model developed for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Scanlon et al., 2001) was constructed to match water levels and spring flow from a period wetter than that of the 1950's drought. Because the model was calibrated to a relatively wet period, it overestimates spring flow and under-predicts water-level elevations compared with measurements when simulating the 1950s drought of record. The model was recalibrated by Smith and Hunt (2004) so that simulated and measured spring-flow and water-level data from the 1950s drought matched better. This recalibrated model was the model that was used as the basis to determine the Modeled Available Groundwater during joint planning in 2010 and during the current cycle of joint planning.

In 2008, the TWDB, in collaboration with the Barton Springs/Edwards Aquifer Conservation District, contracted with Southwest Research Institute® to develop a groundwater flow model for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer utilizing the MODFLOW-DCM code (Winterle et al., 2009). This model was calibrated based on data from 1989 to 1998. This model is referred to as the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer MODFLOW-DCM model and is considered an alternative Groundwater Availability Model for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. The 2001 Groundwater Availability Model (Scanlon et al., 2001) was more recently recalibrated by Hutchison and Hill (2011) for the period January 1943 to December 2004. This Groundwater Availability Model is also considered an alternative Groundwater Availability Model.

Evaluation of the various model results during the drought of record indicated that water levels and spring discharge are significantly impacted by 1950s drought conditions and increasing levels of pumping. The models show nearly a one-to-one relationship between pumping increases and spring discharge decreases during low-flow conditions. Hunt et al. (2011) determined that for a total water budget of 11.7 cfs, springflow is simulated at 11 cfs for pumping of 0.7 cfs. This relationship, which has become a key tenet of this aquifer's conceptual model and extreme-drought management, is graphically illustrated in Figures 3 and 4 (Hunt et al., 2011).

Since exempt uses are not metered, unlike permitted (non-exempt) uses, pumping data for exempt wells are not available. It is necessary to account for pumping by exempt wells by alternate means when using the Modeled Available Groundwater to determine non-exempt groundwater availability. To do this, the TWDB developed a standardized method for estimating exempt use for domestic and livestock purposes in an area based on projected changes in population and the ratio of domestic and livestock wells to the total number of wells. If a district believes it has a more appropriate estimate of exempt pumping, it may submit the estimate, along with a description of how it was developed, to the TWDB for consideration. The Barton Springs/Edwards Aquifer Conservation District developed a GIS-based analysis of exempt use for its relatively small geographic area, for which the TWDB method was not readily applicable. The TWDB accepted the District's estimate of exempt use for this aquifer subdivision. Pumping for exempt uses was estimated using the District's alternative method to be 0.5 cfs (361 acre-ft/yr) in the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Hunt et al. 2011). Once established, the estimates of exempt pumping were subtracted from the total pumping calculation to yield the portion of the estimated Modeled Available Groundwater for uses under permits.

Although the official and alternate Groundwater Availability Models (Scanlon et al., 2001; Smith and Hunt, 2004; Hutchison and Hill, 2011) were used to confirm a reasonable water budget for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer for the 1950s drought of record, the Modeled Available Groundwater was actually based on this water budget rather than model simulations.

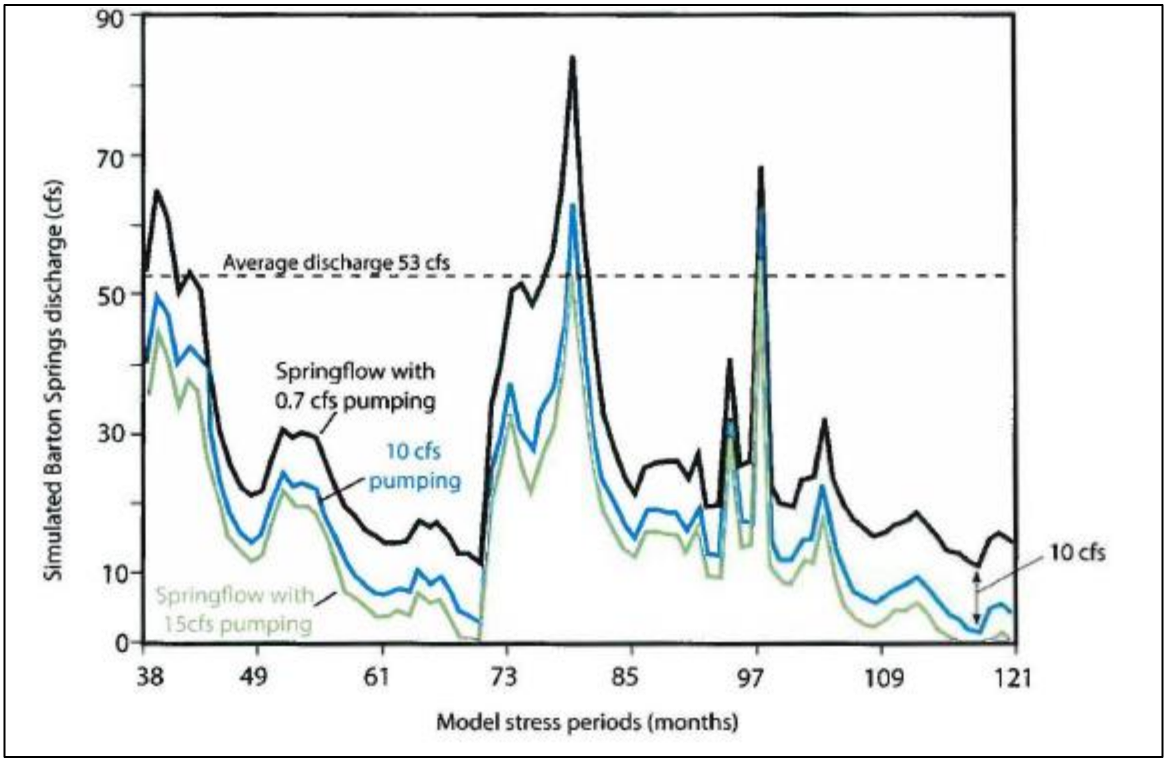

Figure 3. Hydrograph of simulated springflow during the drought of record conditions with variable pumping rates (0.7, 10, and 15 cfs). An increase of pumping from 0.7 to 10 cfs results in a decline in springflow of the same amount. Figure from Hunt et al. (2011).

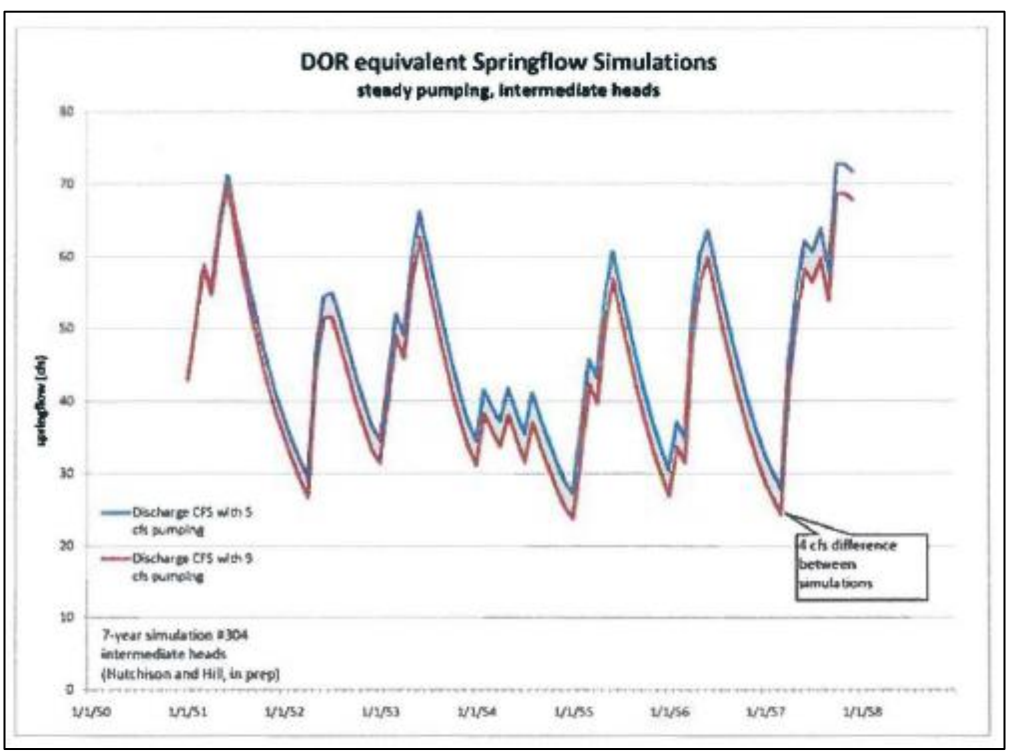

Figure 4. Hydrograph of springflow from two simulations in which pumping that differs by 4 cfs results in spring discharge that differs by 4 cfs (Hunt el al., 2011)

The water budget for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer for the 1950s drought of record is calculated by adding the lowest springflow during the drought of record (11 cfs) to the estimated pumping during the drought of record (0.7 cfs) to provide the total discharge from the aquifer at that time (11.7 cfs). To arrive at the estimated Modeled Available Groundwater, the one-to-one correspondence between pumping and spring discharge is used to justify subtracting DFCs pring discharge from the water budget of 11.7 cfs, as shown in in Table 2. The DFC of 6.5 cfs of minimum spring discharge plus the estimated amount of current exempt use of 0.5 cfs are subtracted from the total water budget calculated above to yield an amount of 4.7 cfs available for non-exempt withdrawals during a recurrence of the drought-of-record (Hunt el al., 2011). Hunt et al. (2011) noted that the water-budget approach reflected in Table 2 is conservative, but prudent given current available data. The water budget, and hence the Modeled Available Groundwater estimates, may be revisited should the influences of urban recharge, the dynamic southern boundary, and climate change be better understood and quantified.

Table 2. Calculations of drought Modeled Available Groundwater (MAG) by decade using water-budget approach (Hunt et al., 2011)

	2010	2020	2030	2040	2050	2060
Total Water Budget in cfs (acre-ft/yr)	11.7 (8,470)	11.7 (8,470)	11.7 (8,470)	11.7 (8,470)	11.7 (8,470)	11.7 (8,470)
Desired Future Condition in cfs (acre-ft/yr)	6.5 (4,705)	6.5 (4,705)	6.5 (4,705)	6.5 (4,705)	6.5 (4,705)	6.5 (4,705)
Modeled Available Groundwater in cfs (acre-ft/year)	5.2 (3,765)	5.2 (3,765)	5.2 (3,765)	5.2 (3,765)	5.2 (3,765)	5.2 (3,765)
Exempt Pumping in cfs (acre-ft/yr)	0.5 (361)	0.5 (361)	0.5 (361)	0.5 (361)	0.5 (361)	0.5 (361)
Non-Exempt Pumping cfs (acre-ft/yr)	4.7 (3,402)	4.7 (3,402)	4.7 (3,402)	4.7 (3,402)	4.7 (3,402)	4.7 (3,402)

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 nine 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 summarize the information that the GCDs used in their deliberations and discussions.

6.1 Aquifer Uses or Conditions

6.1.1 Description of Factors in the Northern Subdivision, GMA 10

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). Groundwater use within the Barton Springs/Edwards Aquifer Conservation District is comprised primarily of pumpage from the freshwater Edwards (Balcones Fault Zone) Aquifer with a small but increasing component of pumpage from the Trinity Aquifer. An incidental amount of groundwater is derived from the Taylor and Austin Groups and more geologically recent alluvial deposits. These withdrawals, however, are largely from exempt wells and are not permitted. Given the current Barton Springs/Edwards Aquifer Conservation District management scheme of conditional permitting and the drought restrictions and curtailment requirements associated with mandatory interruptible-supply for new pumpage authorizations for the freshwater Edwards (Balcones Fault Zone) Aquifer, it is likely that future groundwater production will trend more towards pumpage from the Middle and Lower Trinity Aquifers and, eventually, the Saline Edwards (Balcones Fault Zone) Aquifer.

Data presented in Table 3 are a compilation of the Barton Springs/Edwards Aquifer Conservation District monthly meter readings reported by the Barton Springs/Edwards Aquifer Conservation District permittees and are therefore, a more accurate representation of actual District groundwater use than estimates provided by the TWDB (http://www.twdb.texas.gov/waterplanning/waterusesurvey/historical-pumpage.asp). The reported use data are organized by Major Aquifer and Water Use Type (using the Barton Springs/Edwards Aquifer Conservation District's water-use type designations) in Table 3 and by County and Management Zone in Table 4. These data include neither Exempt Use, which is primarily from the Edwards (Balcones Fault Zone) Aquifer and is estimated to be about 105,000,000 gallons (322.2 acre-ft) annually, nor Non-exempt Domestic Use under the District's Non-exempt Domestic Use general permit, which is also primarily from the Edwards (Balcones Fault Zone) Aquifer and is estimated to be about 20,600,000 gallons (63.2 acre-ft) annually.

Table 3. Type of use of the Edwards (Balcones Fault Zone) Aquifer in the Barton Springs/Edwards Aquifer Conservation District for the years 2007–2010 (the Barton Springs/Edwards Aquifer Conservation District Management Plan) (in gallons and acre-ft)

	Public Water System	**Commercial**	**Irrigation**	**Industrial**	**Totals**
2007	1,237,098,520	9,157,492	90,327,219	145,977,492	1,482,560,723
	3,797	28	277	448	4,550
2008	1,635,001,051	8,129,101	95,486,300	223,125,231	1,961,741,683
	5,018	25	293	685	6,020
2009	1,334,838,604	6,858,106	81,294,200	174,509,965	1,597,500,875
	4,096	21	249	536	4,903
2010	1,398,211,160	8,565,229	91,338,590	240,230,719	1,738,345,698
	4,291	26	280	737	5,335
2011	1,647,368,453	8,791,848	104,405,640	261,507,704	2,022,073,645
	5,056	27	320	803	6,206

Table 4. Use of the Edwards (Balcones Fault Zone) Aquifer in the Barton Springs/Edwards Aquifer Conservation District for the years 2007–2010 by county and aquifer management zone (the Barton Springs/Edwards Aquifer Conservation District Management Plan) (in gallons and acre-ft)

	Edwards (Balcones Fault Zone) Aquifer		Trinity Aquifers		Totals
	Freshwater Zones	Saline Zone	Middle Trinity	Lower Trinity	
Hays County					
2007	862,705,785	0	0	-	**862,705,785**
	2,648	0	0	-	**2,648**
2008	1,130,608,005	0	0	-	**1,130,608,005**
	3,470	0	0	-	**3,470**
2009	892,759,134	0	0	-	**892,759,134**
	2,740	0	0	-	**2,740**
2010	1,079,339,042	0	0	-	**1,079,339,042**
	3,312	0	0	-	**3,312**
2011	1,171,615,241	0	8,937,000	-	**1,180,552,241**
	3,596	0	27	-	**3,623**
Travis County					
2007	619,854,938	0	129,680	3,508,300	**623,492,918**
	1,902	0	0.4	11	**1,913**
2008	831,133,678	0	111,640	9,107,100	**840,352,418**
	2,551	0	0.3	28	**2,579**
2009	704,741,741	0	139,510	5,801,300	**710,682,551**
	2,163	0	0.4	18	**2,181**
2010	659,006,656	0	81,520	6,449,900	**665,538,076**
	2,022	0	0.3	20	**2,042**
2011	850,458,404	0	1,502,910	5,694,600	**857,655,914**
	2,610	0	5	17	**2,632**

6.1.2 DFC Considerations

The dominant use of the aquifer by pumping is public water supply, 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 this karst aquifer groundwater supply is drought, notably extreme drought that stresses the entire aquifer, but especially the western portion of the northern subdivision. Both DFCs support and are, in fact, linchpins of a drought management program to promote long-term sustainability of both springflow and water supplies. Additional firm-yield water supplies must be provided from other sources, while conditional-permitted withdrawals from the aquifer are only available on an interruptible basis.

The All Conditions DFC is expressly designed to postpone as long as possible permitted pumping curtailments that would be triggered by a District-declared drought. Postponement would be effected by delaying, to an acceptable degree, the elevation of a designation of drought from a non-drought designation that is attendant with pumping. The Extreme Drought DFC is designed to serve the mutual management objectives of: 1) preserving water supplies, especially in the more vulnerable western portions of the District and 2) minimizing the amount of take and avoiding jeopardy of the two endangered species that have the natural outlets of the aquifer as sole habitat. The DFC allows an amount of groundwater use that would produce a lower springflow than the historically low springflow during the 1950s drought of record, but still maintain acceptable minimum spring discharge levels.

6.2 Water-Supply Needs

6.2.1 Description of Factors in the Northern Subdivision, GMA 10

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). For estimating projected water supply needs (i.e., water demand vs. supply) the Barton Springs/Edwards Aquifer Conservation District used data extracted from the State Water Plan and provided by the TWDB. The TWDB provides water-supply needs estimates by decade as well as by county. The decadal estimates for 2020 are used to approximate demand for the year 2022, the final year of the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). A summary of the projected water-supply needs is provided in the Table 5 by decade in acre-ft/yr.

Table 5. Projected water-supply needs in the Barton Springs/Edwards Aquifer Conservation District for the State Water Plan planning period 2010-2060

	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Travis	-3,538	-11,053	-14,067	-18,134	-55,470	-92,045
Hays	-1,674	-5,738	-11,146	-18,871	-28,549	-36,273
Caldwell	-210	-892	-1,910	-3,054	-4,300	-5,694
Totals	**-5,422**	**-17,683**	**-27,123**	**-40,059**	**-88,319**	**-134,012**

The projections in Table 5 show that for the State Water Plan planning period (2010-2060), there is a progressively increasing water-supply deficit, increasing from 5,422 acre-ft in 2020 up to 134,012 acre-ft in 2060. These water-supply needs in the Barton Springs/Edwards Aquifer Conservation District arise primarily from and are dominated by the burgeoning growth on the southern fringe of the Austin metropolitan area, and also in the gradual diminution of the surface-water supplies, as reservoir capacity decreases with time. As in prior plans, some of the water-demand deficits in the Barton Springs/Edwards Aquifer Conservation District area in the out-years (the later years in the planning period) include numerous contractual shortages. These contractual shortages will be addressed on an *ad-hoc* basis, through the renewal and expansion of contracts with wholesale water suppliers and the contractual reallocation of existing supplies in order to address the projected water demands for these and other area water-user groups. But even so, it is projected that there will be unmet needs in the Barton Springs/Edwards Aquifer Conservation District, especially under drought-of-record conditions and in the out-years.

6.2.2 DFC Considerations

The population growth of the Austin-San Marcos metropolitan area is creating demand for additional water supplies from all sources, both within and outside of the northern subdivision. 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 Northern Subdivision, GMA 10

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013), the 2011 Regions K and L Water Planning Group Plans, and the 2012 State Water Plan, which relies on the Water Planning Group Plans.

Water management strategies for the northern subdivision included in the regional and state water plans are diverse, arising from the increasing deficit in supply relative to the burgeoning demand in the northern subdivision. Strategies include increased public/municipal water conservation, drought management, use/transfer of available or re-allocated surface water supplies, purchase of water from wholesale water providers, purchase of Carrizo-Wilcox water, development of the saline zone of the Edwards (Balcones Fault Zone) water, development of the Trinity Aquifer, Edwards/Middle Trinity aquifer storage and recovery, and saline Edwards aquifer storage and recovery. Perhaps even more on point here is that increased use of the fresh Edwards (Balcones Fault Zone) Aquifer water is not included as a strategy, as it is widely recognized as fully subscribed. None of the Water User Groups in the northern subdivision include allocation or transfer of their existing supplies.

6.3.2 DFC Considerations

The DFCs under consideration here are specific to the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of GMA 10. The saline portion of that aquifer has a different DFC and is the subject of a separate groundwater management zone, designed to promote utilization of the saline resource via desalination and/or as host for aquifer storage and recovery facilities. The All-Conditions DFC, by design, accommodates a certain amount of use for Aquifer Storage and Recovery (ASR) during non-drought periods. Both DFCs, 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. These curtailments in pumping also promote the use of alternative water supplies consistent with the water management strategies.

6.4 Hydrological Conditions

6.4.1 Description of Factors in Northern Subdivision, GMA 10

6.4.1.1 Total Estimated Recoverable Storage

Texas statute requires that the total estimated recoverable storage of relevant aquifers be determined (Texas Water Code § 36.108) 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.

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.

The total recoverable storage estimated for the Edwards (Balcones Fault Zone) Aquifer within the Barton Springs/Edwards Aquifer Conservation District in Groundwater Management Area 10 is listed in Table 6 (Jones et al., 2013). The total recoverable storage estimated for the Edwards (Balcones Fault Zone) Aquifer within Hays and Travis counties in GMA 10 is listed in Table 7 (Jones et al., 2013). The total recoverable storage estimated for Hays County includes groundwater in the San Antonio segment as well as the Barton Springs segment of the Edwards Aquifer, so not all of the water shown in Table 7 is in the northern subdivision of GMA 10.

Table 6. Total estimated recoverable storage for the Edwards (Balcones Fault Zone) Aquifer within Barton Springs/Edwards Aquifer Conservation District in Groundwater Management Area 10. Estimates are rounded within two significant numbers (Jones et al., 2013).

Total Storage (acre-ft)	25 percent of Total Storage (acre-ft)	75 percent of Total Storage (acre-ft)
130,000	32,500	97,500

Table 7. Total estimated recoverable storage for the Edwards (Balcones Fault Zone) Aquifer within Hays and Travis counties in Groundwater Management Area 10. Estimates are rounded within two significant numbers (Jones et al., 2013).

County	Total Storage (acre-ft)	25 percent of Total Storage (acre-ft)	75 percent of Total Storage (acre-ft)
Hays	200,000	50,000	150,000
Travis	69,000	17,250	51,750

6.4.1.2 Average Annual Recharge

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). For the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer, the long-term mean surface recharge should approximately equal the mean natural (i.e., with no well withdrawals) spring discharge, which is reported to be about 53 cfs at Barton Springs (Slade et al., 1986; Scanlon et al., 2001). Since the 1950s drought, the mean natural springflow at Barton Springs has been higher, about 62 cfs (Hunt et al., 2012; Johns, 2016). The distribution and volume of this recharge have been modeled multiple times. Scanlon et al. (2001) estimated average recharge at 55 cfs (39,844 acre-ft/yr) in the initial groundwater availability model of the Barton Springs segment for the TWDB. A later report by the TWDB, GAM Run 08-37 (Oliver, 2008), summarized the estimated amount of recharge from precipitation, the amount of spring discharge, and the amount of flow into and out of the Barton Springs/Edwards Aquifer Conservation District for steady-state conditions in 1989 (Table 8). As illustrated in Table 7, annual recharge from precipitation for the modeling was 42,858 acre-ft.

The majority (as much as 85 percent) of recharge to the aquifer is derived from streams originating on the contributing zone, located up gradient and to the west of the recharge zone. Water flowing onto the recharge zone sinks into numerous caves, sinkholes, and fractures along its six major, ephemeral losing streams. The remaining recharge (15 percent) occurs in the upland areas of the recharge zone (Slade et al., 1986). Current studies indicate that upland recharge may constitute a larger fraction (up to 30 percent) of recharge (Hauwert, 2009; Hauwert, 2011); Slade (2014) more recently calculated the upland recharge at 25 percent of the total. Studies have shown that recharge is highly variable in space and time and is focused within discrete features (Smith et al., 2011). For example, Onion Creek is the largest contributor of recharge (34 percent) with maximum recharge rates up to 160 cfs (Slade et al., 1986; Fieseler, 1998). Antioch Cave is located within Onion Creek and is the largest-capacity recharge feature with an average recharge of 46 cfs and a maximum of 95 cfs during one 100-day study (Fieseler, 1998). Recent work at Antioch Cave has also documented greater than 100 cfs of recharge entering the aquifer through the entrance to Antioch Cave (Smith et al., 2011). Dye-tracing studies have shown that some of this water flows directly and very rapidly to Barton Springs with an unknown percentage contributing to storage.

Table 8. Summarized information needed for the Barton Springs/Edwards Aquifer Conservation District's groundwater management plan. All values are reported in acre-ft/yr. All numbers are rounded to the nearest 1 acre-ft. Negative values indicate water is leaving the aquifer system using the parameters or boundaries listed in the table (Oliver, 2008).

Barton Springs/Edwards Aquifer Conservation District Management Plan Requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Edwards and associated limestones	42,858[a]
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards and associated limestones	-39,723
Estimated annual volume of flow into the district within each aquifer in the district	Edwards and associated limestones	3,191[b]
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards and associated limestones	-2,651[b]
Estimated net annual volume of flow between each aquifer in the district	Edwards into Trinity	0[c]

[a] Recharge value includes concentrated infiltration of water from stream channels. Scanlon and et al. (2001) estimated that approximately 15 percent of recharge in the model was due to diffuse inter-stream recharge, or direct infiltration of precipitation, which equates to approximately 6,429 acre-ft/yr.

[b] The orientation of the model cells and the political jurisdictional boundaries of the district do not align perfectly, therefore even though the district is larger than the model boundaries, some flow into and out of the district is reported due to the method of data extraction from the model.

[c] The Groundwater Availability Model (cite model) does not consider flow into or out of the Edwards (Balcones Fault Zone) Aquifer from other formations.

Groundwater divides delineate the boundaries of aquifer systems and influence not only the local aquifer hydrodynamics, but also the groundwater budget (recharge and discharge). The groundwater divide separating the San Antonio and Barton Springs segments of the Edwards (Balcones Fault Zone) Aquifer has historically been drawn along topographic or surface water divides between the Blanco River and Onion Creek in the recharge zone, and along potentiometric highs in the confined zone between the cities of Kyle and Buda in Hays County. Recent studies reveal that during wet conditions the groundwater divide is located generally along Onion Creek in the recharge zone, extending easterly along a potentiometric ridge between the cities of Kyle and Buda toward the saline-zone boundary (Hunt et al. 2006). During dry conditions, Hunt et al. (2006) posit that the hydrologic divide migrates south and is located along the Blanco River in the recharge zone, extending southeasterly to San Marcos Springs (Johnson et al., 2011). Thus, the groundwater divide is a hydrodynamic feature dependent upon the hydrologic conditions (wet versus dry) and the resulting hydraulic heads between Onion Creek and the Blanco River. Under extreme drought conditions, some groundwater flow from the west may bypass San Marcos Springs and continue toward Barton Springs (Land et al., 2011) and some surface water from the Blanco River may recharge the Barton Springs segment rather than the San Antonio segment (Smith et al., 2012).

6.4.1.3 Inflows

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). The amount of cross-formational inflow (subsurface recharge) occurring through adjacent aquifers into the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is unknown, although it is thought to be relatively small on the basis of water-budget analysis for surface recharge and discharge (Slade et al., 1985). Recent studies by the Barton Springs/Edwards Aquifer Conservation District and others have shown the potential for cross-formational flow both to and from the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. Sources of cross-formational flow are discussed below and include the saline-water zone, San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer, the Trinity Aquifer, and urban recharge.

Leakage from the saline-water zone into the freshwater zone is probably minimal, although leakage appears to influence water chemistry at Barton Springs during low-flow conditions (Senger and Kreitler, 1984; Slade et al., 1986). Recent studies indicate that the fresh-saline zone interface may be relatively stable over time (Lambert et al., 2010; Brakefield, 2015). On the basis of a geochemical evaluation, Hauwert et al. (2004) state that the saline-water zone contribution could be as high as 3 percent for Old Mill Spring and 0.5 percent for Main and Eliza Springs under low-flow conditions of 17cfs (combined) Barton Springs flow. These estimates were independently recalculated and corroborated by Johns (2006) and are similar to the results of Garner and Mahler (2007). Under normal flow conditions contribution from the saline-water zone would be smaller. Massei et al. (2007) noted that specific conductance of Barton Springs increased 20 percent under the 2000 drought condition, probably from saline-water zone contribution.

Subsurface flow into the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer from the adjacent San Antonio segment located to the southwest is limited when compared with surface recharge (Slade et al., 1985). Hauwert et al. (2004) indicated that flow across the southern boundary of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is probably insignificant under normal conditions. Recent studies have documented that the southern boundary of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is hydrodynamic in nature and fluctuates between Onion Creek and the Blanco River. Accordingly, groundwater from the recharge zone of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer is flowing into the Barton Springs segment during drought conditions (Smith et al,, 2012). Results of recent dye-trace studies indicate that under certain high-flow conditions water recharging along Onion Creek flows from the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer to San Marcos Springs (Hunt et al., 2006).Under moderate drought conditions, water recharged along the Blanco River can flow to both San Marcos and Barton springs (Smith et al., 2012). Under extreme drought conditions, it has been estimated that up to 5 cfs of groundwater flow bypasses (underflows) San Marcos Springs and flows toward Barton Springs (Land et al., 2011).

Changes in land use influence the inflows of aquifers systems. Recent studies have shown that urbanization may increase recharge to the Edwards (Balcones Fault Zone) Aquifer (Sharp, 2010;

Sharp et al., 2009). Sources of the increase in recharge include leaking infrastructure such as pressurized potable water lines, wastewater from both collector lines and septic tank drainfields, and stormwater in infiltration basins in the recharge zone. Recharge in urban environments is increased from the return flows of irrigation practices (e.g. lawn watering) and when impervious cover decreases evapotranspiration (Sharp, 2010; Sharp et al., 2009).

6.4.1.4 Discharge

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). The largest natural discharge point of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is Barton Springs, the fourth largest spring in Texas. Barton Springs consist of four major outlets: Main, Eliza, Old Mill, and Upper. Main Spring is the largest and discharges directly into Barton Springs Pool. Springflow at Barton Springs is determined and reported by the U.S. Geological Survey. Discharge reported for Barton Springs is based on a rating-curve correlation between water levels in the Barton Well (State Well Number 5842903) and physical flow measurements from Main, Eliza, and Old Mill. Flow from Upper Barton Springs, which is located about 400 feet upstream of the pool, is not included in the reported discharge, and bypasses the pool. Upper Barton Springs is characterized as an "overflow" spring and only flows when the total discharge at Barton Springs exceeds about 40 cfs (Hauwert et al., 2004).

Barton Springs has a long record of continuous discharge data beginning in 1917. Monthly mean data are available from 1917 to 1978 (Slade et al., 1986), and daily mean discharge data are available thereafter. The long-term average springflow at Barton Springs is 53 cfs based on data from 1917 to 1995 and is a widely reported value (Slade et al., 1986; Scanlon et al., 2001; Hauwert et al., 2004). More recent studies indicate that average springflows after the 1950s drought are higher, about 62 cfs (Hunt et al., 2012; Johns, 2016). The maximum and minimum measured discharges are 166 and 9.6 cfs, respectively. The lowest measured spring discharge value occurred on March 26, 1956 during the 1950s drought (Slade et al., 1986). Low-flow periods are defined as discharge below 35 cfs, moderate-flow conditions occur between 35 and 70 cfs, and high-flow conditions correspond to flows greater than 70 cfs (Hauwert et al., 2004). Mahler et al. (2006) define low flow as below 40 cfs. A peak in the daily average flow occurs in June following the average peak rainfall in May.

Barton Springs discharge is typical of a spring in a karst system that responds dynamically to recharge events and integrates conduit, fracture, and matrix flow. Springflow recessions and discharge rates are in large part determined by pre-existing conditions, the magnitude of recharge, and location of recharge. Massei et al. (2007) identify several source-water types contributing to the specific conductivity measured in Barton Springs. Sources include matrix, surface water, saline water, and other unidentified sources. Their relative contributions are dependent upon aquifer response to climatic and hydrologic conditions. Generally speaking; however, base springflow during periods of drought is sustained by the discharge of the matrix-flow system into the conduit system (White, 1988; Mahler et al., 2006).

The Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer contains other smaller springs. Cold Springs discharges directly into the Colorado River and is partially submerged by Lady Bird Lake. There are very few discharge data for Cold Springs, but its discharge is estimated to be about 5 percent of Barton Springs discharge (Scanlon et al., 2001). Similarly, Slade (2014) indicates the long-term average discharge of Cold Springs is about 5.5 cfs. A small spring named Rollingwood Spring, near Cold Springs, discharges into the Colorado River at a rate of about 0.02 to 0.06 cfs. Backdoor Spring is a small, perched spring located on Barton Creek and has discharge of about 0.02 cfs. Bee Springs is a small, perched spring and seep horizon discharging along Bee Creek and into Lake Austin and discharges about 0.2 to 0.6 cfs (Hauwert et al., 2004).

GAM Run 08-37 (Oliver, 2008) states that discharge from Barton and Cold springs was 39,723 acre-ft/yr (54.9 cfs) under steady-state conditions in 1989. The amount of water withdrawn from wells was 3,135 acre-ft (4.3 cfs) at that time (Table 7).

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

The discussion in this section is taken from the Barton Springs/Edwards Aquifer Conservation District Management Plan (Barton Springs/Edwards Aquifer Conservation District, 2013). The surface-water supply in the Barton Springs/Edwards Aquifer Conservation District is provided primarily by run-of-river diversions and especially by reservoirs in the Colorado River basin. The southeastern-most part of the Barton Springs/Edwards Aquifer Conservation District in Hays County and Caldwell County is supplied by the Guadalupe-Blanco River system, especially water from main-stem reservoirs like Canyon Lake. Most of this Guadalupe-Blanco water is conveyed to some users in the Barton Springs/Edwards Aquifer Conservation District by the Hays County Pipeline.

Projected water-supply data have been extracted from the 2012 State Water Plan database and provided by the TWDB at the county level. The projections are estimated using an apportioning multiplier derived from the ratio of the land area of Barton Springs/Edwards Aquifer Conservation District in the county relative to the entire county area. The apportioning multiplier was used for all water-user groups except for public-water supplies (i.e. municipalities, water supply corporations, and utility districts). The derivation of these apportioning multipliers is shown in Table 9.

Table 9. Areal distribution of Barton Springs/Edwards Aquifer Conservation District by County. Most of the Barton Springs/Edwards Aquifer Conservation District is in Travis and Hays Counties, in sub-equal amounts; the Barton Springs/Edwards Aquifer Conservation District comprises only a small part of any one county (Barton Springs/Edwards Aquifer Conservation District Management Plan) (acre-ft/yr).

County	Total Acres in County	Acres in District	Percent in Co.	Apportioning Multiplier
Travis	656,348	75,377	48%	11.5%
Hays	433,248	66,748	42%	15.4%
Caldwell	350,498	15,823	10%	4.5%
Totals	**1,440,094**	**157,948**	**100%**	**100%**

The total annual projected surface-water supply in the counties of the Barton Springs/Edwards Aquifer Conservation District is estimated to be 293,027acre-ft in 2020 (2020 is the closest decadal estimate to 2022, the final year of the Barton Springs/Edwards Aquifer Conservation District Management Plan). These supplies refer to the firm-yield supplies from surface-water sources during a recurrence of the drought of record. For comparison purposes, the projected surface-water supplies from the three primary counties comprising the Barton Springs/Edwards Aquifer Conservation District (Bastrop was excluded because its area has been de-annexed since the previous management plan was approved) are provided in Table 10 by decade in acre-ft.

Table 10. Projected annual surface-water supplies provided by county (Barton Springs/Edwards Aquifer Conservation District Management Plan) (acre-ft/yr)

	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Travis	287,687	286,132	277,118	263,891	254,337	244,503
Hays	4,120	4,680	4,680	4,680	4,680	4,680
Caldwell	195	195	195	195	195	195
Total	**294,012**	**293,027**	**284,023**	**270,806**	**261,262**	**251,438**

6.4.2 DFC Considerations

The DFCs are proposed on the basis that the aquifer is hydrologically a classic karst aquifer, with temporally variable inflows from various recharge sources and a major natural discharge point at Barton Springs that is also temporally variable with aquifer conditions. This hydrologic condition denotes that it is highly vulnerable to drought, and water supplies are substantially adversely affected by drought. Additionally, the geologic strata that form the aquifer dip regionally to the southeast, such that both the saturated thickness in the unconfined zone and the artesian pressure head in the confined zone are larger to the southeast. However, while faulted, the aquifer is well-integrated hydrologically and has a common potentiometric surface throughout the subdivision.

The springflow at Barton Springs is directly and essentially solely related to the elevation of the potentiometric surface, regardless of the different thickness and depth of groundwater that exists in various parts of the subdivision or other hydrologic conditions, except as they affect the potentiometric surface. So the proposed DFCs relate to the elevations of the potentiometric surface corresponding to two different conditions, regardless of the volumes of water in storage at any one location. The elevation of water near the drought/non-drought boundary combines with the geometric configuration of the aquifer host at that elevation and the rate of aquifer discharge, including the amount of pumping, to control the rate of acceleration into drought from non-drought conditions.

Preservation of a minimal springflow at Barton Springs and a related dissolved oxygen concentration that will sustain the endangered species at the spring outlets is mandated by federal law. The Extreme Drought DFC is expressly designed to provide that level of environmental and ecological protection.

7. Subsidence Impacts

Subsidence has historically not been an issue with the Edwards (Balcones Fault Zone) Aquifer in GMA10. 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. Similarly, when the aquifer recharges the same volume of water is able to be stored as existed before an equivalent volume was withdrawn. Hence, the proposed DFCs are not affected by and do not affect land-surface subsidence or compaction of any aquifer.

8. Socioeconomic Impacts Reasonably Expected to Occur

8.1 Description of Factors in Northern Subdivision, GMA 10

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process. The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs [§357.7 (4)]. 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) and also the Lower Colorado Regional Water Planning Group (Region K). 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 2011 South Central Texas Regional Water Plan and is illustrative of these types of analyses.

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 socioeconomic impact reports for Water Planning Groups K, L, and M are included in Appendix A. These reports are supportive of a cost-benefit assessment of the water management strategies and the socioeconomic impact of not promulgating those strategies.

The maintenance of the natural discharge of the Aquifer at iconic Barton Springs supports recreation and tourism that is a recognized socioeconomic engine for central Austin.

8.2 DFC Considerations

Because none of the water management strategies involve changes in the current use of the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of GMA 10, 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 Northern Subdivision, GMA 10

The interests and rights in private property, including ownership and the rights of GMA10 landowners and their lessees and assigns in groundwater, are recognized under Texas Water Code Section 36.002. The legislature recognized that a landowner owns the groundwater below the surface of the landowner's land as real property. Joint planning must take into account the impacts on those rights in the process of establishing DFCs, including the property rights of both existing and future groundwater users. Nothing should 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. At the same time, the law holds that no landowner is guaranteed a certain amount of such groundwater below the surface of his/her land.

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 and as ecological habitat for protected species. Neither DFC prevents 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 Barton Springs/Edwards Aquifer Conservation District to manage the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer to achieve the DFCs, including promulgating and enforcing rules and other board actions that support the DFCs. The feasibility of achieving this goal is limited by (1) the finite nature of the resource and how it responds to drought; (2) the pressures placed on this resource by the high level of economic and population growth within the area served by this resource; and (3) how the endangered species habitat at Barton Springs is protected in response to federal statute. Texas State law provides Groundwater Conservation Districts with the responsibility and authority to conserve, preserve, and protect these resources and to ensure for the recharge and prevention of waste of groundwater and control of subsidence in the management area; State law also provides that GMAs assist in that endeavor by joint regional planning that balances aquifer protection and highest practicable production of groundwater. The feasibility of achieving these goals could be altered if state law is revised or interpreted differently than is currently the case.

The caveats above notwithstanding, the current regulatory program of the Barton Springs/Edwards Aquifer Conservation District is designed to achieve the proposed DFCs, and there is no reason to consider that it is not feasible to achieve the DFCs.

11. Discussion of Other DFCs Considered

No other DFCof the fresh Edwards (Balcones Fault Zone) Aquifer in the GMA's northern subdivision was considered.

12. Discussion of Other Recommendations

12.1 Advisory Committees

An Advisory Committee for GMA10 has not been established.

12.2 Public Comments

GMA 10 approved its proposed DFCs on March 14, 2016. 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 11. Public comments for GMA 10 are included in Appendix B.

Table 11. Dates on which each GCD held a public meeting allowing for stakeholder input on the DFCs

GCD	Date
Barton Springs/Edwards Aquifer Conservation District	May 26, 2016
Comal Trinity GCD	May 16, 2016
Edwards Aquifer Authority	May 10, 2016
Kinney County GCD	May 12, 2016
Medina County GCD	May 18, 2016
Plum Creek Conservation District	May 17, 2016
Uvalde County UWCD	April 10, 2016

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 specifically addressed one or both of the DFCs for the Freshwater Edwards Aquifer in GMA 10's Northern Subdivision, or were reasonably inferred to address such a DFC. 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. Comments and assessments related to the Northern Subdivision's Freshwater Edwards Aquifer DFCs are summarized below.

Generally, the recommendations or suggestions made in public comments that were specifically directed to the Northern Freshwater Edwards Aquifer relate to the appropriateness of the amount of the minimum springflow under its Extreme Drought DFC. The GMA 10 responses to Comments #19 - 26 in Appendix B provide the rationale for utilizing the selected springflow as an Extreme Drought DFC for this aquifer, rather than an alternative amount. In summary:

- This karst aquifer may naturally experience extreme high and low volumes of water in storage within a relatively short period of time, including a recurrence of a DOR at essentially any time;
- The best science now available does not establish a firm threshold amount of springflow at which the endangered species at the discharge locations of the aquifer will encounter conditions that would prevent survival or recovery of the species;
- The current Extreme Drought DFC has been established as a balance between aquifer protection (and habitat quality) and groundwater production (and supported uses);
- The proposed DFCs for this aquifer are a critical habitat conservation measure in a proposed BSEACD Habitat Conservation Plan and Incidental Take Permit from the US Fish and Wildlife Service that are intended to minimize and mitigate ecological "take" of endangered species incidental to lawful groundwater withdrawals;
- Current levels of permitted groundwater production from this aquifer are based on reasonable, conservation-oriented, non-speculative demand, and temporary curtailments during drought; and
- No GCD, including BSEACD under its HCP, can compel its permittees to switch to alternative supplies beyond that required to meet the applicable curtailments specified in their permits, even if such supplies are available.

The above notwithstanding, one commenter recommended the following as an alternate DFC for Extreme Drought Conditions (Comment #26):

> "The primary Desired Future Condition for Year 2065 for the freshwater portion of the Barton Springs Edwards Aquifer shall be to maintain Barton Springs flows at or above 10 cubic feet per second on a monthly average during a recurrence of the drought of record, and to make progress toward this Desired Future Condition by immediate and near-term District regulatory and non-regulatory actions designed to maintain Barton Springs flows at or above 7.5 cfs on a monthly average during a recurrence of the drought of record."

As noted in the GMA-10 responses to this comment and to others for this aquifer, the extreme curtailments necessary to achieve this goal are not practical or reasonable, because:

- the current realities of water supply and demand faced by permittees, especially after extreme drought management measures have been implemented, limit the feasibility of such extreme measures, at this time;

- DFCs for this drought-prone karst aquifer must be achievable immediately and at any time during the term of the joint groundwater planning period, not at some time in the future;
- the currently proposed DFCs and the drought management regulations that implement them require the most stringent degree of curtailment currently achievable, regardless of how they might be revised under some stretch goal in the future; and
- the efficacy of more stringent DFCs in the future will be determined by changes in the then-prevailing infrastructural, technological, legal, regulatory, and political environments that are largely beyond the control of GMA 10 and its member GCDs; these may be more appropriately accommodated in subsequent rounds of joint groundwater planning.

In addition to those comments specifically directed to the Northern Freshwater Edwards Aquifer DFCs, a number of commenters also questioned or proposed changes to the purpose, scope, schedule, and/or basis of essentially all GMA-10 DFCs, including the Northern Freshwater Edwards Aquifer DFCs (see Comments #3, 5, 6, 7, 8, 17, and 18; and the more general comments of #27-33). GMA 10's responses to these comments in Appendix B reinforce the fact that statutes and regulations constrain the actions and outputs of any GMA, including GMA 10, in these matters.

13. Any Other Information Relevant to the Specific DFCs

As the down-dip Trinity Aquifer is increasingly used as a water supply in GMA 10 in lieu of the more restricted Edwards (Balcones Fault Zone) Aquifer, additional information on how its groundwater relates to the Edwards (Balcones Fault Zone) Aquifer is being elucidated. This new information may ultimately change what DFC for the northern subdivision of the fresh Edwards is and isn't feasible, and therefore what MAG is consistent with that DFC.

In the northern subdivision of GMA 10, there is no evidence that the Edwards and the Middle Trinity (and by inference, the Lower Trinity) aquifers are significantly hydrologically connected (Wong et al., 2014). So pumpage from one is not likely to appreciably affect the water available in the other. On the other hand, there is a demonstrable hydrologic connection between the Upper Trinity Aquifer and the Edwards Aquifer where the Upper Trinity Aquifer underlies the Edwards Aquifer; in fact, from a hydrostratigraphic standpoint, the top 100 feet or so of the Upper Glen Rose (i.e., traditionally, the uppermost Upper Trinity Aquifer) is more correctly considered part of the Edwards Aquifer (Wong et al., 2014). Pumping in the Edwards Aquifer near its western boundary can induce flow from the Upper Trinity Aquifer, and that induced water flow may be of considerably poorer quality that could affect the existing use of the Edwards Aquifer wells.

In addition, as noted earlier, the Blanco River, which has base flow largely determined by discharges from the Middle and Upper Trinity Aquifers, now appears to be a substantial source for part of the springflows at Barton Springs during extreme drought conditions. Increased pumping of the Trinity Aquifer, especially the Middle Trinity Aquifer, in the watersheds above the recharge zone of the Edwards Aquifer may reduce the amount of recharge available to the Edwards Aquifer and therefore the springflows at Barton Springs during extreme droughts (Hunt et al., 2012). While this pumping would occur in GMA 9, its adverse impacts would be felt in the northern subdivision of GMA 10.

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

The TWDB has not developed guidance on how to approach this factor. It is up to the wishes of the GCDs on how they wish to approach it, whether in a qualitative, quantitative, or combination manner. But, the GCDs need to include stakeholder input so that this factor can be satisfactorily addressed. GCD management plans will be used to complete this requirement.

That said, it is relevant here that Barton Springs/Edwards Aquifer Conservation District has established a conditional permitting program that promotes responsible use of the resources of this particular aquifer while the necessary restrictions during extreme drought conditions can continue to be effective. The Extreme Drought DFC, among other things, will become a specified part of the District's planned response to comply with federal law concerning endangered species once the now-pending federal Incidental Take Permit has been received, which will allow a curtailed amount of pumping to take place even during extreme drought. And in addition, the primary objective of the All Conditions DFC is to delay the onset of conditions triggering district-declared drought and minimize the length of time that all Barton Springs/Edwards Aquifer Conservation District permittees are required to curtail all or part of their authorized groundwater use during drought.

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.

15. References

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Appendix A

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

Prepared in Support of the 2016 Region K Regional Water Plan

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Executive Summary

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

Based on projected water demands and existing water supplies, the Region K planning group identified water needs (potential shortages) that would occur within its region under a repeat of the drought of record for six water use categories. The TWDB then estimated the socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

The analysis was performed using an economic 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 during a drought of record within each of the planning decades. For each water use category, the evaluation focused on estimating income losses and job losses. 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 were estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

It is estimated that not meeting the identified water needs in Region K would result in an annually combined lost income impact of approximately $1.6 billion in 2020, increasing to $3.6 billion in 2070 (Table ES-1). In 2020, the region would lose approximately 9,900 jobs, and by 2070 job losses would increase to approximately 45,000.

All impact estimates are in year 2013 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from the TWDB annual water use estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and Texas Municipal League.

Table ES-1: Region K Socioeconomic Impact Summary

Regional Economic Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Income losses ($ millions)*	$1,560	1,557	1,233	1,093	1,975	3,568
Job losses	9,877	11,880	10,414	11,894	24,187	45,282
Financial Transfer Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Tax losses on production and imports ($ millions)*	$236	$217	$160	$113	$145	$248
Water trucking costs ($ millions)* -	$3	$4	$4	$2	$6	
Utility revenue losses ($ millions)*	$23	$84	$138	$205	$339	$592
Utility tax revenue losses ($ millions)*	$0	$1	$2	$3	$6	$10
Social Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Consumer surplus losses ($ millions)*	$1	$29	$51	$105	$194	$347
Population losses	1,813	2,181	1,912	2,184	4,441	8,314
School enrollment losses	335	403	354	404	822	1,538

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

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 existing businesses and industry, 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.

Administrative rules (31 Texas Administrative Code §357.33 (c)) require that regional water planning groups evaluate the social and economic impacts of not meeting water needs as part of the regional water planning process, and rules direct the TWDB staff to provide technical assistance upon request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of the Region K Regional Water Planning Group.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 summarizes the water needs calculation performed by the TWDB based on the regional water planning group's data. Section 2 describes the methodology for the impact assessment and discusses approaches and assumptions specific to each water use category (i.e., irrigation, livestock, mining, steam-electric, municipal and manufacturing). Section 3 presents the results for each water use category with results summarized for the region as a whole. The appendix presents details on the socioeconomic impacts by county.

1.1 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for each water user group (WUG) with input from the planning groups. WUGs are composed of cities, utilities, combined rural areas (designated as county-other), and the county-wide water use of irrigation, livestock, manufacturing, mining and steam-electric power. The demands are then compared to the existing water supplies of each WUG to determine potential shortages, or needs, by decade. Existing water supplies are legally and physically accessible for immediate use in the event of drought. Projected water demands and existing supplies are compared to identify either a surplus or a need for each WUG.

Table 1-1 summarizes the region's identified water needs in the event of a repeat of drought of the 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 meet 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 and economic growth. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are presented in aggregate in Table 1-1. Projected needs for individual water user groups within the aggregate vary greatly, and may reach 100% for a given WUG and water use category. Detailed water needs by WUG and county appear in Chapter 4 of the 2016 Region K Regional Water Plan.

Table 1-1 Regional Water Needs Summary by Water Use Category

Water Use Category		2020	2030	2040	2050	2060	2070
Irrigation	Water Needs (acre-feet per year)	335,489	319,584	304,106	289,044	274,387	260,124
	% of the category's total water demand						
Livestock	Water Needs (acre-feet per year)	55%	54%	53%	52%	50%	49%
	% of the category's total water demand	570	692	810	913	1,059	1,216
Manufacturing	Water Needs (acre-feet per year)	1%	1%	1%	1%	1%	1%
	% of the category's total water demand	4,260	8,618	9,747	10,719	12,153	14,164
Mining	Water Needs (acre-feet per year)	20%	33%	35%	36%	38%	41%
	% of the category's total water demand	7,389	27,362	45,011	66,372	118,804	180,979
Municipal	Water Needs (acre-feet per year)	2%	8%	11%	14%	24%	32%
	% of the category's total water demand	25,363	26,751	26,775	31,974	42,212	54,627
Steam-electric power	Water Needs (acre-feet per year)	14%	14%	14%	16%	21%	26%
	% of the category's total water demand	373,071	383,007	386,449	399,022	448,615	511,110
Total water needs (acre-feet per year)		373,071	383,007	386,449	399,022	448,615	511,110

2 Economic Impact Assessment Methodology Summary

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 (volume), and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts were based on the overall composition of the economy using many underlying economic "sectors." Sectors in this analysis refer to one or more of the 440 specific production sectors of the economy designated within IMPLAN (Impact for Planning Analysis), the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 310 of those sectors, with the focus on the more water intense production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple related economic sectors.

2.1 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic impacts of shortages due to a drought of record. Consistent with previous water plans, several key variables 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 GDP made by an individual producer, industry, sector, or group of sectors within a year. For a shortage, value added is a measure of the income losses to the region, county, or WUG and includes 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.
Financial Transfer Impacts	**Description**
Tax losses on production and imports	Sales and excise taxes (not collected due to the shortage), customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies.
Water trucking costs	Estimate for shipping potable water.
Utility revenue losses	Foregone utility income due to not selling as much water.
Social Impacts	**Description**
Description	A welfare measure of the lost value to consumers accompanying less water use.
Population losses	A welfare measure of the lost value to consumers accompanying less water use.
School enrollment losses	School enrollment losses (K-12) accompanying job losses.

2.1.1 Regional Economic Impacts

Two key measures were included within the regional economic impacts classification: income losses and job losses. Income losses presented consist of the sum of value added losses and additional purchase costs of electrical power. Job losses are also presented as a primary economic impact measure.

Income Losses - Value Added Losses

Value added is the value of total output less the value of the intermediate inputs also used in production of the final product. Value added is similar to Gross Domestic Product (GDP), a familiar measure of the productivity of an economy. The loss of value added due to water shortages was estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region.

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 were represented in this analysis by the additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employed additional power purchase costs as a proxy for the value added impacts for that water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it was 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 from the recent drought period in 2011.

Job Losses

The number of jobs lost due to the economic impact was estimated using IMPLAN output associated with the water use categories noted in Table 1-1. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates were not calculated for the steam-electric power production or for certain municipal water use categories.

2.1.2 Financial Transfer Impacts

Several of the impact measures estimated within the analysis are presented as supplemental information, providing additional detail concerning potential impacts on a sub-portion of the economy or government. Measures included in this category 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. Many of 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 was used to estimate reduced tax collections associated with the reduced output in the economy.

Water Trucking Costs

In instances where water shortages for a municipal water user group were estimated to be 80 percent or more of water demands, it was assumed that water would be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed cost of $20,000 per acre-foot of water was calculated and presented as an economic cost. This water trucking cost was applied for both the residential and non-residential portions of municipal water needs and only impacted a small number of WUGs statewide.

Utility Revenue Losses

Lost utility income was calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates resulted from city-specific pricing data for both water and wastewater. These water rates were applied to the potential water shortage to determine estimates of lost utility revenue as water providers sold less water during the drought due to restricted supplies.

Utility Tax Losses

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

2.1.3 Social Impacts

Consumer Surplus Losses of 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 the 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. However, consumer's access to that water may be limited, and the associated consumer surplus loss is an estimate of the equivalent monetary value of the negative impact to the consumer's wellbeing, for example, associated with a diminished quality of their landscape (i.e., outdoor use). Lost consumer surplus estimates for reduced outdoor and indoor use, as well as residential and commercial/institutional demands, were included in this analysis. Consumer surplus is an attempt to measure effects on wellbeing by monetizing those effects; therefore, these values should not be added to the other monetary impacts estimated in the analysis.

Lost consumer surplus estimates varied widely by location and type. For a 50 percent shortage, the estimated statewide consumer surplus values ranged from $55 to $2,500 per household (residential use), and from $270 to $17,400 per firm (non-residential).

Population and School Enrollment Losses

Population losses due to water shortages, as well as the related loss of school enrollment, were based upon the job loss estimates and upon a recent study of job layoffs and the resulting adjustment of the labor market, including the change in population.1 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 an estimate of the change in the population as the result of a job layoff event. Layoffs impact both out-migration, as well as in-migration into an area, both of which can negatively affect the population of an area. In addition, the study found that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county. Based on this study, a simplified ratio of job and net population losses was calculated for the state as a whole: for every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses were estimated as a proportion of the population lost.

2.2 Analysis Context

The context of the economic impact analysis involves situations where there are physical shortages of surface or groundwater due to drought of record conditions. Anticipated shortages 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.

2.2.1 IMPLAN Model and Data

Input-Output analysis using the IMPLAN (Impact for Planning Analysis) software package was the primary means of estimating value added, jobs, and taxes. This analysis employed county and regional level models to determine key 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 2011 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 440 sector specific Industry Codes, and those that rely on water as a primary input were assigned to their relevant planning water user categories (manufacturing, mining, irrigation, etc.). 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. Similar calculations were performed for the job and tax losses on production and import impact estimates. Note that the value added estimates, as well as the job and tax estimates from PLAN, 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.

2.2.2 Elasticity of Economic Impacts

The economic impact of a water need is based on the relative size of the water need to the water demand for each water user group (Figure 2-1). Smaller water shortages, for example, less than 5 percent, were 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 deepens, 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 such ability to adjust, an elasticity adjustment function was used in estimating impacts for several of the measures. Figure 2-1 illustrates the general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage percentage reaches the lower bound b1 (10 percent in Figure 2-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound for adjustment reaches the b2 level shortage (50 percent in Figure 2-1 example).

Initially, the combined total value of the three value added components (direct, indirect, and induced) was calculated and then converted into a per acre-foot economic value based on historical TWDB water use estimates within each particular water use category. As an example, if the total, annual value added for livestock in the region was $2 million and the reported annual volume of water used in that industry was 10,000 acre-feet, the estimated economic value per acre-foot of water shortage would be $200 per acre-foot. Negative economic impacts of shortages were then estimated using this value as the maximum impact estimate ($200 per acre-foot in the example) applied to the anticipated shortage volume in acre-feet and adjusted by the economic impact elasticity function. This adjustment varied with the severity as percentage of water demand of the anticipated shortage. If one employed the sample elasticity function shown in Figure 2-1, a 30% shortage in the water use category would imply an economic impact estimate of 50% of the original $200 per acre-foot impact value (i.e., $100 per acre-foot).

Such adjustments were not required in estimating consumer surplus, nor for the estimates of utility revenue losses or utility tax losses. Estimates of lost consumer surplus relied on city-specific demand curves with the specific lost consumer surplus estimate calculated based on the relative percentage of the city's water shortage. Estimated changes in population as well as changes in school enrollment were indirectly related to the elasticity of job losses.

Assumed values for the bounds b1 and b2 varied with water use category under examination and are presented in Table 2-2.

Figure 2-1 Example Economic Impact Elasticity Function (as applied to a single water user's shortage)

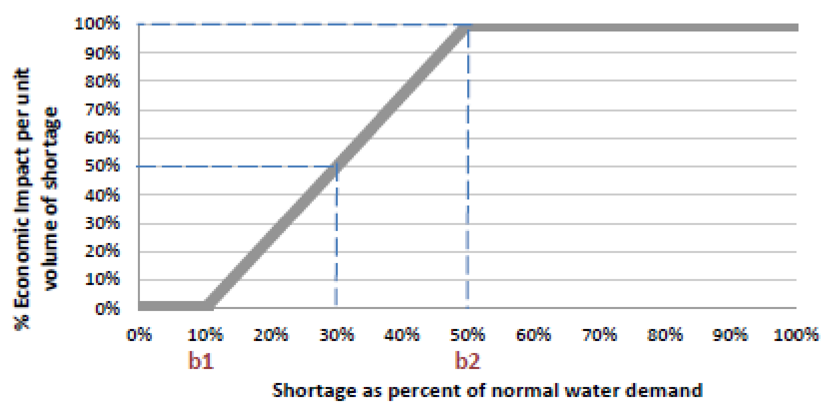

Table 2-2 Economic Impact Elasticity Function Lower and Upper Bounds

Water Use Category	Lower Bound (b1)	Upper Bound (b2)
Irrigation	**5%**	**50%**
Livestock	**5%**	**10%**
Manufacturing	**10%**	**50%**
Mining	**10%**	**50%**
Municipal (non-residential water intensive)	**50%**	**80%**
Steam-electric power	**20%**	**70%**

2.3 Analysis Assumptions and Limitations

Modeling of complex systems requires making assumptions and accepting limitations. This is particularly true when attempting to estimate a wide variety of economic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of the methodology include:

1. The foundation for estimating socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified as part of the regional water planning process. These needs have some uncertainty associated with them, but serve as a reasonable basis for evaluating potential economic impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshot estimates of impacts 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 severe drought conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs, future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented were not cumulative (i.e., summing up expected impacts from today up to the decade noted), but were simply an estimate of the magnitude of annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated 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, supplies of limited resources, and other structural changes to the economy that may occur into the future. This 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 analysis is not a 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 procedures to weigh future costs differently through time.

5. Monetary figures are reported in constant year 2013 dollars.

6. Impacts are annual estimates. The estimated economic model 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.

7. 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 categories (value added and consumer surplus) are both valid impacts but should not be summed.

8. The value added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects described in Section 2.2.1. 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.

9. The majority of impacts estimated in this analysis may be considered smaller than those that might occur under drought of record conditions. 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 these types of economic impact modeling efforts, 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, which is one reason why the impact estimates are likely conservative.

10. The methodology did not capture “spillover” effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

11. The model did 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 the landscaping industry immediately following a drought;
b. The cost and years to rebuild liquidated livestock herds (a major capital item 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 accurately 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.

3 Analysis Results

This section presents a breakdown of the results of the regional analysis for Region K. Projected economic impacts for six water use categories (irrigation, livestock. municipal, manufacturing, mining, and steam-electric power) are also reported by decade.

3.1 Overview of the Regional Economy

Table 3-1 presents the 2011 economic baseline as represented by the IMPLAN model and adjusted to 2013 dollars for Region K. In year 2011, Region K generated about $88 billion in gross state product associated with 975,000 jobs based on the 2011 IMPLAN data. These values represent an approximation of the current regional economy for a reference point.

Table 3-1 Region K Economy

Income ($ millions)*	Jobs	Taxes on production and imports ($ millions)*
$88,344	**975,269**	**$6,335**

[1]Year 2013 dollars based on 2011 IMPLAN model value added estimates for the region.

The remainder of Section 3 presents estimates of potential economic impacts for each water use category 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.

3.2 Impacts for Irrigation Water Shortages

Four of the 14 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 3-2. 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. Two factors led to excluding any reported tax impacts: 1) Federal support (subsidies) has lessened greatly since the year 2011 IMPLAN data was collected, and 2) It was not considered realistic to report increasing tax revenue collections for a drought of record.

Table 3-2 Impacts of Water Shortages on Irrigation in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$56	$52	$49	$46	$43	$40
Job losses	1,338	1,258	1,181	1,108	1,039	974

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.3 Impacts for Livestock Water Shortages

None of the 14 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 3-3. Note that tax impacts are not reported for this water use category for similar reasons that apply to the irrigation water use category described above.

Table 3-3 Impacts of Water Shortages on Livestock in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	-	-	-	-	-	-
Job losses	-	-	-	-	-	-

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000***

3.4 Impacts for Municipal Water Shortages

Eleven of the 14 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 the two subtypes of use within municipal use: residential, and non-residential. The latter includes commercial and institutional users. Consumer surplus measures were made for both residential and nonresidential demands. In addition, available data for the non-residential, water-intensive portion of municipal demand allowed use of IMPLAN and TWDB Water Use Survey data to estimate income loss, jobs, and taxes. Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed cost of $20,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 3-4.

Table 3-4 Impacts of Water Shortages on Municipal Water Users in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$1	$152	$175	$376	$1,135	$2,325
Job losses	21	2,634	3,074	6,604	19,795	40,435
Tax losses on production and imports[1] ($ millions)*	$0	$12	$14	$30	$92	$187
Consumer surplus losses ($ millions)*	$1		$51	$105	$194	$347
Trucking costs ($ millions)*	-	$3	$4	$4	$2	$6
Utility revenue losses ($ millions)*	$23	$84	$138	$205	$339	$592
Utility tax revenue losses ($ millions)*	$0	$1	$2	$3	$6	$10

[1] Estimates apply to the water-intensive portion of non-residential municipal water use.
**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by azero ($0) indicate income losses less than $500,000.***

3.5 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in 3 of the 14 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 3-5.

Table 3-5 Impacts of Water Shortages on Manufacturing in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$35	$35	$70	$88	$106	$126
Job losses	390	575	788	985	1,165	1,365
Tax losses on production and imports ($ millions)*	$4	$6	$8	$10	$13	$16

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.6 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in 4 of the 14 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use type appear in Table 3-6.

Table 3-6 Impacts of Water Shortages on Mining in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$1,403	$1,236	$872	$485	$299	$342
Job losses	8,128	7,414	5,371	3,196	2,187	2,508
Tax losses on production and imports ($ millions)*	$230	$197	$136	$71	$39	$44

***** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.7 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in 4 of the 14 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 3-7.

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

- Are reflected as an income loss proxy in the form of the estimated additional purchasing costs for power from the electrical grid 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.
- Does 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 3-7 Impacts of Water Shortages on Steam-Electric Power in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$63	$66	$66	$98	$392	$736

***** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.8 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 3-8.

Table 3-8 Region-wide Social Impacts of Water Shortages in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Consumer surplus losses ($ millions)*	$1	$29	$51	$105	$194	$347
Population losses	1,813	2,181	1,912	2,184	4,441	8,314
School enrollment losses	335	403	354	404	822	1,538

***** Year 2013 dollars, rounded. Entries denoted by a dash***

Appendix - County Level Summary of Estimated Economic Impacts for Region K

County level summary of estimated economic impacts of not meeting identified water needs by water use category and decade (in 2013 dollars, rounded). Values presented only for counties with projected economic impacts for at least one decade.

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

		Income Losses (Millions $)*						**Job Losses**						**Consumer Surplus (Millions $)***					
County	Water Use Category	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Hays	Mining	3	4	6	6	$7	$8	29	42	57	62	74	87	-	-	-	-	-	-
Hays	Municipal	-	-	-	44	$214	$557	-	-	-	771	3,705	9,655	-	$0	$1	$7	$22	$52
Hays Total		$3	$4	$6	$50	$221	$565	29	42	57	833	3,779	9,741	-	$0	$1	$7	$22	$52
Travis	Municipal	-	$149	$173	$256	$469	$702	-	2,589	3,041	4,531	8,242	12,299	$0	$27	$44	$83	$126	$170
Travis	Steam Electric Power	-	-	-	$32	$325	$668	-	-	-	-	-	-	-	-	-	-	-	-
Travis Total		-	$149	$173	$288	$794	$1,370	-	2,589	3,041	4,531	8,242	12,299	$0	$27	$44	$83	$126	$170

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

Prepared in Support of the 2016 Region L Regional Water Plan

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Executive Summary

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

Based on projected water demands and existing water supplies, the Region L planning group identified water needs (potential shortages) that would occur within its region under a repeat of the drought of record for six water use categories. The TWDB then estimated the socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

The analysis was performed using an economic 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 during a drought of record within each of the planning decades. For each water use category, the evaluation focused on estimating income losses and job losses. 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 were estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

It is estimated that not meeting the identified water needs in Region L would result in an annually combined lost income impact of approximately $62 million in 2020, increasing to $71 million in 2070 (Table ES-1). In 2020, the region would lose approximately 1,400 jobs, and by 2070 job losses would increase to approximately 1,600.

All impact estimates are in year 2013 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from the TWDB annual water use estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and Texas Municipal League.

Table ES-1: Region L Socioeconomic Impact Summary

Regional Economic Impacts	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$1,990	$2,928	$3,320	$3,841	$4,633	$5,911
Job losses	18,277	20,809	23,550	25,559	30,450	50,102
Financial Transfer Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Tax losses on production and imports ($ millions)*	$175	$187	$193	$182	$192	$290
Water trucking costs ($ millions)* -	$0	$0	$0	$1	$1	$3
Utility revenue losses ($ millions)*	$210	$304	$418	$537	$625	$809
Utility tax revenue losses ($ millions)*	$4	$6	$8	$10	$12	$15
Social Impacts	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Consumer surplus losses ($ millions)*	$29	$58	$108	$171	$264	$403
Population losses	3,356	3,821	4,324	4,693	5,591	9,199
School enrollment losses	621	707	800	868	1.034	1,702

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate 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 existing businesses and industry, 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.

Administrative rules (31 Texas Administrative Code §357.33 (c)) require that regional water planning groups evaluate the social and economic impacts of not meeting water needs as part of the regional water planning process, and rules direct the TWDB staff to provide technical assistance upon request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of the Region L Regional Water Planning Group.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 summarizes the water needs calculation performed by the TWDB based on the regional water planning group's data. Section 2 describes the methodology for the impact assessment and discusses approaches and assumptions specific to each water use category (i.e., irrigation, livestock, mining, steam-electric, municipal and manufacturing). Section 3 presents the results for each water use category with results summarized for the region as a whole. The appendix presents details on the socioeconomic impacts by county.

2.1 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for each water user group (WUG) with input from the planning groups. WUGs are composed of cities, utilities, combined rural areas (designated as county-other), and the county-wide water use of irrigation, livestock, manufacturing, mining and steam-electric power. The demands are then compared to the existing water supplies of each WUG to determine potential shortages, or needs, by decade. Existing water supplies are legally and physically accessible for immediate use in the event of drought. Projected water demands and existing supplies are compared to identify either a surplus or a need for each WUG.

Table 1-1 summarizes the region's identified water needs in the event of a repeat of drought of the 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 meet 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 and economic growth. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are presented in aggregate in Table 1-1. Projected needs for individual water user groups within the aggregate vary greatly, and may reach 100% for a given WUG and water use category. Detailed water needs by WUG and county appear in Chapter 4 of the 2016 Region L Regional Water Plan.

Table 1-1 Regional Water Needs Summary by Water Use Category

Water Use Category		2020	2030	2040	2050	2060	2070
Irrigation	Water Needs (acre-feet per year)	105,799	$97,325	$89,057	$81,302	$73,968	$67,383
	% of the category's total water demand	31%	0	0	0	0	0
Livestock	Water Needs (acre-feet per year)	-	-	-	-	-	-
	% of the category's total water demand	-	-	-	-	-	-
Manufacturing	Water Needs (acre-feet per year)	6,616	$10,213	$13,778	$19,265	$29,210	$40,376
	% of the category's total water demand	5%	8%	9%	12%	17%	23%
Mining	Water Needs (acre-feet per year)	10,822	$10,481	$8,694	$5,147	$2,073	$666
	% of the category's total water demand	22%	0	0	0	0	0
Municipal	Water Needs (acre-feet per year)	86,856	124,059	$168,754	$215,946	$268,513	$322,831
	% of the category's total water demand	19%	24%	29%	34%	39%	43%
Steam-electric power	Water Needs (acre-feet per year)	4,506	29,778	37,178	53,599	70,696	70,696
	% of the category's total water demand	8%	33%	37%	44%	48%	46%
Total water needs (acre-feet per year)		**3,857**	**214,599**	**271,856**	**317,461**	**375,259**	**444,460**

3 Economic Impact Assessment Methodology Summary

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 (volume), and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts were based on the overall composition of the economy using many underlying economic "sectors." Sectors in this analysis refer to one or more of the 440 specific production sectors of the economy designated within IMPLAN (Impact for Planning Analysis), the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 310 of those sectors, with the focus on the more water intense production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple related economic sectors.

2.1 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic impacts of shortages due to a drought of record. Consistent with previous water plans, several key variables 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 GDP made by an individual producer, industry, sector, or group of sectors within a year. For a shortage, value added is a measure of the income losses to the region, county, or WUG and includes 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.
Financial Transfer Impacts	**Description**
Tax losses on production and imports	Sales and excise taxes (not collected due to the shortage), customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies.
Water trucking costs	Estimate for shipping potable water.
Utility revenue losses	Foregone utility income due to not selling as much water.
Social Impacts	**Description**
Description	A welfare measure of the lost value to consumers accompanying less water use.
Population losses	A welfare measure of the lost value to consumers accompanying less water use.
School enrollment losses	School enrollment losses (K-12) accompanying job losses.

2.1.1 Regional Economic Impacts

Two key measures were included within the regional economic impacts classification: income losses and job losses. Income losses presented consist of the sum of value added losses and additional purchase costs of electrical power. Job losses are also presented as a primary economic impact measure.

Income Losses - Value Added Losses

Value added is the value of total output less the value of the intermediate inputs also used in production of the final product. Value added is similar to Gross Domestic Product (GDP), a familiar measure of the productivity of an economy. The loss of value added due to water shortages was estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region.

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 were represented in this analysis by the additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employed additional power purchase costs as a proxy for the value added impacts for that water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it was 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 from the recent drought period in 2011.

Job Losses

The number of jobs lost due to the economic impact was estimated using IMPLAN output associated with the water use categories noted in Table 1-1. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates were not calculated for the steam-electric power production or for certain municipal water use categories.

2.1.2 Financial Transfer Impacts

Several of the impact measures estimated within the analysis are presented as supplemental information, providing additional detail concerning potential impacts on a sub-portion of the economy or government. Measures included in this category 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. Many of 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 was used to estimate reduced tax collections associated with the reduced output in the economy.

Water Trucking Costs

In instances where water shortages for a municipal water user group were estimated to be 80 percent or more of water demands, it was assumed that water would be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed cost of $20,000 per acre-foot of water was calculated and presented as an economic cost. This water trucking cost was applied for both the residential and non-residential portions of municipal water needs and only impacted a small number of WUGs statewide.

Utility Revenue Losses

Lost utility income was calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates resulted from city-specific pricing data for both water and wastewater. These water rates were applied to the potential water shortage to determine estimates of lost utility revenue as water providers sold less water during the drought due to restricted supplies.

Utility Tax Losses

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

2.1.3 Social Impacts

Consumer Surplus Losses of 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 the 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. However, consumer's access to that water may be limited, and the associated consumer surplus loss is an estimate of the equivalent monetary value of the negative impact to the consumer's wellbeing, for example, associated with a diminished quality of their landscape (i.e., outdoor use). Lost consumer surplus estimates for reduced outdoor and indoor use, as well as residential and commercial/institutional demands, were included in this analysis. Consumer surplus is an attempt to measure effects on wellbeing by monetizing those effects; therefore, these values should not be added to the other monetary impacts estimated in the analysis.

Lost consumer surplus estimates varied widely by location and type. For a 50 percent shortage, the estimated statewide consumer surplus values ranged from $55 to $2,500 per household (residential use), and from $270 to $17,400 per firm (non-residential).

Population and School Enrollment Losses

Population losses due to water shortages, as well as the related loss of school enrollment, were based upon the job loss estimates and upon a recent study of job layoffs and the resulting adjustment of the labor market, including the change in population.[1] 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 an estimate of the change in the population as the result of a job layoff event. Layoffs impact both out-migration, as well as in-migration into an area, both of which can negatively affect the population of an area. In addition, the study found that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county. Based on this study, a simplified

[1] Foote, Andre, 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/uploads/150194

ratio of job and net population losses was calculated for the state as a whole: for every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses were estimated as a proportion of the population lost.

2.2 Analysis Context

The context of the economic impact analysis involves situations where there are physical shortages of surface or groundwater due to drought of record conditions. Anticipated shortages 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.

2.2.1 IMPLAN Model and Data

Input-Output analysis using the IMPLAN (Impact for Planning Analysis) software package was the primary means of estimating value added, jobs, and taxes. This analysis employed county and regional level models to determine key 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 2011 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 440 sector specific Industry Codes, and those that rely on water as a primary input were assigned to their relevant planning water user categories (manufacturing, mining, irrigation, etc.). 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. Similar calculations were performed for the job and tax losses on production and import impact estimates. Note that the value added estimates, as well as the job and tax estimates from PLAN, 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.

2.2.2 Elasticity of Economic Impacts

The economic impact of a water need is based on the relative size of the water need to the water demand for each water user group (Figure 2-1). Smaller water shortages, for example, less than 5 percent, were 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 deepens, 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 such ability to adjust, an elasticity adjustment function was used in estimating impacts for several of the measures. Figure 2-1 illustrates the general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage percentage reaches the lower bound b1 (10 percent in Figure 2-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound for adjustment reaches the b2 level shortage (50 percent in Figure 2-1 example).

Initially, the combined total value of the three value added components (direct, indirect, and induced) was calculated and then converted into a per acre-foot economic value based on historical TWDB water use estimates within each particular water use category. As an example, if the total, annual value added for livestock in the region was $2 million and the reported annual volume of water used in that industry was 10,000 acre-feet, the estimated economic value per acre-foot of water shortage would be $200 per acre-foot. Negative economic impacts of shortages were then estimated using this value as the maximum impact estimate ($200 per acre-foot in the example) applied to the anticipated shortage volume in acre-feet and adjusted by the economic impact elasticity function. This adjustment varied with the severity as percentage of water demand of the anticipated shortage. If one employed the sample elasticity function shown in Figure 2-1, a 30% shortage in the water use category would imply an economic impact estimate of 50% of the original $200 per acre-foot impact value (i.e., $100 per acre-foot).

Such adjustments were not required in estimating consumer surplus, nor for the estimates of utility revenue losses or utility tax losses. Estimates of lost consumer surplus relied on city-specific demand curves with the specific lost consumer surplus estimate calculated based on the relative percentage of the city's water shortage. Estimated changes in population as well as changes in school enrollment were indirectly related to the elasticity of job losses.

Assumed values for the bounds b1 and b2 varied with water use category under examination and are presented in Table 2-2.

Figure 2-1 Example Economic Impact Elasticity Function (as applied to a single water user's shortage)

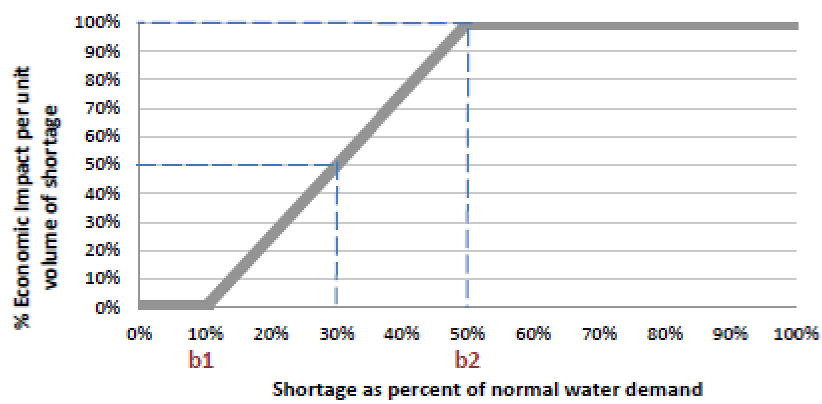

Table 2-2 Economic Impact Elasticity Function Lower and Upper Bounds

Water Use Category	Lower Bound (b1)	Upper Bound (b2)
Irrigation	**5%**	**50%**
Livestock	**5%**	**10%**
Manufacturing	**10%**	**50%**
Mining	**10%**	**50%**
Municipal (non-residential water intensive)	**50%**	**80%**
Steam-electric power	**20%**	**70%**

2.3 Analysis Assumptions and Limitations

Modeling of complex systems requires making assumptions and accepting limitations. This is particularly true when attempting to estimate a wide variety of economic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of the methodology include:

1. The foundation for estimating socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified as part of the regional water planning process. These needs have some uncertainty associated with them, but serve as a reasonable basis for evaluating potential economic impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshot estimates of impacts 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 severe drought conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs, future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented were not cumulative (i.e., summing up expected impacts from today up to the decade noted), but were simply an estimate of the magnitude of annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated 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, supplies of limited resources, and other structural changes to the economy that may occur into the future. This 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 analysis is not a 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 procedures to weigh future costs differently through time.

5. Monetary figures are reported in constant year 2013 dollars.

6. Impacts are annual estimates. The estimated economic model 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.

7. 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 categories (value added and consumer surplus) are both valid impacts but should not be summed.

8. The value added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects described in Section 2.2.1. 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.

9. The majority of impacts estimated in this analysis may be considered smaller than those that might occur under drought of record conditions. 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 these types of economic impact modeling efforts, 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, which is one reason why the impact estimates are likely conservative.

10. The methodology did not capture “spillover” effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

11. The model did 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:

e. The likely significant economic rebound to the landscaping industry immediately following a drought;
f. The cost and years to rebuild liquidated livestock herds (a major capital item in that industry);
g. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
h. 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 accurately 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.

3 Analysis Results

This section presents a breakdown of the results of the regional analysis for Region L. Projected economic impacts for six water use categories (irrigation, livestock. municipal, manufacturing, mining, and steam-electric power) are also reported by decade.

3.1 Overview of the Regional Economy

Table 3-1 presents the 2011 economic baseline as represented by the IMPLAN model and adjusted to 2013 dollars for Region L. In year 2011, Region L generated about $119 billion in gross state product associated with 1.4 million jobs based on the 2011 IMPLAN data. These values represent an approximation of the current regional economy for a reference point.

Table 3-1 Region L Economy

Income ($ millions)*	Jobs	Taxes on production and imports ($ millions)*
$118,558	**1,421,846**	**$8,686**

[1]Year 2013 dollars based on 2011 IMPLAN model value added estimates for the region.

The remainder of Section 3 presents estimates of potential economic impacts for each water use category 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.

3.2 Impacts for Irrigation Water Shortages

Eight 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 3-2. 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. Two factors led to excluding any reported tax impacts: 1) Federal support (subsidies) has lessened greatly since the year 2011 IMPLAN data was collected, and 2) It was not considered realistic to report increasing tax revenue collections for a drought of record.

Table 3-2 Impacts of Water Shortages on Irrigation in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$32	$28	$25	$22	$19	$16
Job losses	1,377	1,233	1,091	950	814	701

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.3 Impacts for Livestock Water Shortages

None 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 3-3. Note that tax impacts are not reported for this water use category for similar reasons that apply to the irrigation water use category described above.

Table 3-3 Impacts of Water Shortages on Livestock in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	-	-	-	-	-	-
Job losses	-	-	-	-	-	-

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000***

3.4 Impacts for Municipal Water Shortages

Seventeen 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 the two subtypes of use within municipal use: residential, and non-residential. The latter includes commercial and institutional users. Consumer surplus measures were made for both residential and nonresidential demands. In addition, available data for the non-residential, water-intensive portion of municipal demand allowed use of IMPLAN and TWDB Water Use Survey data to estimate income loss, jobs, and taxes. Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed cost of $20,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 3-4.

Table 3-4 Impacts of Water Shortages on Municipal Water Users in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$178	$243	$340	$450	$658	$1,600
Job losses	3,225	4,407	6,169	8,163	11,931	28,863
Tax losses on production and imports[1] ($ millions)*	$15	$21	$29	$38	$56	$136
Consumer surplus losses ($ millions)*	$29	$58	$108	$171	$264	$403
Trucking costs ($ millions)*	$0	$0	$0	$1	$1	$3
Utility revenue losses ($ millions)*	$210	$304	$418	$537	$625	$809
Utility tax revenue losses ($ millions)*	$4	$6	$8	$10	$12	$15

[1] Estimates apply to the water-intensive portion of non-residential municipal water use.
**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by azero ($0) indicate income losses less than $500,000.***

3.5 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in 6 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 3-5.

Table 3-5 Impacts of Water Shortages on Manufacturing in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$724	$889	$1,123	$1,367	$1,709	$2,176
Job losses	8,455	10,113	12,091	14,005	16,702	20,267
Tax losses on production and imports ($ millions)*	$44	$55	$71	$89	$113	$148

**** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.6 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in 4 of the 21 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use type appear in Table 3-6.

Table 3-6 Impacts of Water Shortages on Mining in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$925	$895	$743	$432	$177	$48
Job losses	5,220	5,055	4,199	2,441	1,002	272
Tax losses on production and imports ($ millions)*	$114	$110	$92	$53	$22	$6

***** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.7 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in 1 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 3-7.

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

- Are reflected as an income loss proxy in the form of the estimated additional purchasing costs for power from the electrical grid 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.
- Does 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 3-7 Impacts of Water Shortages on Steam-Electric Power in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Income losses ($ millions)*	$132	$872	$1,089	$1,570	$2,070	$2,070

***** Year 2013 dollars, rounded. Entries denoted by a dash (-) indicate no economic impact. Entries denoted by a zero ($0) indicate income losses less than $500,000.***

3.8 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 3-8.

Table 3-8 Region-wide Social Impacts of Water Shortages in Region

Impact Measures	2020	2030	2040	2050	2060	2070
Consumer surplus losses ($ millions)*	$29	$58	$108	$171	$264	$403
Population losses	3,356	3,821	4,324	4,693	5,591	9,199
School enrollment losses	621	$707	$800	$868	$1,034	$1,702

***** Year 2013 dollars, rounded. Entries denoted by a dash***

Appendix - 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 2013 dollars, rounded). Values presented only for counties with projected economic impacts for at least one decade.

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

		Income Losses (Millions $)*						**Job Losses**						**Consumer Surplus (Millions $)***					
County	Water Use Category	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
Bexar	Irrigation	$2	$1	$1	$1	$1	$1	72	61	51	42	34	27	-	-	-	-	-	-
Bexar	Manufacturing	-	-	-	-	-	$6	-	-	-	-	-	60	-	-	-	-	-	-
Bexar	Municipal	$23	$34	$44	$56	$68	$476	422	613	799	1,015	1,231	8,631	$15	$34	$68	$107	$158	$216
Total Bexar		$25	$35	$45	$57	$69	$483	493	674	849	1,057	1,265	8,718	$15	$34	$68	$107	$158	$216
Caldwell	Municipal	$0	$0	$0	$1	$4	$36	5	7	8	9	70	658	$0	$0	$0	$1	$2	$5
Total Caldwell		$0	$0	$0	$1	$4	$36	5	7	8	9	70	658	$0	$0	$0	$1	$2	$5
Comal	Manufacturing	$4	$3	$3	$3	$3	$2	96	84	76	70	64	59	-	-	-	-	-	-
Comal	Municipal	$710	832	950	1,052	1,195	1,350	8,327	9,757	11,149	12,341	14,017	15,834	-	-	-	-	-	-
Total Comal		-	-	-	-	$61	$161	-	-	-	-	1,110	2,914	$1	$4	$10	$20	$32	$49
Guadalupe	Manufacturing	$710	$832	$950	$1,052	$1,256	$1,510	8,327	9,757	11,149	12,341	15,127	18,748	$1	$4	$10	$20	$32	$49
Guadalupe	Municipal	-	-	-	-	2	16	-	-	-	-	28	219	-	-	-	-	-	-
Total Guadalupe		-	-	$42	$92	$148	$243	-	-	761	1,666	2,687	4,415	$0	$4	$10	$17	$30	$49
Hays	Manufacturing	$14	$16	$18	$20	$21	$23	129	146	165	182	198	214	-	-	-	-	-	-
Hays	Municipal	$1	$1	$2	$3	$30	$292	20	27	35	46	542	5,148	0	1	$2	$4	$18	$57
Total Hays		$15	$17	$20	$22	$51	$316	149	173	201	228	740	5,363	$0	$1	$2	$4	$18	$57
Medina	Irrigation	$11	$10	$10	$9	$7	$6	524	485	447	399	346	301	-	-	-	-	-	-
Medina	Municipal	-	-	-	$0	$2	$3	-	-	-	1	29	60	$0	$0	$0	$0	$0	$1
Total Medina		$11	$10	$10	$9	$9	$10	524	485	447	399	375	361	$0	$0	$0	$0	$0	$1
Uvalde	Irrigation	$9	$8	$7	$6	$5	$4	453	399	344	297	255	221	-	-	-	-	-	-
Uvalde	Municipal	-	-	-	-	-	-	-	-	-	-	-	-	$0	$0	$0	$0	$0	$0
Total Uvalde		$9	$8	$7	$6	$5	$4	453	399	344	297	255	221	$0	$0	$0	$0	$0	$0

Appendix B

RESPONSES TO PUBLIC COMMENTS ON PROPOSED DFCs
Received by Members of GMA 10 during Comment Period

List of Comments

1. **Aquifer:** Central Subdivision of Edwards Aquifer. (No aquifer was designated by the commenter, but the context of the comment and its being originally sent to EAA indicate the commentary related to the San Antonio segment of the Edwards Aquifer.)
   Summary of Comment: Must monitor, maintain, protect, and restore springflows at San Marcos Springs, especially by reducing pumping associated with ill-advised, water-intensive (downstream) agricultural practices and land cover changes.
   GMA 10 Response: See Note A below the enumerated comments.

2. **Aquifer:** Central Subdivision of Edwards Aquifer (see parenthetical note in Item 1 above)
   Summary of Comment: DFC must prevent 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 (hereafter referred to as "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.

3. **Aquifer:** Central Subdivision of Edwards Aquifer (see parenthetical note in Item 1 above), but perhaps comment is intended to apply to all aquifers
   Summary of Comment: Texas and GMA 10 must regulate water both above and below ground in a similar fashion, using a non-"schizophrenic" approach.
   GMA 10 Response: GMA 10 agrees that at some temporal and areal scale, groundwater and surface water are hydrologically connected. But Texas law prescribes how both surface water and groundwater are to be regulated, largely reflecting their different ownership. 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. GMA 10 does, however, have an obligation under Texas Water Code Ch. 36.108(d) to consider certain factors before adopting DFCs which includes impacts on "…springflow and other interactions between

groundwater and surface water ” (TWC Ch. 36.108(d)(4)). See also Note A and the Responses to Comments 21-26 below.

4. **Aquifer:** Undesignated
   Summary of Comment: These Commenters suggested GMA 10 use “zero drawdown” as a DFC where applicable. Generally, the Commenters are concerned that the GMA is conflating an *Inevitable* Future Condition that is currently feasible with a *Desired* Future Condition that does no further harm to well-water levels or springflows. The Commenters’ specific concerns and rationale for this suggestion and GMA-10’s responses are elaborated in comments that follow this over-arching one.
   GMA 10 Response: See Note B below. The Commenters may be conflating the goal of zero-drawdown with a common definition of the concept of “sustainability.” 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 above notwithstanding, a DFC has a statutory requirement to balance aquifer protection and the maximum groundwater production feasible. 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.

5. **Aquifer:** Undesignated
   Summary of Comment: These Commenters offered a number of broad recommendations for improving the groundwater planning and management processes, to include: (a) adopting and applying a set of guiding principles for sustainability; (b) considering management rules that specifically protect minimum springflows; (c) continuing current rational practice of not permitting above the MAG; (d) encouraging use of rainwater harvesting for meeting various demands; and (e) prioritizing the development of water-neutral solutions using GCD rules.
   GMA 10 Response: While individual or all GMA 10 members may support such recommendations, these recommendations are not on point with evaluating the currently proposed DFCs, so the GMA cannot respond or act upon them here. Implementing most of these involve approvals of individual Groundwater Conservation Districts (GCDs) rather than a GMA or, as noted by the Commenters, actions by the Texas Legislature and/or administrative agencies like the TWDB or TCEQ.

6. **Aquifer:** Undesignated
   Summary of Comment: These Commenters encouraged initiating or continuing various studies and investigations focusing on aquifer science; relationships of headwaters, groundwater, and springflows; groundwater/surface-water relationships; and unpermitted withdrawals of water in riparian alluvium.
   GMA 10 Response: GMA 10 members grasp the importance of better understanding the hydrologic relationships between aquifers, including the relationship between groundwater and surface water interactions. For example, The Edwards Aquifer Authority has begun a multiyear study, the Inter-formational Flow Study (IFF), to research the interactions between the Trinity and Edwards Aquifers along four major focus areas between the Nueces River Basin and the Guadalupe/Blanco River Basins. GMA 10 members, including Barton Springs/Edwards Aquifer Conservation District (BSEACD), Trinity Glen Rose Groundwater Conservation District, and Uvalde County Groundwater Conservation District are serving as regional partners in the IFF research effort. In a related multi-year investigation, BSEACD is installing a network of multiport monitoring wells to elucidate the dynamics of cross-formational flows among aquifers in the northern subdivision of GMA 10, including between the Edwards and Trinity Aquifers and between freshwater and brackish groundwater. The districts also agree that more data are needed to have good science for determinations about relationships between recharge to and discharge from aquifers and surface water flows. The need for those data may require or allow revisions to DFCs as such data become available, but the requirement at the present is to make decisions on the proposed DFCs on the basis of currently known science.

7. **Aquifer:** Undesignated/Multiple
   Summary of Comment: Because all aquifers are connected, at least to some degree, every fresh and saline aquifer should be considered relevant for planning purposes.
   GMA 10 Response: A relevance determination does not equate to importance. An aquifer can be locally important and even regulated by the local GCD without being relevant, at the local GCD's option. Relevance for joint planning purposes reflects the relative size of the water supply compared to other water supplies for one or more Water User Groups or the relative geographic extent of an aquifer, particularly when an aquifer is shared and jointly managed by multiple member GCDS. Relevance may also reflect the need for it to be included in the regional water planning because of its strategic importance or its possible use to support state-funding of a key water project. Those are the key tests for relevance. Every relevant aquifer requires a DFC and a MAG to be established and a set of rules to be promulgated that ensures the DFC is achieved; making every aquifer relevant could be accompanied by unreasonable administrative/regulatory burdens at the GCD(s), GMA, and

TWDB levels that exceeds its utility; further, the rulemaking, monitoring, and enforcement efforts could adversely affect establishing DFCs/MAGs for other, clearly more relevant aquifers and their management. In addition, the modeling for the MAG takes into account any appreciable interconnectedness with other aquifers. The GMAs are best able to ascertain the pros and cons of whether a particular aquifer is relevant, and where it is relevant. That said, there is no prohibition on a GMA's declaring all of its aquifers throughout the GMA as relevant, but a requirement to do so conceivably could strain one or more GCDs' limited resources without a lot of benefit to that GCD. Regardless, very few aquifers in GMA 10 have been declared non-relevant for the purposes of joint planning.

8. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
   Summary of Comment: The DFC should be calculated using a methodology based on an historic groundwater level baseline from 1950 and that utilizes annual monitoring of well water elevations and springflow to ensure riparian flora and fauna are sustained.
   GMA 10 Response: It seems like this comment applies to GMA 9, not GMA 10. While GMA 10 proposes to use periodic monitoring well data and grid analysis to ascertain compliance with the Trinity DFC (and evaluate the efficacy of the corresponding MAG), it should be recognized that wells in the Trinity in GMA 10 from the 1950s are extremely rare, and those that might have existed were likely only incidental ones in the Upper Trinity. Further, there are no riparian biota related to the Trinity in GMA 10, as it is a confined aquifer there, i.e., without surface outcrop. There are no springs and seeps from the Trinity in GMA 10. The large springs in GMA 10 support abundant, and in some cases, rare biota, but they are solely associated with the Edwards Aquifer. In the judgment of the GMA (and for the San Antonio Pool, the mandate of the Texas Legislature), these prolific karst aquifers are best protected and sustained by establishing and enforcing production limits for the Edwards that incorporate substantial drought management provisions. Their DFCs are most appropriately expressed as resultant springflows, rather than as regional drawdown and annually measuring water levels in wells for compliance. See also Note A below.

9. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
   Summary of Comment: Zero-drawdown can be successfully achieved with current aquifer uses and conditions.
   GMA 10 Response: It physically could be achieved, but with little to no benefit. 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 of the Trinity here would not conform to highest practicable water withdrawals to meet extant demand while protecting the aquifer. See also the Response to Comment No. 4 above, and Note B below.

10. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
   Summary of Comment: Zero-drawdown is consistent with the *State Water Plan*'s mandate for water management strategies not to exceed the established MAG, and that there are no water management strategies that would be affected by a zero-drawdown DFC. Future growth would be achieved by enhanced conservation, low impact design, and/or rainwater harvesting.
   GMA 10 Response: This comment is not correct. Zero-drawdown DFC would produce a new MAG that would be negative for any non-exempt use, which is inconsistent with even the currently permitted Trinity production in GMA 10. Further, Trinity production based on the existing (and proposed) DFCs is already in the regional water plans, and substantial production has historically used other non-Edwards aquifers. See also the Response to Comment No. 4 above, and Note B below.

11. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
   Summary of Comment: The Commenters disavow utility of the TERS estimates for (even) water planning purposes. Zero-drawdown would bring aquifers in GMA 10 into "hydrologic balance" and would increase flows to surface water systems except during extraordinary drought conditions.
   GMA 10 Response: This comment is misleading. TERS is not a controlling factor in establishing DFCs and MAGs in GMA 10. The putative hydrologic balance cannot be achieved without considering the sources for satisfying the existing large demands for water in the system equation. Further, the hydrologic system will adjust so it will eventually be in equilibrium or balance with any DFC, if all sources and sink terms in the equation are included, provided water is available in the connected system. In that regard, zero-drawdown is not unique. See also Response to Comment No. 4 above, and Note B below.

12. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
   Summary of Comment: Zero-drawdown would have significant beneficial impact on springflow and every other type of surface-water/groundwater interaction.

GMA 10 Response: No evidence to support this comment relative to GMA 10 aquifers is offered. For the Trinity in GMA 10, zero-drawdown would have no effect or beneficial impact on springflows, as no springflows depend on the Trinity. Additional groundwater withdrawals from an aquifer will induce additional recharge, to a degree dependent on the hydrogeological properties of aquifer systems in communication and their water availability. Whether that is beneficial or not depends on the frame of reference. See also Response to Comment No. 4 above, and Note B below.

13. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
    Summary of Comment: While not expected to be important, fuller aquifers produced by a zero-drawdown DFC would generally tend to reduce subsidence.
    GMA 10 Response: Subsidence is not a factor that affects the DFC of any aquifer in GMA 10. See also Response to Comment No. 2.

14. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
    Summary of Comment: "Managed depletion" associated with anything other than zero-drawdown will degrade real and other property values and harm the business climate.
    GMA 10 Response: 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. Further, reduced supply of groundwater that would accompany a zero-drawdown DFC would in fact degrade property values and the business climate, rather than enhance it as the Commenters maintain. The GMA 10 members are charged with defining what (non-zero) drawdown may sustain the water supply and thereby protect and enhance property values, while protecting the aquifer, and this is a more rational basis for DFCs. See also the Response to Comment No. 4 above, and Note B below.

15. **Aquifer:** Undesignated/Multiple
    Summary of Comment: Zero-drawdown would benefit exempt well owners, because the competition for groundwater with non-exempts would be less. The property rights of the exempt well owners would therefore be enhanced. Non-exempts would have larger curtailments during severe drought than under the proposed DFCs.
    GMA 10 Response: The rights to groundwater of exempt users and their ability to access it would not be affected, either beneficially or adversely, by a DFC. But non-exempts are affected in variable ways by a particular DFC. With a zero-drawdown DFC, existing non-exempts users would be required to reduce their groundwater withdrawals, either all of the time or during certain drought stages, to preserve such a DFC, which would affect reliable access to expected water supplies.   See also Note B.

16. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
    Summary of Comment: Zero-drawdown would be no more costly to administer than the existing/proposed DFC, other than updating Management Plans and more stringent rules to implement it. Since equipment for water well monitoring and springflow measurements is the same as now and already in place, there is no difference in feasibility of achieving the DFC between the proposed one and zero-drawdown.
    GMA 10 Response: GMA 10 believes the Commenters are misinterpreting the intent of this factor in establishing DFCs. What needs to be addressed is not the administrative and technical work by GCDs in implementing various DFCs, rather it is the likelihood of the groundwater users to be able to physically and economically achieve the DFC. In this respect, a zero-drawdown, DFC would likely create substantial dislocations on non-exempt users by forcing demand reductions and locating alternative sources of water supply. GMA 10 believes that in aggregate a zero-drawdown is not likely to be feasible at all, and would likely create causes of legal action that would unnecessarily interfere with normal groundwater management. See also Response to Comment No. 4, and Note B below.

17. **Aquifer:** Undesignated (but context indicates the comments primarily relate to the Trinity Aquifer)
    Summary of Comment: The Commenters feel that the economic benefit of maintaining long-term hydrologic integrity of aquifer/surface-water systems outweighs the economic losses of commercial pumpers.

GMA 10 Response: No evidence or supporting documentation is offered to support this assertion for any aquifer/surface-water system. Neither cost-benefit term has been quantified so it is difficult to assess its validity. For now, GMA 10 considers that it can be used to neither confirm nor refute the reasonableness of the proposed DFCs.

18. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: Commenter requests more time for it and other members of the public to participate in the process, and for the GMA to take more time while considering its decision-making. Commenter also acknowledges that the timing is largely set by the state process.
GMA 10 Response: GMA 10 understands the amount of information to be digested by the public in this process can be daunting, especially that related to the DFC for this particular Aquifer. However, as noted by the Commenter, 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.

19. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: Commenter cautions that the DFC should reflect what is the desired condition of the Aquifer at the end of the 50-year planning period, not what is immediately feasible or possible during the five-year joint planning period.
GMA 10 Response: GMA 10 agrees with the intent of this comment but disagrees with the putative elements in the proposed approach. This is a karst aquifer volume that relatively rapidly discharges and recharges, so its condition does not conform to being managed on a 50-year or even a 5-year cycle. The proposed DFCs reflect enduring goals as to the condition of this aquifer, regardless of when the recurrence of the Drought of Record (DOR) might occur (e.g., in the next five years or in the 45th year of the planning period.) The All Conditions DFC is expressly designed to restrict the acceleration of the Aquifer from non-drought to drought conditions and to increase the effectiveness of the drought management program, regardless of when or how often that transition might occur during the 50-year planning cycle. Again, if conditions change that either require or allow more or less pumping and springflow, then the DFC can be revised in subsequent rounds of joint planning to accommodate those new conditions or information.

20. Aquifer: Freshwater Edwards (BFZ), Northern Subdivision

Summary of Comment: Commenter recommends establishing a series of interim DFC goals, linked to management actions, which in turn lead to the 50-year planning goal.

GMA 10 Response: See the response to Item 19 immediately above. Importantly, the DFC and MAG processes recur every five years, and require readopting the DFCs, revised as necessary to accommodate new information and conditions, at least that often, which essentially become a series of shorter-term "interim" goals that are always consistent with the prevailing 50-year state water plan.

21. Aquifer: Freshwater Edwards (BFZ), Northern Subdivision

Summary of Comment: The GMA and BSEACD should revise the magnitude of the (Extreme Drought) DFC to ensure springflow during a recurrence of a DOR that existed during the DOR period, or about 11 cfs on a monthly average basis, in order to minimize harm to the endangered salamander species, as indicated by the best available science.

GMA 10 Response: As part of its now complete Draft 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. GMA 10 has therefore once again established that springflow as the DFC condition, which BSEACD's regulatory program and HCP will be designed to achieve.

22. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: The Commenter questions why BSEACD did not utilize studies completed since 2010, when the previous DFC was established, and revise the proposed DFC accordingly.
GMA 10 Response: BSEACD did utilize the most recent data and analyses in finalizing its HCP (available at http://bseacd.org/uploads/BSEACD_DraftHCP_2014_Nov_13_print.pdf) and in recommending the proposed DFC. Generally, the new data and information refined the salamander-DO-springflow relationships, but they did not indicate a need to change the HCP conservation measures dealing with production restrictions or the efficacy of doing so, which would in turn relate to a change in the DFC. What the data did suggest, and what BSEACD later adopted, was the need for some additional mitigation, which was incorporated into the final analyses. Along with some additional commitments made for certain foreseeable circumstances, which are described in detail in the District Draft HCP, the HCP and the DFCs minimize and mitigate take to the endangered species, although as the Commenter asserts, take cannot be completely avoided, only minimized.

23. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: A DFC of less than 9.6 cfs springflow guarantees jeopardy of both species.
GMA 10 Response: This is not correct. The US Fish and Wildlife Service has never asserted that the historical low springflow is equivalent to a jeopardy condition. Jeopardy means that the species population is unable to survive and/or recover. There is no evidence that occurs at any particular springflow, as the DO-springflow characteristics of the proximate habitat are indeterminate. See the Response to Comment No. 21 above for relevant additional information.

24. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: The DFC does not provide a minimum flow to prevent harm to the salamander populations.
GMA 10 Response: This is correct. But the DFC and the HCP are not intended to prevent harm. As the Commenter also noted, the species begins to be adversely, if non-lethally affected (harmed) at combined springflows of about 40 cfs. Take of the species, which is harm associated with BSEACD managed activities (which harm may also be caused by natural conditions), begins about 30 cfs and progressively increases as both springflow and DO concentrations decrease. Harm caused by BSEACD activities would be prohibited under federal law without the Incidental Take Permit (ITP)supported by the District HCP. But the prohibition on such harm ("take") is excepted by that same federal law, as long as an ITP is

acquired and jeopardy doesn't occur. Take but not jeopardy is a consequence of the use of the aquifer as a sole-source water supply. And that is the reason BSEACD has developed an HCP and is seeking an Incidental Take Permit.

25. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: Commenter asserts that with diligence and cooperation among the District, its permittees, and various other parties, all or nearly all of the historic pumping could be curtailed during extreme drought given adequate time to make this happen. This comment is apparently based on the reported ability in 2010 of 4.3 cfs of historic-use pumping to switch to alternate sources.
GMA 10 Response: This is a misleading comment. In 2010, authorized historic-use amounted to about 10 cfs. At that time, some permittees with access to alternative supplies informally indicated to the District that during extreme drought they might consider voluntarily and temporarily cease pumping the aquifer and switch to another water source that was then available to them. (By design, the District's mandatory and stringent drought curtailment program largely encouraged this response, although the permittees also have their own vital interest in preserving the water supply from the aquifer as long as possible.) But it is important to recognize that most permittees did not then, and still do not now, have access to such alternative supplies or the ability otherwise to curtail use beyond that required by the District's drought management plan. The continuing best efforts of this set of permittees in further reducing pumping during DOR recurrence are not likely to replicate the reductions suggested earlier by the first set of permittees, because the earlier set consumed the "low hanging fruit" with respect to available alternative water supplies. So contrary to the Commenter's suggestion, the voluntary potential actions of a smaller set of historic users cannot confidently be extrapolated to the remaining larger set of historic users. Only if and until additional water supplies become available to these users at an affordable cost would such additional participation in a curtailment program be likely to occur. However, even then, regardless of what alternative sources are available to any permittee, BSEACD cannot compel, only encourage their switching to other water supplies. The Extreme Drought DFC is based on what BSEACD can legally mandate as part of its regulatory program; it cannot be based on speculative and voluntary commitments of its permittees.

26. **Aquifer:** Freshwater Edwards (BFZ), Northern Subdivision
Summary of Comment: On the basis of its preceding comments (Items 18-25), Commenter proposed the following alternate DFC for the Aquifer's primary, Extreme Drought DFC:

> "The primary Desired Future Condition for Year 2065 for the freshwater portion of the Barton Springs Edwards Aquifer shall be to maintain Barton Springs flows at or above 10

cubic feet per second on a monthly average during a recurrence of the drought of record, and to make progress toward this Desired Future Condition by immediate and near-term District regulatory and non-regulatory actions designed to maintain Barton Springs flows at or above 7.5 cfs on a monthly average during a recurrence of the drought of record."

This DFC expression represents an increased DOR springflow (and concomitant reduction in allowed DOR pumpage) of 1.0 cfs on an interim, near-term basis, presumably to include the DFC for the current joint planning period, and also an increased springflow and concomitant pumpage reduction during a DOR recurrence of 3.5 cfs at the end of the regional water planning period.

GMA 10 Response: The Commenter's objective, while understandable as a stretch goal, does not conform to the realities that permittees face and that relate DFCs and groundwater regulation. Compliance with applicable DFCs is the backbone requirement that must be met in any and all permitting decision now and in the future, so the DFC must be both realistic and achievable immediately and throughout the joint planning period. Absent that condition, the GCDs will be working to manage formidable challenges with limited resources and/or authority. The current and proposed DFCs require the most stringent and achievable degree of curtailment, regardless of whether they might be revised in the future. There is no utility in proposing some unachievable DFC at this point, in that such a goal *per se* does not promote future achievement of that goal. Rather, the efficacy of future DFCs will be determined by changes in the prevailing infrastructural, legal, regulatory, and political environments that are largely beyond the control of BSEACD and GMA 10.

27. **Summary of Comment:** Agriculture needs to be suited to climate.

GMA 10 Response: This is a GCD by GCD issue, not a GMA 10 issue, one which may be addressed in Management Plans of a GCD and in GCD Rules. Further, GCDs can only evaluate whether a particular use is a "beneficial use" which is defined by statute to describe a variety of specific uses including Agriculture. A GCD cannot prioritize use or make value judgments with regard to whether a particular use is "suitable" or not. Article 16. Section 59. of the Texas Constitution says "CONSERVATION AND DEVELOPMENT OF NATURAL RESOURCES AND PARKS AND RECREATIONAL FACILITIES; CONSERVATION AND RECLAMATION DISTRICTS. (a) The conservation and development of all of the natural resources of this State, [...] including [...] the reclamation and irrigation of its arid, semiarid and other lands needing irrigation [...] the preservation and conservation of all such natural resources of the State are each and all hereby declared public rights and duties; and the Legislature shall pass all such laws as may be appropriate thereto." In this, it is the lands needing irrigation beyond what the climate may provide, which is constitutionally addressed.

28. **Summary of Comment:** Regulate water above and below ground.
GMA 10 Response: GCDs have statutory authority to manage groundwater, and have no authority over surface water. Surface water is considered waters of the state and diversions are regulated by the TCEQ. As such, surface water is legislatively outside of a GCDs jurisdictional authority.

29. **Summary of Comment:** Has received little input from stakeholders.
GMA 10 Response: Opportunity, in accordance with statute, has been provided for public input. The statute prescribes a process in which all GMA meetings held during the planning cycle are open to the public. Each of these meetings are noticed in advance and have a specific agenda item allowing public comment. Additionally, the process requires a 90-day public comment period on proposed DFCs and public hearings to be held by each GCD within that comment period to allow opportunity to provide public input.

30. **Summary of Comment:** Not to feel too constrained by what you believe is feasible.
GMA 10 Response: A DFC provides the measure by which feasibility is derived. Further, DFCs require an explanatory report describing how each of the required factors for proposed DFCs was considered. This explanation is intended to collectively describe the rationale for each DFC including the relative consideration of feasibility.

31. **Summary of Comment:** Limit to the MAG
GMA 10 Response: The MAG, as provided for in Chapter 36.1132, is one of several factors in GCD permitting decisions. Given the uncertainty associated with MAG estimates, the more relevant planning objective is achieving a DFC under section 36.108.

32. **Summary of Comment:** Encourage rainwater harvesting.
GMA 10 Response: This is a GCD by GCD issue, not a GMA 10 issue, one which may be addressed in Management Plans of a GCD and in GCD Rules. Encouraging rainwater harvesting along with other water planning strategies are in fact a required goal that all GCDs must address when developing Management Plans.

33. **Summary of Comment:** Encourage water neutral solutions to increase demand
GMA 10 Response: This is a GCD by GCD issue, not a GMA 10 issue, one which may be addressed in Management Plans of a GCD and in GCD Rules.

Continue on to Notes A and B

Note A (for Item 1): In regards to San Marcos (and Comal) Springs, the DFC and the amount of Modeled Available Groundwater (MAG) have been set for the entirety of the EAA-regulated portions of the Edwards Aquifer - Balcones Fault Zone. They were adopted by statute during the 80th Regular Session of the Texas Legislature and can only be amended through subsequent legislative actions. Specifically, Sections 1.14(a), (f) and (h), and Section 1.26 of the EAA Act serve as the current DFC, and Section 1.14(c) of the Act serves as the MAG (equating to 572,000 acre-feet of permitted withdrawal each calendar year). To further protect springflow, the EAA has implemented a Critical Period Management system that requires incrementally greater pumping reductions at five successive stages of declining aquifer levels or springflows. Within the San Antonio Pool of the Edwards Aquifer reductions range between 20 percent and 44 percent of permitted groundwater use based on declining water levels at the J-17 Index well in San Antonio, or reduced springflow at Comal and San Marcos Springs.

Another series of programs and conservation initiatives called the Edwards Aquifer Habitat Conservation Plan (EAHCP), was finalized and permitted by the United States Fish and Wildlife Service in 2013 in an effort to provide further protections for the Edwards Aquifer, springflow, and threatened and endangered species endemic to Comal and San Marcos Springs. Programs within the EAHCP, such as the Voluntary Irrigation Suspension Program Option and Aquifer Storage and Recovery leasing, allow for the conservation of Edwards Aquifer water and non-direct Edwards Aquifer water use during periods of prolonged drought. Habitat protection and restoration measures and research are currently being conducted at both Comal and San Marcos Springs in conjunction with the EAHCP.

Note B (for Item 4, and others): There are several aspects of the Commenters' suggested revision to have a "zero drawdown" DFC that make it difficult to formulate a specific response. This difficulty arises for several reasons. First, it fails to name specifically the aquifer or aquifers covered by their statement, and because of this it introduces several assumptions questioning what these aquifers may be. For example, it could be referring to "all aquifers" in GMA 10. Or it could refer to all "relevant aquifers with a proposed DFC". Or, it could be referring to just one of the aquifers for which GMA 10 has submitted proposed DFCs. GMA 10 has DFCs for the following eight aquifers: Austin Chalk (Uvalde County), Buda Limestone (Uvalde County), Trinity, Edwards (BFZ) Northern Subdivision, Saline Edwards (BFZ) Northern Subdivision, Edwards (BFZ) within Edwards Aquifer Authority, Edwards (Kinney County), and Leona Gravel (Uvalde County). Each aquifer is unique and has an associated groundwater assessment and/or Groundwater Availability Model (GAM) that was used, in part, for determining DFCs. If the GMA 10 Committee were to assume one thing and it was not what the Commenters were referring to, it would only serve to add more confusion.

Second, in this statement, "…***where applicable, specific DFCs be set at a zero drawdown"***, the Commenters do not provide guidance or additional information on what ***"where applicable***" 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 ***"...zero draw down"*** of these aquifers refer or apply.

Third, urging the adoption of a "zero drawdown" DFC for any aquifer may not be legally possible given the facts that, (a) under Texas law, surface landowners own the groundwater under their property and have a right to access some of it at any time; (b) some use is exempt from groundwater permitting and restrictions, such as domestic and livestock use, which consume small quantities of groundwater,and use by certain oil and gas operations that can consume large quantities of groundwater; (c) groundwater conservation districts generally have no legal authority to address issues related to real property subdivision so large parcels can be split with each subdivided parcel carrying its own exempt groundwater production quantity; and (d) the Texas Water Code requires the Districts in a GMA to establish DFCs that balance groundwater protection and maximum practicable production.

Lastly, the ***"...zero drawdown"*** in the Commenters' statement is not clearly defined. GMA 10 is not sure if a zero drawdown is intended to refer to an average drawdown geographically for a set period of time over the entire GMA, or whether it refers to not exceeding a drawdown of zero at any one specific geographical location at any one point of time. These two scenarios could allow for quite a variation between the two.

In order for the TWDB to calculate the Modeled Available Groundwater (MAG), they use the model or assessment that was developed to analyze and propose a DFC. These models include important specific reference parameters like starting dates, the specific aquifer being modeled, the area covered, and the type of draw down analysis, spring flow, and/or other measures involved. Where it is necessary for clarity, DFC statements include these references. For example, the Trinity DFC references include "during average recharge conditions" and the "regional average well drawdown" of 25 feet. Trying to calculate a MAG using a DFC such as suggested by the Commenters with no specific references would only introduce speculative possibilities that would make it impossible to determine a viable MAG.

Attempts by GMA 10 to respond comprehensively to the suggested revision to the proposed DFC(s) without designating additional aquifer-specific information needed, as identified above, would simply be speculative and at end of the day futile. GMA 10 responds to specific comments made in support of a "zero drawdown" DFC in the enumerated sections above.