Lone Wolf Groundwater Conservation District

July 9, 2019

Jeff Walker
Executive Administrator
Texas Water Development Board
P O Box 13231
Austin, Texas 78711-3231

Dear Mr. Walker:

The Lone Wolf Groundwater Conservation District Board of Directors approved the Management Plan for Years 2019-2024 on June 11, 2019. At this time, the Board officially submits its plan to the Texas Water Development Board.

Should you have questions regarding the plan, please contact us at 325.728.2027.

Sincerely,

Sue Young

Sue Young
General Manager

139 West 2nd Street Colorado City, TX 79512
(325) 728-2027 Fax (325) 728-9304
sueyoung@lwgcd.org

LONE WOLF GROUNDWATER CONSERVATION DISTRICT

GROUNDWATER MANAGEMENT PLAN 2019-2024

Adopted: June 11. 2019

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Lone Wolf Groundwater Conservation District

Please direct correspondence to:

Sue Young, General Manager

139 West 2nd Street, Colorado City, Texas 79512

325-728-2027

sueyoung@lwgcd.org

(No attorney nor consultant hired by the District for correspondence with TWDB staff)

MISSION STATEMENT

The Mission of the Lone Wolf Groundwater Conservation District is to encourage conservation and the efficient, beneficial use of groundwater through monitoring and protecting the resource while upholding private property rights.

TIME PERIOD FOR THIS PLAN

This plan becomes effective upon approval of the District's Board of Directors and approval by the Texas Water Development Board. The plan remains in effect for five years after the date of approval by the Texas Water Development Board, or until a revised or amended plan is approved.

STATEMENT OF GUIDING PRINCIPLES

The District recognizes that its groundwater resources are of utmost importance to the economy and environment, first to the residents of the District and then to the region. Also recognized is the importance of understanding the aquifers and aquifer characteristics for proper management of these resources. In addition, the integrity and ownership of groundwater play an important role in the management of this precious resource. One of the primary goals of the District is to preserve the integrity of the groundwater in the District from all potential contamination sources. This is accomplished as the District sets objectives to provide for the conservation, preservation, protection, recharge, prevention of waste and pollution, and efficient use of water including:

- Acquiring, understanding, and beneficially employing scientific data on the District's aquifers and their hydrogeologic qualities and identifying the extent and location of water supplies within the District, for the purpose of developing sound management procedures;
- Protecting the private property rights of landowners of groundwater by ensuring that such landowners continue to have the opportunity to use the groundwater underlying their land;
- Promulgating rules for permitting and regulation of spacing of wells and transportation of groundwater resources in the District to protect the quantity and quality of the resource;
- Educating the public and managing for the conservation and beneficial use of the water;
- Educating the public and managing the prevention of pollution of groundwater resources;
- Cooperating and coordinating with other groundwater conservation districts with which the District shares aquifer resources.

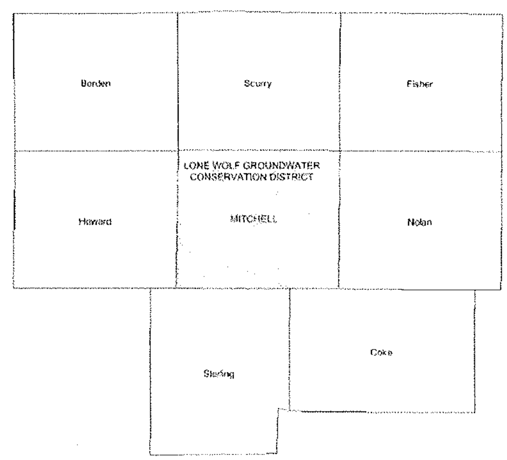
These objectives are best achieved through guidance from the locally elected board members who understand the county's conditions and can manage the resource for the benefit of the citizens of the District and region.

Since a basic understanding of the aquifers and their hydrogeologic properties, as well as a quantification of resources, is the foundation from which to build prudent planning measures, this management plan is intended as a tool to focus the thoughts and actions of those given the responsibility for the execution of District activities.

GENERAL DESCRIPTION OF THE DISTRICT

History

The Lone Wolf Groundwater Conservation District was initially authorized to operate with "temporary" status during the 76th Texas Legislature with the passage of Senate Bill 1911. Subsequent actions of the 77th Texas Legislature removed the temporary status and allowed for the creation of the Lone Wolf Groundwater Conservation District. House Bill 2529 and Senate Bill 2 formally authorized the creation of the District. The voters of Mitchell County approved the District on February 2, 2002.



Location of the Lone Wolf Groundwater Conservation District.

Location and Extent

The Lone Wolf Groundwater Conservation District is located in West Texas and consists solely of Mitchell County. The District covers 576,000 acres or 900 square miles. The Colorado River runs through the county giving the county seat its name of Colorado City.

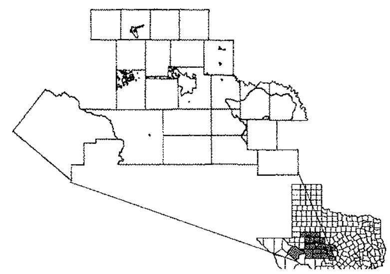
The County's and District's economy are mainly derived from agriculture and oil production. Cotton and wheat, along with cattle and goat raising, make up the majority of the agricultural income. Mitchell County has developed several wind energy projects and is developing solar projects, which shall be a future economic staple for the area.

The boundaries of the District follow those of the County. The County is home to approximately 8,400 people and consists of three towns: Colorado City, Loraine and Westbrook.

Topography and Drainage

The District lies within the Colorado River Basin and the Great Plains. The topography of the area ranges from flat to rolling hills, but becomes rugged in the south portion of the County, especially in the vicinity of the Colorado River and major creeks. Farms and ranches dominate the area. Drainage from both sides of the county, east and west, flows towards the Colorado River which splits the county in half. Tributaries in the area are intermittent and few springs exist.[1]

REGIONAL COOPERATION AND COORDINATION



Territory in the West Texas Regional Alliance.

The District is a member of the West Texas Regional Groundwater Alliance (WTRGA). This regional alliance consists of seventeen (17) locally created and locally funded districts that encompass approximately eighteen (18.2) million acres or twenty eight thousand three hundred sixty eight (28,368) square miles of West Texas. Due to the diversity of this region, each member district provides its own unique programs to best serve its constituents.

In May of 1988, four (4) groundwater conservation districts, Coke County UWCD, Glasscock County UWCD, Irion County WCD, and Sterling County UWCD adopted the original Cooperative Agreement. In the fall of 1996, the original Cooperative Agreement was redrafted and the West Texas Regional Groundwater Alliance was created. The current member districts and the year they joined the Alliance are:

Coke County UWCD (1988)	Crockett County GCD (1992)	Glasscock GCD (1988)
Hickory UWCD # 1 (1997)	Hill Country UWCD (2005)	Irion County WCD (1988)
Kimble GCD (2004)	Lipan-Kickapoo WCD (1989)	Lone Wolf GCD (2002)
Menard County UWD (2000)	Middle Pecos GCD (2005)	Permian Basin UWCD (2006)
Plateau UWC & SD (1991)	Santa Rita UWCD (1990)	Sterling County UWCD (1988)
Sutton County UWCD (1991)	Wes-Tex GCD (2005)	

This Alliance was created because the local districts have a common objective to facilitate the conservation, preservation, and beneficial use of water and related resources. The Alliance provides coordination essential to the activities of these member districts to monitor these activities and to accomplish their objectives.

The District is active in the Region F Water Planning Group. The group meetings provide input in developing and adopting the Regional Water Plans. The District will continue to be actively involved in future planning processes.

The District is a member of Groundwater Management Area 7, which covers all or part of thirty-three counties and includes twenty-one groundwater conservation districts. These Districts manage groundwater at the local level. The District actively participates in meetings and discussions to determine a feasible desired future condition of its aquifer.

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[1] Victor M. Shamburger, Jr., Report 50: Groundwater Resources of Mitchell and Nolan Counties, Texas, (Texas Water Development Board, June 1967) Page 12

GROUNDWATER RESOURCES

The data provided for this section of the groundwater management plan, unless otherwise noted, is obtained from a study conducted by Arcadis Geraghty and Miller (Review and Evaluation of Groundwater Resources Availability in Colorado City Area, Mitchell County, Texas and Research Information for Water Districts Prepared for Mitchell County Commissioners, Colorado City, Texas, December 22, 1998). The study was conducted primarily to determine an alternate resource for the public water supply since the surface water resources were quickly evaporating due to drought. The study consisted of researching and reviewing available information (including published literature, reports, files, data, etc) which contain information pertinent to evaluating the groundwater resources available in the county.

Although the Dockum Aquifer underlies more than 40 counties in West Texas, its low water-yielding ability and generally inferior quality results in its categorization as a minor aquifer.

The boundaries of the Lone Wolf Groundwater Conservation District are coextensive with the boundaries of Mitchell County, Texas, covering 583,562 acres. The towns of Colorado City, Loraine and Westbrook are the main population centers in Mitchell County, Texas. The City of Colorado City currently obtains its water supply from water wells located near Loraine. Loraine obtains its water supply from water wells located within the city of Loraine. The City of Westbrook, as well as the Lake Colorado City customers purchase their water from Corix Utilities whose wells are located to the east of Colorado City.

Geology

The geologic rock formations of fresh water-bearing significance in Mitchell County consist of strata of Permian Period, the Dockum Group of Triassic Period, the Trinity and Fredericksburg Groups of Cretaceous Period, the Ogallala Formation of Tertiary Period and alluvium of Quaternary Period. All of these strata crops out in Mitchell County. Of paramount importance are the Santa Rosa Formation of the Dockum Group and the sands of the Trinity Group which constitute the principal source of groundwater in the area.[2]

Historically, the uppermost Dockum shale rocks were thought to be correlative with the Chinle Formation found in New Mexico and Arizona. The sandstones below the Chinle were called the Santa Rosa and Trujillo Formations water bearing units and correlated with sandstones found in northeastern New Mexico. The Santa Rosa typically is composed of an upper sandstone unit, a middle shale member, and lower conglomerate sandstone. This division of the Triassic geology has commonly been used in West Texas and was the terminology followed in a report on the groundwater resources in

2 Victor M Shamburger, Jr., Report 50: Groundwater Resources of Mitchell and Nolan Counties, Texas, (Texas Water Development Board, June, 1967) page 23

Mitchell County prepared by Victor Shamburger and published by the Texas Water Development Board in June 1967. Although recent studies contest the historic Triassic correlations and nomenclatures and advance proposals for new divisions to the Triassic section found in Mitchell County, the Arcadis G&M report chose to base its findings from the TWDB 1967 report as it is apparent the stated debate will remain ongoing for quite some time.

Permian Strata

Strata of Permian Period underlie much of the area but crops out on the surface in the southeastern part of Mitchell County. The Permian strata consist mainly of red beds which are dense red silt shale with gray-green inclusions interbedded with tight reddish-brown, fine-grained laminated sandstones and occasional gypsum or anhydrite beds. The Permian beds dip westward at a slope of about 25 to 30 feet per mile, steepening considerably in the western part of Mitchell County.

Dockum Group (Santa Rosa and Chinle Foundations)

Strata of the Dockum Group occur on the surface or subsurface in much of Mitchell County. The Dockum Group is generally subdivided into the Santa Rosa Sandstone, the Tecovas Formation, the Trujillo Sandstone and the Cooper Canyon Formation by Lehman. The Cooper Canyon Formation is generally absent in the area except in the extreme western part of Mitchell County. The Cooper Canyon Formation is predominately red clay and shale with thin, ventricular, sandstone interbeds and it overlies the Trujillo Sandstone in the areas where the Cooper Canyon occurs. The Cooper Canyon Formation is generally unimportant as a source of water except for livestock because it yields only small quantities of water which are usually highly mineralized.

The Trujillo Sandstone is a cross-bedded unit composed of sandstones and conglomerates. The base of the unit (top of the Tecovas Formation) is marked by erosional unconformity. The Trujillo may be as much as 100 feet or more in thickness. The Tecovas shale is beneath the Trujillo and is composed of mostly dark gray mudstones and shales. The thickness of the unit may be as much as 45 to 50 feet in some areas.

The Santa Rosa Sandstone occurs beneath the Tecovas and it unconformably overlies older Permian rocks. It consists of a basal conglomerate overlain by alternating beds of red and gray micaceous shale, clay and sand. The thickness of the formation ranges from a few feet to as much as 45 to 50 feet or more in other areas based on the work done by Lehman and Lucas. The thickness of the entire Dockum Group ranges from a few feet to over 300 feet in the area northeast of Colorado City.[3]

Cretaceous Rocks (Trinity and Fredericksburg Groups)

The Cretaceous rocks which occur in the area are of Lower Cretaceous Epoch and belong to the Trinity and Fredericksburg Groups. These rocks crop out in southwestern

[3] Victor M. Shamburger, Jr., Report 50: Groundwater Resources of Mitchell and Nolan Counties, Texas, (Texas Water Development Board, June 1967) Page 23

and central Nolan County and are beneath Tertiary Ogallala deposits in northwestern Nolan County. Cretaceous rocks are completely absent in Mitchell County, except for the extreme eastern part of the county.

Sands of the Trinity Group consist of moderate to loosely consolidated, white to purple color, fine to medium-grained quartz sand with occasional lenses of quartz gravel at the base of the unit. The thickness of the Trinity sands ranges from 60 to approximately 100 feet. The Trinity sand overlies the Dockum Group (Santa Rosa Formation) in Western Nolan County but it lies directly on Permian strata farther to the east.

The Fredericksburg Group consists of up to 220 feet of calcareous sediments which overlie the Trinity Group in Nolan County. These rocks are of little importance as a source of groundwater in the area.[4]

Tertiary Ogallala Formation

Ogallala sediments of Tertiary age occur in the northwestern part of Nolan County (around Roscoe), the northeastern part of Mitchell County and in west central and northwestern Mitchell County. Near Roscoe, the Ogallala sediments consist of up to 50 feet of caliche, sand and gravel interbedded with light-colored clay. In this area, the Ogallala sediments are generally above the regional water table and are not a source of groundwater. However, they appear to constitute an effective avenue for recharge to the underlying Santa Rosa Formation and Trinity sand.

In the western part of Mitchell County, the Ogallala consists of up to 100 feet of unconsolidated buff-brown sand with a zone of coarse gravel at the base of the formation. In this area, the Ogallala sediments yield small quantities of usable water of variable quality to domestic and livestock wells.[5]

Hydrology

The water-bearing formation of primary interest in Mitchell County is the Santa Rosa Formation which consists of basal gravel and sand of Triassic Period overlain by alternating beds of red and gray micaceous shale, clay and sand (which comprises the Tecovas Formation and the Trujillo Sandstone based on Lehman's nomenclature). These strata occur on the surface over most of the county. The Permian rocks only yield small quantities of water to wells and are generally regarded as the base of the fresh water occurrence in the area. In the western part of the county, the Ogallala sediments yield small quantities of usable water of variable quality to domestic and livestock wells. The Permian beds dip westward at an approximate slope of 25 to 30 feet per mile for most of the county, but the dip steepens considerably in the western part of the county.

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[4] Victor M. Shamburger, Jr., Report 50: Groundwater Resources of Mitchell and Nolan Counties, Texas, (Texas Water Development Board, June 1967) Page 24

[5] Victor M. Shamburger, Jr., Report 50: Groundwater Resources of Mitchell and Nolan Counties, Texas, (Texas Water Development Board, June 1967) Page 30

The literature indicates that the basal gravel and sand of the Santa Rosa Sandstone is highly productive and provides most of the water to wells in the area. In the area north and northeast of Colorado City, the upper part of the Dockum Group (probably the Trujillo Sandstone) is saturated and makes a significant contribution to well yields in the area. However, these upper sands apparently have a different water level than the lower Santa Rosa and generally contain water of inferior quality to that found in the basal sand and gravel.

Although the Santa Rosa/Trujillo Aquifer is very productive over most of the area, the literature indicates that the groundwater quality in the aquifer west of the Colorado River is poor and is not suitable for public consumption. In view of this, the remainder of this report focuses primarily on the Santa Rosa/Trujillo Aquifer and the upper productive sands of the Dockum Group in the area east of the river. The thickness of the Dockum Group as a whole in this area may be as much as 300 feet, but the saturated thickness is only approximately 50% or less of the total thickness. Reported yields for water supply wells in this area are up to 1,000 gallons per minute (gpm).

Santa Rosa/Trujillo Aquifer Water Table

Groundwater in the Santa Rosa/Trujillo Aquifer and the overlying rocks of the Dockum Group that are saturated (Trujillo Sandstone) occurs under either slightly artesian conditions or water table conditions. Pumping tests conducted on several wells completed in the Santa Rosa/Trujillo Aquifer and/or the Trujillo Sandstone in the area indicate that, under static conditions, the water in the aquifer may be artesian, but with pumping and lowering of the water table below confining strata, water table conditions are produced.

Recharge to the aquifer is from infiltration and percolation of precipitation on the outcrop areas (including the overlying Ogallala and alluvium formations where they occur). The area west of Loraine (where the surface is fairly sandy) is highly conducive to recharge. Significant recharge also occurs along the creeks in the area where alluvium occurs on the surface along the stream channel. The amount of recharge to the Santa Rosa and the Trujillo Sandstone in this area has not been determined. A rough estimate of recharge in this area is approximately 0.5 inches per year which amounts to approximately 26.7 acre-feet per section of land.

The altitude as shown in TWDB maps of the water table in the Santa Rosa/Trujillo Aquifer and or the Trujillo Sandstone for the period of 1960-1961 shows that the direction of groundwater movement in the aquifer was to the west toward the Colorado River where significant discharge to the river occurred. West of the river, the direction of groundwater movement was to the east toward the river.

The static water levels in most (or all) of the Santa Rosa/Trujillo water wells in the area were as high as or higher in the mid-1990s than they were back in the early 1960s. This is reflected by the hydrographs of State observation wells which have historical records spanning the period from the early-1960s to the mid-1990s. Several of the hydrographs show that the water table/piezometric surface in the Santa Rosa/Trujillo Aquifer/Trujillo

Sandstone responds quite rapidly and significantly to heavy pumping or cessation in pumping of water wells.

The fact that the water table in this area is at or above the levels in the early 1960s indicates a substantial cessation of groundwater withdrawal from the aquifer for irrigation purposes during that time. The elevation of the water table appears to be approximately 20 feet higher in the mid 1990s than in 1960-61. However due to the sustained drought conditions during the late 1990s, groundwater usage in Mitchell County increased dramatically with irrigation and municipal use. As part of this plan, the District will monitor the groundwater levels regularly to determine the continued effects of increased pumping.

Groundwater Reserves

The gross saturated thickness of the Santa Rosa/Trujillo sediments in the eastern part of Mitchell County range from less than 60 feet in the southern part of the area to over 200 feet in the north. In the areas situated north, northeast and east of Colorado City, the thickness of Santa Rosa/Trujillo sediments ranged from 140 feet to over 200 feet in 1960-61. Accounting for the additional 20 feet in the water table by the mid-1990s, the gross saturation of the aquifer in this area in the mid 1990s ranged from approximately 160 feet to over 220 feet.

An estimate of the amount of groundwater reserves in storage in the aquifer can be made knowing the saturated thickness of Santa Rosa/Trujillo sediments and the effective porosity of the sediments. The effective porosity of the aquifer represents the void space from which water can be drained by gravity expressed as a percentage of the total volume of sediments. No values of the effective porosity for the Santa Rosa/Trujillo Aquifer have been reported in literature. However, based on Arcadis Geraghty and Miller's experience in working with this and other aquifers in West Texas, a conservative value of 10 percent is assumed for the effective porosity of the aquifer. This value was used to estimate the amount of reserves in the aquifer.

Based on the range of gross saturated thickness of the aquifer discussed above for the areas north, northeast and east of Colorado City (160 feet to over 220 feet), the assumed effective porosity of the sediments of 10% and a recovery factor of 70%, the volume of recoverable groundwater presently in place in the aquifer is estimated to range from approximately 7,168 acre-feet per section to over 9,856 acre-feet per section depending on the location of the property. This represents groundwater reserves present in the aquifer that can be produced by pumping, and it does not include any recharge to the aquifer or exterior drainage from adjoining properties that may be captured once a well field is developed and production begins.

These estimates for groundwater reserves in the aquifer include the apparent poorer quality water that may exist in the upper part of the aquifer which may not be suitable for municipal purposes and may have to be sealed off during construction of water supply wells. The saturated thickness of this upper productive zone is not known with any degree of certainty and would need to be addressed in any subsequent exploratory work to verify the aquifer reserves, quality and productivity.

Groundwater Quality in the Santa Rosa/Trujillo Aquifer

State observation wells completed in the Dockum Aquifer for which chemical analysis data were available in 1967 and more recent water quality data obtained from the TNRIS are available for a limited number of these observation wells. Data from these observation wells indicate the quality of the groundwater in the Santa Rosa/Trujillo Aquifer is considerably more mineralized in the western part of the county than in the eastern part of the county. Generally speaking, west of the Colorado River the groundwater quality in the aquifer is poor and is unsuitable for municipal purposes. However, east of the river, the water quality in the aquifer is less mineralized and is generally suitable for municipal purposes (with some exceptions). More recent water quality data, where available, confirm this conclusion. For example, State observation well 28-40-608 (located about 10 miles northwest of Colorado City) contained chloride, sulfate and total dissolved solids (TDS) of 560 milligrams per liter (mg/L), 337 mg/L and 1,891 mg/L, respectively, in 1963. In 1986, the chloride, sulfate and TDS concentration in this well were 519 mg/L, 386 mg/L and 1,893 mg/L, respectively. By contrast, State observation well 29-35-702 (located about eight miles east of Colorado City in Loraine) contained chloride, sulfate and TDS of 34 mg/L, 73 mg/L and 418 mg/L, respectively, for these same constituents in 1995. This also indicates that the groundwater quality in this well had not changed appreciably over the indicated time period. In fact, the quality in well 29-35-702 actually improved over the period.

Another important observation concerning the quality of groundwater in the Santa Rosa/Trujillo Aquifer is the fact that the quality in the upper sands (Trujillo Sandstone) appears to be inferior to the quality in the deeper basal sands and gravels (Santa Rosa Sandstone). This appears to be true even for wells located east of the Colorado River.

Based on the available chemical quality data, it appears that wells completed in the lower (basal) sands or gravels (the Santa Rosa/Trujillo Aquifer) contain groundwater which would meet the TCEQ standards for municipal water supplies in terms of the chloride, sulfate and TDS content. These standards are 300 mg/L, 300 mg/L and 1,000 mg/L respectively, for these constituents.

The concentrations of nitrate in the groundwater are another important factor in determining the suitability of a water supply for municipal purposes. The MCL for nitrates in public water supplies (as established by the EPA) is 10 mg/L of nitrogen (or 45 mg/L as nitrates). Above this level, adverse health effects can result. The groundwater quality in the Santa Rosa/Trujillo Aquifer in the area east of Colorado City appears to be generally acceptable for municipal purposes from the standpoint of the nitrate content of the water. However, several wells in the area do exhibit elevated nitrate concentrations above the maximum contaminant level (MCL) of 45 mg/L. For example, State Well 29-27-902 had nitrates of 81 mg/L in 1978 which increased to 109.9 mg/L in 1986. Well 29-34-515 had nitrate of 66 mg/L in 1963, well 29-34-801 had nitrate levels of 98 in 1946 and well 29-35-108 had nitrate levels of 320 in 1963. No recent nitrates data are available for these wells. The source could be septic systems or areas where nitrate-rich fertilizers are stored. Additional exploration would be necessary to identify and delineate the nature and extent of this problem.

Hydraulic Properties of the Santa Rosa/Trujillo Aquifer and Aquifer Productivity
The results of pumping tests conducted by the Texas Water Development Board in the 1960s on several water wells in the area completed in the Santa Rosa/Trujillo Aquifer were used to estimate the transmissivity and storage coefficient of the aquifer. The transmissivity of the aquifer is defined as the rate at which water flows through a vertical strip of the full saturated thickness of the aquifer one foot wide and under a unit hydraulic gradient. It is a measure of the ability of the aquifer to transmit water. High values indicate greater transmitting capabilities of the aquifer. The storage coefficient is defined as the volume of water released from storage or taken into storage per unit of surface area of the aquifer per unit change in head in the aquifer. For water table aquifers, the storage coefficient is the same as the specific yield (or effective porosity). As discussed earlier, in this area the Santa Rosa/Trujillo Aquifer appears to exhibit slightly artesian conditions under static conditions due to the stratified nature of the aquifer. However, when the aquifer is pumped and the water level lowered below confining strata, water table conditions may be produced. The specific yield (effective porosity) of an aquifer is the volume of water which can be drained by gravity from a unit volume of the aquifer expressed as a fraction or percentage of the unit volume.

The transmissivity values obtained from the pumping tests conducted by the Texas Water Development Board ranged from 5,868 gallons per day per foot (gpd/ft) to 12,300 gpd/ft and averaged 8,845 gpd/ft. Because the tested wells were located over a wide area (east of Colorado City), this range of transmissivity values appears to be representative of the Santa Rosa/Trujillo Aquifer in this area.

The storage coefficient values from the pumping tests ranged from 0.00008 to 0.00044 which are typical of aquifers under artesian conditions. With sustained pumping of the aquifer and lowering of the water table below confining strata, water table conditions are expected to be produced. Storage coefficients (or specific yields) in the range of 0.01 to 0.35 are typical of aquifers under water table conditions.

Reported yields for Santa Rosa/Trujillo water supply wells in the north, northeast and east of Colorado City are up to 1,000 gallons per minute (gpm). However, well yields and the productivity of the aquifer will vary across the area and depend on factors such as the lithology of the formation and the gross saturated thickness of the aquifer. The design of the wells also has a significant impact on the yield of the well. Therefore, it would be imperative to conduct exploration and testing to better assess these factors and to determine the productivity of the aquifer and well yields in specific areas of interest.

ADDITIONAL NATURAL OR ARTIFICAL RECHARGE

Each year, annual precipitation in and around the district results in a recharge of the aquifer of approximately 18,108 acre-feet into the lower Dockum Aquifer while an estimated 11,998 acre feet of water discharges from the aquifer to springs and other surface water bodies. According to GAM Run 19-004, an estimated 2,726 acre-feet flow into the district within the lower Dockum Aquifer while about 373 acre-feet flow out of the district. An additional 440 acre-feet of water flows from upper aquifers into the lower portion of the Dockum. However, more can be done to help the recharge rate.

Brush Control

The Lone Wolf Groundwater Conservation District supports brush control as a management practice to maintain and improve groundwater supplies in the District and region. The District, in fact, wrote a grant for the Mitchell and Nolan Soil and Water Conservation Districts in 2002 for a brush control program along the 41,000 acre Champion Creek Watershed. The $1.3 million grant was funded in the fall of 2002.. The District will continue to work with the local Soil and Water Conservation District (SWCD) and state U. S. Geological Survey (USGS) offices to support new and ongoing brush control management projects.

The Texas Water Resources Institute, according to the 2001 Region F Water Plan, estimates that one acre-foot of water is lost annually for every 10 acres of brush. Much of the brush consists of mesquite, salt cedar and juniper. As these plants were introduced into the area they spread from the riverbanks to the plains replacing native grasslands. Some of the potential concerns associated with brush are increased erosion, competition for water with grasses, and reduced runoff infiltration.

Recharge Enhancement

Recharge enhancement is the process in which surface water is intentionally directed to areas where permeable soils or fractured rock allow rapid infiltration of the surface water into the subsurface to increase localized groundwater recharge. This includes any man-made structure that would slow down or hold surface water to increase the probability of groundwater recharge.

To determine possible sites for recharge, Region F utilized the geographic information system (GIS) to map the region. Mitchell County is identified as being mostly moderate to some favorable conditions for recharge enhancement. However, topography, drainages, soil properties and the extent and hydraulic characteristics of aquifer outcrops on a local scale would need to be studied before a site could be selected. Consideration should also be given to the potential reduction of surface runoff and how that affects existing surface water reservoirs. Further study is needed to determine the quantity of increased groundwater supplies from enhanced recharge structures and the potential impacts to surface water rights.

Weather Modification to Enhance Yields

Weather modification is defined as an attempt to increase the efficiency of a cloud to return more of the water drawn into the cloud as precipitation. Hail suppression and rainfall enhancement are common forms of weather modification. Early forms of weather modification began in Texas in the 1880s by firing cannons to induce convective cloud formation. Efforts to enhance rainfall in Texas continue to this day. Most efforts to increase rainfall take place in the spring and summer and are halted during the winter months.

A common agent for cloud seeding is Silver iodide, AgI, which is released from flares located on a plane. Silver iodide enhances ice crystal concentrations in clouds, encouraging larger drops to form thereby increasing the likelihood that precipitation will reach the ground. Environmental concerns have been raised with regard to using a heavy metal as a seeding agent, but research conducted along the Oklahoma border indicated only trace amounts, much smaller than allowed by law, of silver in livestock grazing or in soil downwind.

The Lone Wolf Groundwater Conservation District has participated in a weather modification program for the past four years although the actual effects are difficult to measure. To accurately estimate the benefit of weather modification requires an approximation of how much rainfall would have occurred naturally without weather modification. Research has suggested increases of 15 percent or more of precipitation in areas included in weather modification. Local experiences have shown increases of 27 percent in rainfall. Other methods of measuring the effects of rainfall enhancement, such as dry land farm production, have shown positive benefits of weather modification. Dry land farming has increased in regions participating in rainfall enhancement.

MANAGEMENT OF GROUNDWATER SUPPLIES

Preservation and protection of groundwater quality and quantity has been the guiding principle of the District since its creation while striving to maintain the economic viability of all groundwater user groups, public and private. In consideration of the economic and cultural activities occurring within the District, the District will continue to identify and engage in such activities and practices, that if implemented, would result in preservation and protection of the groundwater. An observation network has been established and maintained for monitoring changing storage conditions of groundwater supplies within the District. The District will continue to make regular assessments of groundwater supply and storage conditions and make them available to the public. Additional monitor wells, both water quality and water level, are continually being added to the well monitor program, along with expansion of programs including the rainfall monitoring program.

The District has adopted rules to regulate groundwater withdrawals by means of spacing regulations and well density (number of wells per section). The District will amend these rules, within the limitations imposed by Chapter 36 of the Texas Water Code, as necessary to regulate groundwater withdrawals by means of additional spacing and/or production limits. District rules also address permitting and registration of wells, waste, well drilling and completion of wells, as well as capping and plugging of unused or abandoned wells. These rules are intended to provide equitable conservation and preservation of the groundwater resources.

The District may deny a drilling permit in accordance with the provisions of the District rules. The relevant factors to be considered in granting, denying, or limiting a permit include:

1) the purpose of the District rules, including but not limited to, preserving and protecting the quality and quantity of the aquifer resources, and protecting existing uses;
2) the equitable conservation and preservation of the resource; and
3) the economic hardship resulting from denial or limitation of a permit.

In pursuit of the District's mission of preserving and protecting the resource, the District will enforce the terms and conditions of permits and the rules of the District by injunction, mandatory injunction, or other appropriate remedies in a court of competent jurisdiction as provided by Chapter 36.102, Texas Water Code.

The District is aware of the importance of brackish groundwater as a potential future water supply. Therefore, the District takes steps within its authority to protect brackish groundwater resources, including participating in proceedings at the Texas Railroad Commission regarding injection wells or other permitted activities that could put either fresh water or brackish water resources at risk. With advances in desalination technology, water that is not economically usable today may prove to be an important resource in the future, and the District believes expending resources to preserve that brackish water in its current state and prevent any third party pollution of same is in the best interests of the public, landowners, the District, the area, and the state. To that end, the District has partnered with Mitchell County in developing a desalination plant that will provide potable water to the unincorporated areas of the county (those not served by the cities).

The District also recognizes the importance of public education to encourage efficient use, promote conservation, prevent waste, and preserve the integrity of groundwater. District personnel will seek opportunities to educate the public on water conservation issues and other matters relevant to the protection of groundwater resources through public meetings, newspaper articles, newsletters, speaking engagements, and other means that may become available.

By implementing more public education programs specifically aimed at irrigation conservation, rainwater harvesting and additional brush control methods, the District anticipates additional groundwater being available to offset future needs.

ACTIONS, PROCEDURES, PERFORMANCE AND AVOIDANCE

FOR PLAN IMPLEMENTATION

The District will implement the provisions of this plan and will utilize the provisions of this plan as a guide for determining the direction and/or priority for District activities. All operations of the District will be consistent with the provisions of this plan.

The District first adopted rules in 1999, has amended the rules periodically and will continue to amend the rules as necessary. Rules adopted or amended by the District shall be pursuant to TWC Chapter 36 and the provisions of this plan. The promulgation and enforcement of the rules will be based on the best scientific and technical evidence available.

The District maintains a website www.lonewolfgwcd.org which contains District Rules, activities, forms, notices of Board meeting and hearings, agendas, and other pertinent information.

The District shall treat all citizens with equality. For good cause, the District, in its discretion and after notice and hearing if required, may grant an exception to the District rules. In so doing, the Board shall consider the potential for adverse effects on adjacent owners and aquifer conditions. The exercise of said discretion by the Board shall not be construed as limiting the power of the Board.

All activities of the District will be undertaken in cooperation and coordination with the appropriate state, regional and local water management entities.

TECHNICAL DISTRICT INFORMATION REQUIRED BY TEXAS ADMINISTRATIVE CODE

Estimate of the modeled available groundwater in the District based on the desired future conditions. Texas Water Code §36.001 defines modeled available groundwater as "the amount of water that the executive administrator determines may be produced on an average annual basis to achieve a desired future condition established under Section 36.108".

The joint planning process set forth in Texas Water Code §36.108 must be collectively conducted by all groundwater conservation districts within the same GMA. The District is a member of GMA 7. GMA 7 adopted a DFC for the Dockum Aquifer on November 22, 2016. The adopted DFC was then forwarded to the TWDB for the development of the MAG calculations. The portions of the explanatory report relevant to Lone Wolf GCD are found in GMA7 Explanatory Report - Final (Appendix A).

The Desired Future Condition for the Dockum Aquifer is based on the HPAS GAM, Scenario 17 as described in GMA 7 Explanatory Report - Final (Appendix A). The resolution adopted by GMA 7 stated that the Dockum Aquifer is not relevant for joint planning purposes in Mitchell County, which coincides with the boundaries of the Lone Wolf Groundwater Conservation District (Appendix A in the Explanatory Report of Appendix A).

Estimated Modeled Available Groundwater for the Dockum Aquifer in Mitchell County is not available based on the fact that the Dockum is not relevant for joint planning purposes in the county (reference: GAM Run 16-026 MAG Version 2, Appendix B; and GMA 7 Explanatory Report - Final, Appendix A).

Estimate of the annual amount of groundwater being used within the District on an annual basis: 13,391 acre feet in the year 2016. Please refer to Appendix C: Estimated Historical Groundwater Use and 2017 State Water Plan Datasets – page 3.

Estimate of the annual amount of recharge from precipitation to the Dockum Aquifer: 18,108 acre feet. (Appendix D: GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan – Table 1).

Estimate of the volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams and rivers: 11,998 acre feet. (Appendix D: GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan – Table 1).

Estimate of the annual volume of flow into the District within the Dockum Aquifer: 2,726 acre feet. (Appendix D: GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan – Table 1).

Estimate of the annual volume of flow out of the District within the Dockum Aquifer: 373 acre feet (Appendix D: GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan – Table 1).

Estimate of the net annual volume of flow from the overlying units of the Dockum Aquifer: 440 acre feet: (Appendix D: GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan – Table 1).

Estimate of the projected annual surface water supply within the District in: 395 acre feet in the year 2020. (Appendix C: Estimated Historical Groundwater Use and 2017 State Water Plan Datasets – page 4).

Estimate of the projected total annual demand for water within the District: 19,575 acre feet in the year 2020. Please refer to Appendix C: Estimated Historical Groundwater Use and 2017 State Water Plan Datasets – page 5.

Estimate of the projected annual water supply needs: -4847 acre feet in the year 2020. Please refer to Appendix C: Estimated Historical Groundwater Use and 2017 State Water Plan Datasets – page 6. The negative value depicted in the water supply needs is attributed to steam electric power. The power plant located at Lake Colorado City is being dismantled and will eventually have no need for the surface water being used.

Water management strategies: Please refer to Appendix C: Estimated Historical Groundwater Use and 2017 State Water Plan Datasets – page 7. The management strategies will be attainable through education for the most part. The reuse of effluent water should lower municipal usage and the steam electric deficit will be eliminated with new power plants coming on line.

METHODOLOGY FOR TRACKING PROGRESS

The methodology that the District will use to track its progress on an annual basis, in achieving all of its management goals will be as follows:

> The District manager will prepare and present an annual report to the Board of Directors on District performance in regards to achieving management goals and objectives for the previous fiscal year, during the first meeting of each new fiscal year. The report will include the number of instances each activity was engaged in during the year.

The annual report will be maintained on file at the District office and will apply to all management goals contained in this plan.

GOALS, MANAGEMENT OBJECTIVES AND PERFORMANCE STANDARDS

The Management Plan Goals and Objectives of the Lone Wolf Groundwater Conservation District are as follows:

Goal
1.0 ***Providing the Most Efficient Use of Groundwater***

Objective
1.1 Gather well production data and intended use (irrigation, domestic, etc) on all new wells permitted in the District each year. Information gathered will be compiled and entered into the District's database. Annual reports detailing the number of wells drilled, production data and intended use of the wells will be maintained at the District office.

Performance Standard
1.1.1 Data gathered and reports generated monthly and annually detailing the number and type of wells drilled.

Objective
1.2 The Lone Wolf Groundwater Conservation District has developed and enforces a set of rules outlining, among other things, the District's policies and water well spacing requirements. The Board will review the rules of the District for possible updates and revisions at least every odd numbered year. Minutes of the meeting will be maintained at the District office.

Performance Standard
1.2.1 Written rules maintained at the District office. Rules reviewed for possible updates at least every other year.

Objective
1.3 Each year the District will provide informative speakers to schools, civic groups, social clubs and organizations for presentations to inform a minimum of 20 citizens on the activities and programs, the geology and hydrology of groundwater and the principles of water conservation relating to the best management practices for the efficient use of groundwater.

Performance Standard
1.3.1 Number of citizens in attendance at District presentations concerning the principles of water conservation relating to the best management practices for the efficient use of groundwater each year

Goal
2.0 ***Controlling and Preventing Waste of Groundwater***

Objective
2.1 Each year the District will take water quality samples from at least two wells in order to monitor water quality trends and prevent the waste of groundwater by contamination.

Performance Standard
2.1.1 Number of wells sampled for water quality analysis by the District to monitor water quality trends each year.

Objective
2.2 Investigate all wasteful practices reported to the District. All reports of wasteful practices will be documented and investigated to ensure compliance with and enforcement of state and local groundwater laws and rules.

Performance Standard
2.2.1 Prompt investigation of all reported wasteful or detrimental activities relating to groundwater and resulting documentations presented at the following Board meeting.

Objective
2.3 All wells drilled within the District will be registered or permitted.

Performance Standard
2.3.1 All wells drilled will be sequentially numbered and the number reported in each year end report.

Goal
3.0 ***Controlling and Preventing subsidence***

Objective
3.1 The District has read the TWDB subsidence risk report: *Identification of the Vulnerability of the Major and Minor Aquifers of Texas to Subsidence with Regard to Groundwater Pumping* and acknowledge the potential for subsidence.

Performance Standard
3.1.1 As any new information becomes available regarding subsidence in the Dockum Aquifer, the District staff will promptly report such findings to the Board to determine if additional action is required.

Goal
4.0 ***Addressing Conjunctive Surface Water Management Issues***

There are no surface water management entities within the District. Therefore, this management goal is not applicable to the operations of the District.

Goal
5.0 ***Addressing Natural Resource Issues that Impact the Use and Availability of Groundwater and Are Impacted by the Use of Groundwater***

Objective

5.1 The District will promote at least once per year by way of press releases, community awareness programs, advertisements or a combination thereof the importance of plugging and/or capping all wells not in use. District staff will maintain a file indicating the methods of promotion used each year.

Performance Standard

5.1.1 Annually publicize the importance of plugging or capping wells.

Goal
6.0 ***Addressing Drought Conditions***

Objective

6.1 The District has developed and maintains a drought contingency plan (Appendix E) that includes recommended rationing and conservation techniques.

Performance Standard

6.1.1 At least annual review of Drought Contingency Plan and review of drought related information at: https://www.waterdatafortexas.org/drought.

Objective

6.2 Monthly review of applicable data including the Palmer Drought Severity Index (PDSI) by Texas Climatic Divisions to determine status of drought conditions and, if necessary, report to the Board on need to implement drought contingency plan.

Performance Standard

6.2.1 Each year complete and distribute to the District Board an Annual Report on drought conditions in preceding year.

Objective

6.3 Monthly the District will monitor the Palmer Drought Severity Index (PDSI) by Texas Climatic Divisions. If PDSI indicates that the District will experience severe drought conditions, the District will notify all public water suppliers within the District.

Performance Standard

6.3.1 The District staff will monitor the PDSI and report findings and actions to the District Board on a monthly basis.

Goal

7.0 ***Addressing Conservation***

Objective

The District has developed and maintains a water level monitoring program that includes at least 15 water wells throughout the District. The District will gather water levels at least twice a year on each of the designated wells to determine the effects of pumping and weather conditions on the aquifer. Data files are maintained at the District office. Annual reports are presented to the Board on the status of the water level monitoring program.

Performance Standard

7.1.1 The number of water wells monitored for levels each year. Annual reports submitted to the District Board.

Objective

7.2 District staff writes or sponsors at least four media releases per year on various issues relating to conservation. These articles are sent to local media outlets for publication. The District maintains a file detailing all newspaper articles and radio and television coverage on conservation issues.

Performance Standard

7.2.1 The number of media releases sent to local media outlets.

Goal

8.0 ***Addressing Recharge Enhancement***

Objective

8.1 Because of the diverse topography and limited knowledge of any specific recharge sites, this goal is not cost effective and therefore is not applicable to the district. .

__Goal__
9.0 ***Addressing Rainwater Harvesting***

Objective
9.1 The District provides literature for the public, as well as public seminars, regarding rainwater harvesting systems. The District has provided barrels for the seminars and subsequent instruction. The District maintains a rainwater harvesting system at the office, from which the public can be educated on developing home and corporate systems.

Performance Standard
9.1.1 Number of systems installed and completed each year.

__Goal__
10.0 ***Addressing Precipitation Enhancement***

Objective
10.1 The District participates in a weather modification project in cooperation with other entities in the west Texas and panhandle region.

Performance Standard
10.1.1 Number of clouds seeded in the District per year.

Objective
10.2 The District maintains a rainfall database from cooperators across the District. The rainfall totals are reported quarterly and are coordinated with the cloud seeding operation.

Performance Standard
10.2.1 Number of cooperators and data gathered reported annually to District Board.

__Goal__
11.0 ***Addressing Brush Control***
The Soil and Water Conservation District (SWCD) will address all brush control issues, therefore this goal is not applicable to the district.

.

__Goal__
12.1 ***Addressing the Desired Future Conditions Established Under TWC 36.108***

Objective
12.1 Although the Dockum Aquifer in Mitchell County is classified as "Not Relevant for Purposes of Joint Planning" and as such no DFC is required, the District will continue to manage groundwater through its management plan and regulate groundwater through its rules.

Performance Standard

12.1.1 Develop, in conjunction with neighboring counties, a local-scale groundwater flow model for the Dockum Aquifer.

Performance Standard

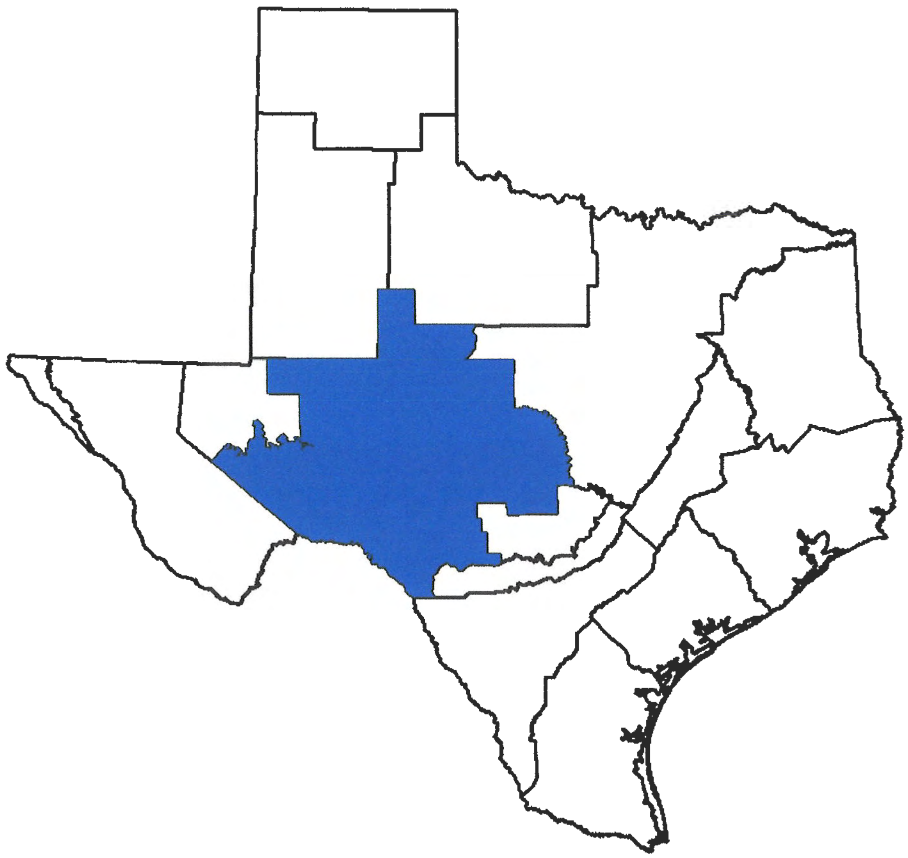
12.1.2 The water well monitoring program, as described in Goal 7.0, allows the District to closely monitor the static and drawdown levels of the water tables across the District gathering seasonal and long-term water level declines, and respond accordingly.

APPENDICES

APPENDIX A

GMA 7 Explanatory Report

GMA 7 Explanatory Report - Final
Ogallala and Dockum Aquifers



Prepared for:
Groundwater Management Area 7

Prepared by:
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November 22, 2016

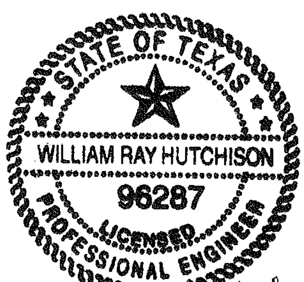
GMA 7 Explanatory Report - Final
Ogallala and Dockum Aquifers

Geoscientist and Engineering Seal

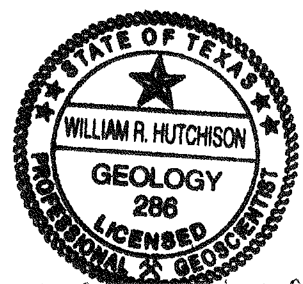
This report documents the work and supervision of work of the following licensed Texas Professional Geoscientist and licensed Texas Professional Engineers:

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

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



William R Hutchison
11/22/2016



William R Hutchison
11/22/2016

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A – Desired Future Conditions Resolution
B – TWDB Pumping Estimates – Dockum Aquifer
C – TWDB Pumping Estimates – Ogallala Aquifer
D – Region F Socioeconomic Impact Report from TWDB

1.0 Groundwater Management Area 7

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

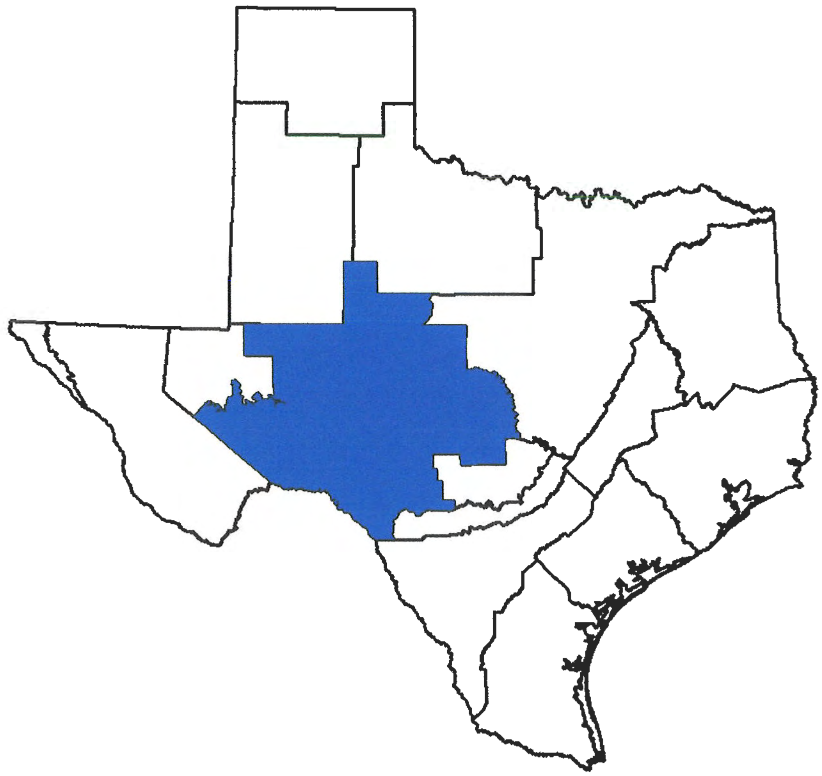

Figure 1. Groundwater Management Area 7

Groundwater Management Area 3 covers all or part of the following counties: Coke, Coleman, Concho, Crockett, Ector, Edwards, Gillespie, Glasscock, Irion, Kimble, Kinney, Llano, Mason, McCulloch, Menard, Midland, Mitchell, Nolan, Pecos, Reagan, Real, Runnels, San Saba, Schleicher, Scurry, Sterling, Sutton, Taylor, Terrell, Tom Green, Upton, and Uvalde (Figure 2).

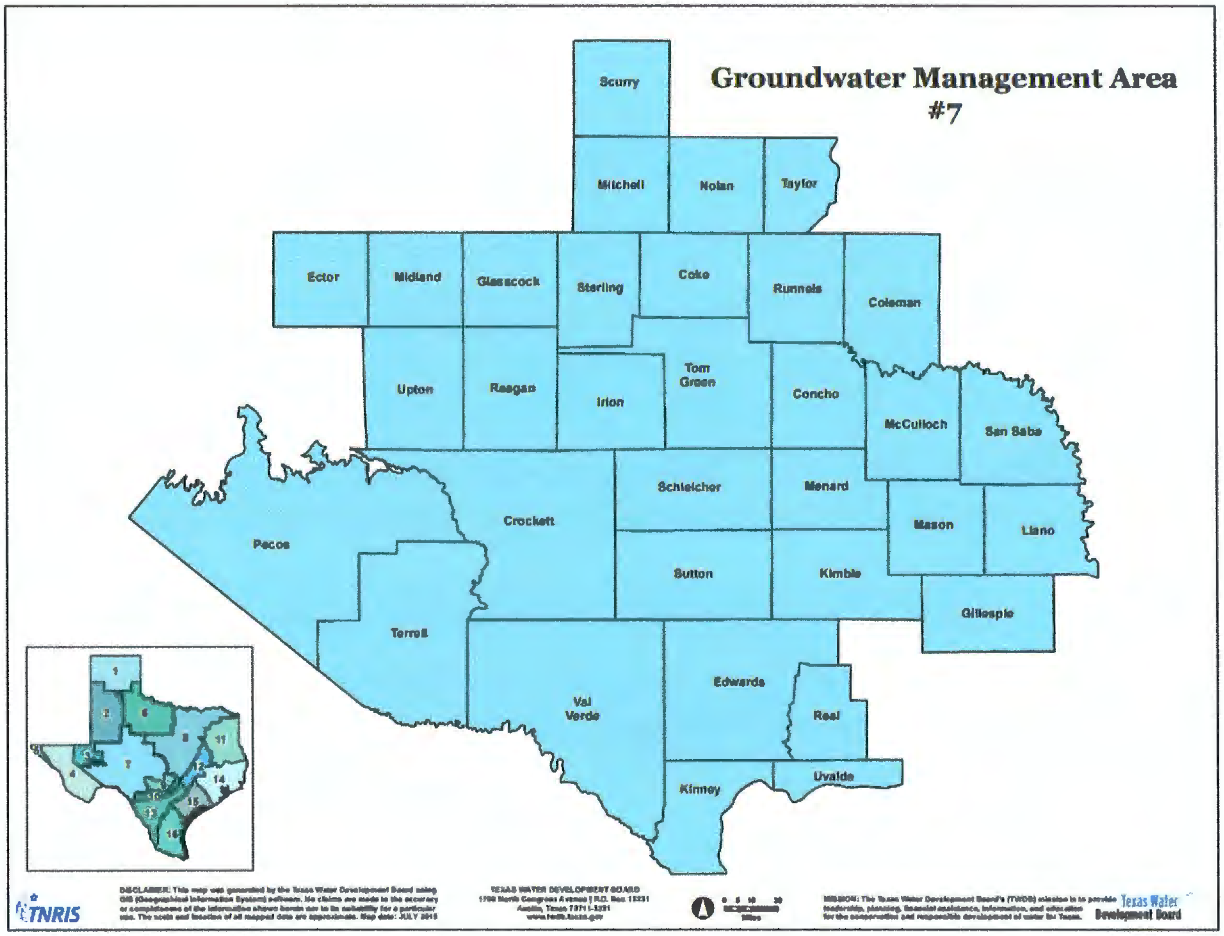

Figure 2. GMA 7 Counties (from TWDB)

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

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

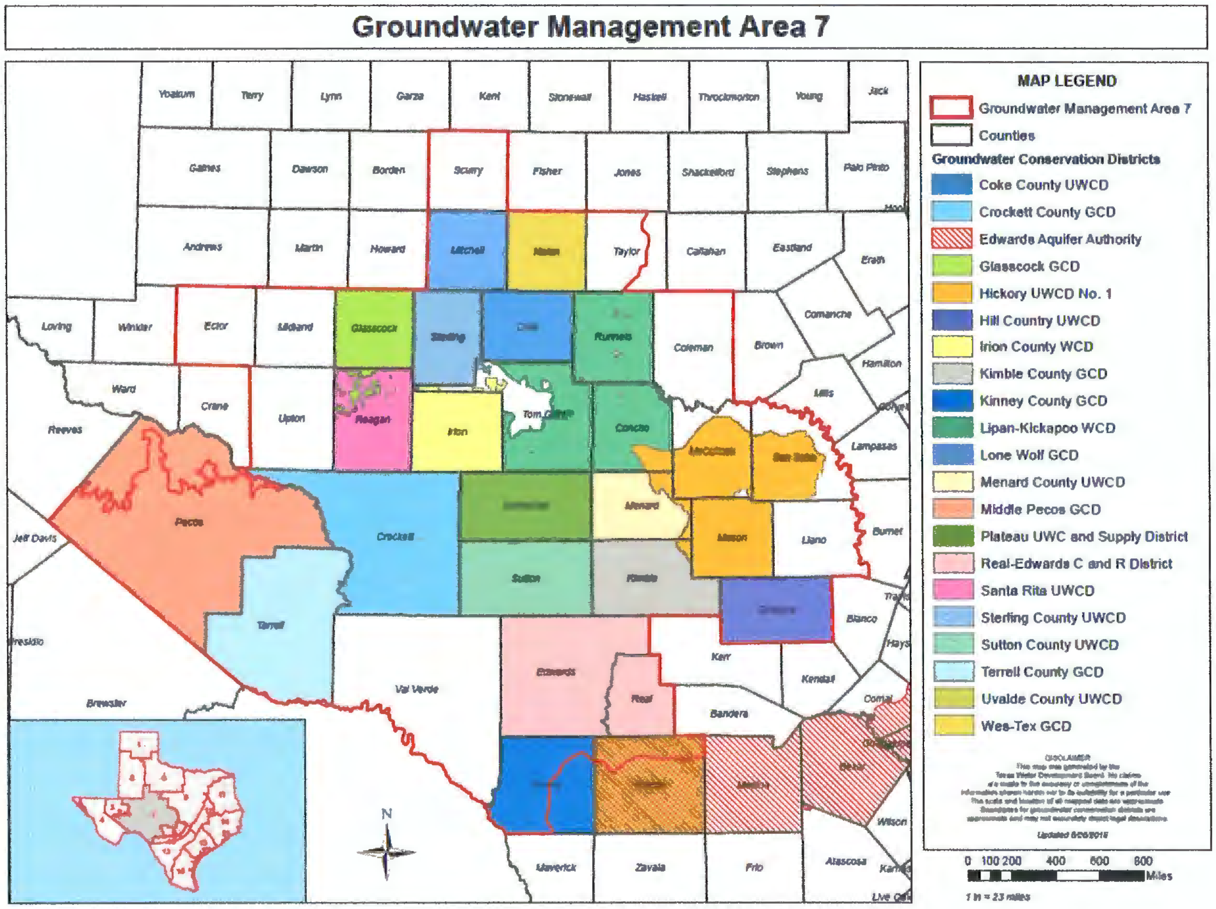

Figure 3. Groundwater Conservation Districts in GMA 7 (from TWDB)

The explanatory report covers the Dockum and Ogallala aquifers. As described in George and others (2011):

> ***The Dockum Aquifer*** *is a minor aquifer found in the northwest part of the state. It is defined stratigraphically by the Dockum Group and includes, from oldest to youngest, the Santa Rosa Formation, the Tecovas Formation, the Trujillo Sandstone, and the Cooper Canyon Formation. The Dockum Group consists of gravel, sandstone, siltstone, mudstone, shale, and conglomerate. Groundwater located in the sandstone and conglomerate units is recoverable, the highest yields coming from the coarsest grained deposits located at the middle and base of the group. Typically, the water-bearing sandstones are locally referred to as the Santa Rosa Aquifer. The water quality in the aquifer is generally poor—with freshwater in outcrop areas in the east and brine in the western subsurface portions of the aquifer—and the water is very hard. Naturally occurring radioactivity from uranium present within the aquifer has resulted in gross alpha radiation in excess of the state's primary drinking water standard. Radium-226 and -228 also occur in amounts above acceptable standards. Groundwater from the aquifer is used for irrigation, municipal water supply, and oil field waterflooding operations, particularly in the southern High Plains. Water level*

declines and rises have occurred in different areas of the aquifer. The regional water planning groups, in their 2006 Regional Water Plans, recommended several water management strategies that use the Dockum Aquifer, including new wells, desalination, and reallocation.

The Ogallala Aquifer *is the largest aquifer in the United States and is a major aquifer of Texas underlying much of the High Plains region. The aquifer consists of sand, gravel, clay, and silt and has a maximum thickness of 800 feet. Freshwater saturated thickness averages 95 feet. Water to the north of the Canadian River is generally fresh, with total dissolved solids typically less than 400 milligrams per liter; however, water quality diminishes to the south, where large areas contain total dissolved solids in excess of 1,000 milligrams per liter. High levels of naturally occurring arsenic, radionuclides, and fluoride in excess of the primary drinking water standards are also present. The Ogallala Aquifer provides significantly more water for users than any other aquifer in the state. The availability of this water is critical to the economy of the region, as approximately 95 percent of groundwater pumped is used for irrigated agriculture. Throughout much of the aquifer, groundwater withdrawals exceed the amount of recharge, and water levels have declined fairly consistently through time. Although water level declines in excess of 300 feet have occurred in several areas over the last 50 to 60 years, the rate of decline has slowed, and water levels have risen in a few areas. The regional water planning groups for the Panhandle and Llano Estacado regions, in their 2006 Regional Water Plans, recommended numerous water management strategies using the Ogallala Aquifer, including drilling new wells, developing well fields, overdrafting, and reallocating supplies.*

2.0 Desired Future Condition

2.1 Existing Desired Future Conditions

GMA 7 adopted a desired future condition for the Ogallala Aquifer on July 29, 2010 as follows:

".. through the year 2060:

1) *Total decline in volume of water within Ector, Glasscock, and Midland counties in the southern portion of the Ogallala aquifer within GMA 7 at the end of the fifty-year period shall not exceed 50 percent of the volume of the aquifer in 2010.*
2) *The Ogallala Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.*

GMA 7 adopted a desired future condition for the Dockum Aquifer on July 29, 2010 as follows:

".. through the year 2060:

1) *Upper Dockum, as delineated in figure 1 of TWDB GAM Run 10-001: net total drawdown not to exceed 29 feet in Midland County; and*
2) *Lower Dockum, as delineated in figure 1 of TWDB GAM Run 10-001: net total drawdown not to exceed 4 feet in Ector, Mitchell, Pecos, Scurry, and Upton Counties (Lone Wolf GCD, Middle Pecos GCD); and*
3) *Lower Dockum Aquifer as delineated in Figure 1 of TWDB GAM Run 10-001: Drawdown not to exceed a net total of 39 feet in Nolan County (Wes-Tex GCD); and*
4) *The Dockum Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.*

The desired future conditions were adopted based on two separate groundwater availability models for the Ogallala and Dockum aquifers. In 2015, the TWDB received a final updated model that includes both the Ogallala and Dockum aquifers (High Plains Aquifer System Groundwater Availability Model, or HPAS).

2.2 High Plains Aquifer System Groundwater Availability Model

The DFCs were developed based on predictive simulations with the recently released High Plains Aquifer System Groundwater Availability Model (Deeds and Jigmond, 2015). The model is also known as the HPAS GAM, or simply the GAM. The GAM includes the Ogallala, Edwards-Trinity (High Plains), and Dockum aquifers.

2.3 Desired Future Condition

The desired future conditions for the Dockum Aquifer in GMA 7 are based on Scenario 17 as described in Technical Memorandum 16-01:

1) Total net drawdown of the Dockum Aquifer not to exceed 14 feet in Reagan County (Santa Rita GCD) in 2070 as compared with 2012 aquifer levels;
2) Total net drawdown of the Dockum Aquifer not to exceed 52 feet in Pecos County (Middle Pecos GCD) in 2070 as compared with 2012 aquifer levels; and
3) The Dockum Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.

The desired future conditions for the Ogallala Aquifer in GMA 7 are based on Scenario 10 as described in Technical Memorandum 16-01:

1) Total net drawdown of the Ogallala Aquifer in Glasscock County (Glasscock GCD) in 2070, as compared with 2012 aquifer levels, not to exceed 6 feet; and
2) The Ogallala Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.

The resolution adopted for the desired future conditions is presented in Appendix A. Please note that the Pecos County DFC covers all of Pecos County (GMA 3 and GMA 7 portions).

2.4 Discussion of Changes to Desired Future Conditions from 2010 to 2016.

The desired future conditions that have been adopted by GMA 7 for the Dockum and Ogallala aquifers relied on a new model (HPAS GAM). The new GAM is an updated tool that replaces the old Ogallala Aquifer GAM and the alternative GAM for the Dockum Aquifer that were the basis for the current DFC and MAG. However, use of this new tool and the updated information that it yields have resulted in changes to the DFCs and MAGs from 2010. Many of the changes are simply reflective of the updated model. These changes to the DFC and/or the MAG could be easily misinterpreted and misused.

2.4.1 Ogallala Aquifer

An example of this is the recently released report by TWDB (Hermitte and others, 2015). This report summarizes differences between 2012 State Water Plan groundwater availability numbers and the MAGs developed from the DFCs that were adopted in 2010. There are many reasons for the noted differences, but Hermitte and others (2015) provided no context to the changes. In fact, there was no opportunity for stakeholders to provide comments to this report, it simply was published. In many cases, the differences are directly attributable to updates in models, and the improved understanding that is the result of updating a model. However, the data and comparisons in this report provide opportunities to mischaracterize these differences as simple policy choices to reduce groundwater availability. It is unfortunate that Hermitte and others (2015) chose not to provide context to their comparisons, and leave so much room for misinterpretation of a complex process that relies on imperfect models.

In this case, the updated simulations of the Ogallala Aquifer were designed to evaluate the effects of a declining saturated thickness on well pumping rates. In reviewing the results and comparing them to the results of model runs using the old model in 2010, it is apparent that the MAG from 2010 reflects a large increase in pumping in Glasscock County during the first several years of the simulation to achieve an arbitrary 50/50 standard. Scenario 10 (on which the Glasscock County DFC is established assumed that the pumping in the first year of the simulation is 150 percent of the current pumping (a significant increase). Essentially, the achievement of an arbitrary 50/50 DFC would require an immediate increase in pumping that could not be sustained over the first few years of the simulation period. The new model shows the decrease in pumping associated with the declining groundwater levels, and is a more realistic simulation of what could occur in the future.

2.4.2 Dockum Aquifer

The Dockum Aquifer includes a DFC for Pecos County that is includes all of Pecos County in both GMA 3 and GMA 7. In 2010, the DFC was adopted separately for GMA 3 and GMA 7.

Also, in 2010, the Dockum Aquifer was classified as not relevant for purposes of joint planning in Reagan County. In 2016, a DFC has been established for Reagan County.

Other areas of GMA 7 (specifically Ector, Midland, Mitchell, Nolan, Scurry, and Upton counties) had DFCs in 2010, and are now classified as not relevant for purposes of joint planning. The new model was released in preliminary form in the spring of 2015, and comments were submitted prior to finalizing the model and its report in August 2015.

Appendix D of the final report on the numerical model included comments and responses to the draft model. In summary, some changes were made to the aquifer parameters in Mitchell County, but only to make the numerical model consistent with the previously released conceptual model. No changes were made to recharge in the final model, which means that recharge is assumed constant every year (no variation with variation in precipitation). The assumed constant recharge was also deemed consistent with the conceptual model.

On pages D-26 and D-27 of the final report, the basis for the assumed constant recharge is summarized. Essentially, the Bureau of Economic Geology completed an analysis of the entire model area, which was focused on the Ogallala region in the panhandle region of Texas, and concluded that rises in groundwater levels are due to "post development-recharge rates" that are different due to changed land use conditions, not precipitation.

On page D-28, in response to comments about the model's calibration, there is a response that acknowledges that some groundwater level recoveries are not simulated by the model. However, the authors of the report state that simulation of those recoveries would require a "point-calibration" to pumping or recharge, and state that such an effort would not improve the confidence in the model or improve its predictive capability. Based on these statements, the authors were focused on the regional aspects of the model only. While the calibration of the model is within industry standards, and may be useful for regional simulations of the Ogallala Aquifer over the entire areas of the model domain, it is not suitable to simulate conditions in the eastern areas of the Dockum, especially Mitchell and Nolan counties.

In general, the classification of portions of an aquifer as not relevant for purposes of joint planning are made when the area of an aquifer is small, when uses are insignificant, or where the management and regulation of groundwater in one GCD would not affect neighboring GCDs. Another way to view joint planning is that DFCs should be set only for those areas where impacts of pumping would cross GCD boundaries.

From a regional perspective, the HPAS is an adequate model (as defined by the TWDB through its acceptance of the model). Based on model results, pumping in Mitchell County and Nolan County does not impact surrounding counties. Given the lack of interaction between counties, the Dockum Aquifer has been classified as not relevant for purposes of joint planning in these counties.

3.0 Policy Justification

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

- Aquifer uses and conditions within Groundwater Management Area 7
- Water supply needs and water management strategies included in the 2012 State Water Plan
- Hydrologic conditions within Groundwater Management Area 7 including total estimated recoverable storage, average annual recharge, inflows, and discharge
- Other environmental impacts, including spring flow and other interactions between groundwater and surface water
- The impact on subsidence
- Socioeconomic impacts reasonably expected to occur
- The impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in Groundwater Management Area 7 in groundwater as recognized under Texas Water Code Section 36.002
- The feasibility of achieving the desired future condition
- Other information

In addition, the proposed desired future condition provides a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater in Groundwater Management Area 7.

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

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

4.0 Technical Justification

The process of using the groundwater model in developing desired future conditions revolves around the concept of incorporating many of the elements of the nine factors (e.g. current uses and water management strategies in the regional plan). For the Dockum and Ogallala aquifers, 17 scenarios were completed, and the results discussed prior to adopting a desired future condition.

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

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

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

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

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

5.0 Factor Consideration

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

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

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

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

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

5.1 Groundwater Demands and Uses

County-level groundwater demands and uses from 2000 to 2012 for the Dockum Aquifer are presented in Appendix B. County-level groundwater demands and uses from 2000 to 2012 for the Ogallala Aquifer are presented in Appendix C. Data were obtained from the Texas Water Development Board historic pumping database:

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

These data, and a comparison to current modeled available groundwater numbers were discussed at the GMA 7 meeting of December 18, 2014 in San Angelo, Texas.

5.2 Groundwater Supply Needs and Strategies

The 2016 Region F Plan lists county-by-county shortages and strategies. Shortages are identified when current supplies (e.g. existing wells) cannot meet future demands. Strategies are then recommended (e.g. new wells) to meet the future demands. No strategies are listed for the Ogallala or Dockum aquifers in GMA 7.

5.3 Hydrologic Conditions, including Total Estimated Recoverable Storage

The groundwater budget for the GMA 7 portion of the Dockum Aquifer for the calibration period of the HPAS (1929 to 2012) is presented in Table 1 along with the groundwater budget for the predictive period (2013 to 2070) under Scenario 17, the basis for the adopted desired future condition.

Table 1. Groundwater Budget for the GMA 7 Portion of the Dockum Aquifer

Inflow	1929 to 2012 Average (AF/yr)	2013 to 2070 Average (AF/yr)
Recharge from Precipitation	21,012	27,986
Inflow from Overlying Formations	5,645	7,026
Inflow from GMA 2	640	674
Total Inflow	27,297	35,686
Outflow		
Pumping	8,478	35,724
Spring Flow	3,125	3,597
Outflow to Surface Water and Boundary Outflow	11,359	11,883
Evapotranspiration	4,961	5,846
Outflow to GMA 3	1,838	1,389
Outflow to GMA 6	342	323
Total Outflow	30,104	58,761
Inflow - Outflow	-2,807	-23,075
Model Estimated Storage Change	-2,807	-23,075
Model Error	0	0

The groundwater budget for the GMA 7 portion of the Ogallala Aquifer for the calibration period of the HPAS (1929 to 2012) is presented in Table 2 along with the groundwater budget for the predictive period (2013 to 2070) under Scenario 10, the basis for the adopted desired future condition.

Table 2. Groundwater Budget for the GMA 7 Portion of the Ogallala Aquifer

Inflow	1929 to 2012 Average (AF/yr)	2013 to 2070 Average (AF/yr)
Recharge from Precipitation	3,555	7,670
Inflow from GMA 2	1,750	2,432
Inflow from Surface Water and Boundary Outflow	N/A	1,621
Total Inflow	5,305	11,723
Outflow		
Pumping	16,447	22,585
Spring Flow	617	528
Outflow to Surface Water and Boundary Outflow	34,205	N/A
Evapotranspiration	2,538	1,371
Outflow to GMA 3	1,855	986
Outflow to GMA 6	20	20
Outflow to Underlying Formations	5,645	7,026
Total Outflow	61,327	32,516
Inflow - Outflow	-56,021	-20,793
Model Estimated Storage Change	-56,021	-20,793
Model Error	0	0

Table 3 presents the total estimated recoverable storage for the GMA 7 portion of the Dockum Aquifer. Table 4 presents the total estimated recoverable storage for the GMA 7 portion of the Ogallala Aquifer.

Table 3. Total Estimated Recoverable Storage - Dockum Aquifer

County	Total Storage (acre-feet)	25 percent of Total Storage (acre-feet)	75 percent of Total Storage (acre-feet)
Coke	520,000	130,000	390,000
Crockett	14,000,000	3,500,000	10,500,000
Ector	100,000,000	25,000,000	75,000,000
Glasscock	11,000,000	2,750,000	8,250,000
Irion	9,100,000	2,275,000	6,825,000
Midland	10,000,000	2,500,000	7,500,000
Mitchell	27,000,000	6,750,000	20,250,000
Nolan	2,100,000	525,000	1,575,000
Pecos	2,500,000	625,000	1,875,000
Reagan	17,000,000	4,250,000	12,750,000
Scurry	32,000,000	8,000,000	24,000,000
Sterling	33,000,000	8,250,000	24,750,000
Tom Green	1,100,000	275,000	825,000
Upton	9,300,000	2,325,000	6,975,000
Total	268,620,000	67,155,000	201,465,000

Table 4. Total Estimated Recoverable Storage - Ogallala Aquifer

County	Total Storage (acre-feet)	25 percent of Total Storage (acre-feet)	75 percent of Total Storage (acre-feet)
Ector	840,000	210,000	630,000
Glasscock	2,000,000	500,000	1,500,000
Midland	3,500,000	875,000	2,625,000
Total	6,340,000	1,585,000	4,755,000

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

Tables 1 and 2 above includes groundwater budget estimates of spring flow and surface water interactions with groundwater for the Dockum and Ogallala aquifers as estimated by the HPAS GAM.

5.5 Subsidence

Subsidence is not an issue in the Dockum and Ogallala aquifers in GMA 7.

5.6 Socioeconomic Impacts

The Texas Water Development Board prepared reports on the socioeconomic impacts of not meeting water needs for each of the Regional Planning Groups during development of the 2011

Regional Water Plans. Because the development of this desired future condition used the State Water Plan demands and water management strategies as an important foundation, it is reasonable to conclude that the socioeconomic impacts associated with this proposed desired future condition can be evaluated in the context of not meeting the listed water management strategies. Groundwater Management Area 7 is covered by Regional Planning Group F. The socioeconomic impact report for Regions F is included in Appendix D.

5.7 Impact on Private Property Rights

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

The desired future conditions adopted by GMA 7 are consistent with protecting property rights of landowners who are currently pumping groundwater and landowners who have chosen to conserve groundwater by not pumping. All current and projected uses (as defined in the 2015 Region F plan) can be met based on the simulations. In addition, the pumping associated with achieving the desired future condition (the modeled available groundwater) will cause impacts to exiting well owners and to surface water. However, as required by Chapter 36 of the Water Code, GMA 7 considered these impacts and balanced them with the increasing demand of water in the GMA 7 area, and concluded that, on balance and with appropriate monitoring and project specific review during the permitting process, the desired future condition is consistent with protection of private property rights.

5.8 Feasibility of Achieving the Desired Future Condition

Groundwater levels are routinely monitored by the districts and by the TWDB in GMA 7. Evaluating the monitoring data is a routine task for the districts, and the comparison of these data with the model results that were used to develop the DFCs is covered in each district's management plan. These comparisons will be useful to guide the update of the DFCs that are required every five years.

5.9 Other Information

GMA 7 did not consider any other information in developing the DFCs.

6.0 Discussion of Other Desired Future Conditions Considered

There were 16 GAM scenarios completed that included a range of future pumping scenarios that were based on historic use (Scenarios 1 to 15). After review of those results, GMA 7 representatives expressed a desire to evaluate a simulation based on pumping that was consistent with the current modeled available groundwater, and included establishing a DFC in Reagan County. This scenario was labeled Scenario 17. Scenario 16 using the HPAS was used in simulations for GMA 2.

Results of the first 15 scenarios were presented and discussed at the GMA 7 meeting of January 14, 2016. Scenario 17 results were presented and discussed at the April 21, 2016 GMA 7 meeting. Results of all scenarios were summarized on Technical Memorandum 16-01.

7.0 Discussion of Other Recommendations

Public comments were invited and each district held a public hearing on the proposed desired future condition for aquifers within their boundaries. Since the DFC for the Ogallala Aquifer was only established for Glasscock County, the Glasscock GCD is the only district that held a public hearing for this DFC. Since DFCs were only established for Pecos and Reagan counties, the only districts to hold public hearings were Middle Pecos GCD and Santa Rita GCD. Dates of the public hearings are summarized below:

Groundwater Conservation District	Date of Public Hearing	Number of Comments Received
Glasscock GCD	July 22, 2016	None
Middle Pecos GCD	July 19, 2016	None
Santa Rita UWCD	July 19, 2016	None

No comments (oral or written) were received on the desired future conditions for the Ogallala and Dockum aquifers.

8.0 References

Bradley, R.G., 2011, GTA Aquifer Assessment 10-13 MAG. Texas Water Development Board, Groundwater Technical Assistance Section, November 18, 2011, 8p.

Ewing, J.E., Kelley, V.A., Jones, T.L., Yan, T., Singh, A., Powers, D.W., Holt, R.M., and Sharp, J.M., 2012. Final Groundwater Availability Model Report for the Rustler Aquifer. Prepared for the Texas Water Development Board, 460p.

Hermitte, S.M., Backhouse S., Kalaswad, S., and Mace, R.E., 2015. Groundwater Availability in Texas: Comparing Estimates from the 2012 State Water Plan and Desired Future Conditions. Texas Water Development Board Technical Note 15-05. August 2015, 102p.

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

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

Appendix A

Desired Future Conditions Resolution

STATE OF TEXAS §

RESOLUTION # 09-22-2016-3

GROUNDWATER §
MANAGEMENT AREA 7 §

Resolution Adopting Desired Future Conditions For the Dockum Aquifer in Groundwater Management Area 7

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

WHEREAS, the Board Presidents or their Designated Representatives of GCDs in GMA 7 have met in various meetings and conducted joint planning in accordance with §36.108, Texas Water Code since September 2011; and

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

WHEREAS, the member GCDs of GMA 7, having given proper and timely notice, held an open meeting on April 21, 2016 at the Hill Country University located at 2818 E U.S. Highway 290, Fredericksburg, Texas, to vote to adopt proposed Desired Future Conditions for the Dockum Aquifer within the boundaries of GMA 7; and

WHEREAS, the member GCDs in which the Dockum Aquifer is relevant for joint planning purposes held open meetings within each said district between May 13, 2016 and August 11, 2016 to take public comment on the proposed DFCs for that district; and

WHEREAS on this day of September 22, 2016, at an open meeting duly noticed and held in accordance with law at the Texas A & M Agrilife Research and Extension Center, 7887 U. S. Highway 87 North, San Angelo, Texas , the GCDs within GMA 7, having considered at this meeting comments submitted to the individual districts during the comment period and at this meeting, have voted, 20 districts in favor, 0 districts opposed, to adopt the following DFCs for Dockum Aquifer in the following counties and districts through the year 2070 as follows:

a) Total net drawdown of the Dockum Aquifer not to exceed 14 feet in Reagan County (Santa Rita GCD) in 2070, as compared with 2012 aquifer levels.
b) Total net drawdown of the Dockum Aquifer not to exceed 52 feet in Pecos County (Middle Pecos GCD) in 2070 as compared with 2012 aquifer levels.
c) The Dockum Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.

NOW THEREFORE BE IT RESOLVED, that Groundwater Management Area 7 does hereby document, record, and confirm the above-described Desired Future Conditions for the Dockum Aquifer which were adopted by vote of the following Designated Representatives of Groundwater Conservation Districts present and voting on September 22, 2016:

Ayes:

DESIGNATED REPRESENTATIVE - COKE COUNTY UWCD

DESIGNATED REPRESENTATIVE - CROCKETT COUNTY GCD

DESIGNATED REPRESENTATIVE - GLASSCOCK GCD

DESIGNATED REPRESENTATIVE - HICKORY UWCD #1

DESIGNATED REPRESENTATIVE - HILL COUNTRY UWCD

DESIGNATED REPRESENTATIVE - IRION COUNTY WCD

DESIGNATED REPRESENTATIVE - KIMBLE COUNTY GCD

DESIGNATED REPRESENTATIVE - KINNEY COUNTY GCD

DESIGNATED REPRESENTATIVE - LIPAN-KICKAPOO WCD

DESIGNATED REPRESENTATIVE - LONE WOLF GCD

DESIGNATED REPRESENTATIVE - MENARD COUNTY UWD

DESIGNATED REPRESENTATIVE - MIDDLE PECOS GCD

DESIGNATED REPRESENTATIVE - PLATEAU UWC & SD

DESIGNATED REPRESENTATIVE - REAL-EDWARDS CON & REC DIST

DESIGNATED REPRESENTATIVE - SANTA RITA UWCD

DESIGNATED REPRESENTATIVE - STERLING COUNTY UWCD

DESIGNATED REPRESENTATIVE - SUTTON COUNTY UWCD

DESIGNATED REPRESENTATIVE - UVALDE COUNTY WCD

DESIGNATED REPRESENTATIVE - WES-TEX GCD

Nays:

DESIGNATED REPRESENTATIVE -

DESIGNATED REPRESENTATIVE -

STATE OF TEXAS §

RESOLUTION # 09-22-2016-7

GROUNDWATER §
MANAGEMENT AREA 7 §

Resolution Adopting Desired Future Conditions for the Ogallala Aquifer in Groundwater Management Area 7

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

WHEREAS, the Board Presidents or their Designated Representatives of GCDs in GMA 7 have met in various meetings and conducted joint planning in accordance with §36.108, Texas Water Code since September 2011; and

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

WHEREAS, the member GCDs of GMA 7, having given proper and timely notice, held an open meeting on April 21, 2016 at the Hill Country University located at 2818 E U.S. Highway 290, Fredericksburg, Texas, to vote to adopt proposed Desired Future Conditions for the Ogallala Aquifer within the boundaries of GMA 7; and

WHEREAS, the member GCDs in which the Ogallala Aquifer is relevant for joint planning purposes held open meetings within each said district between May 13, 2016 and August 11, 2016 to take public comment on the proposed DFCs for that district; and

WHEREAS on this day of September 22, 2016, at an open meeting duly noticed and held in accordance with law at the Texas A & M Agrilife Research and Extension Center, 7887 U. S. Highway 87 North, San Angelo, Texas , the GCDs within GMA 7, having considered at this meeting comments submitted to the individual districts during the comment period and at this meeting, have voted, 20 districts in favor, 0 districts opposed, to adopt the following DFCs for the Ogallala Aquifer in the following counties and districts through the year 2070 as follows:

a) Total net decline of the Ogallala Aquifer in Glasscock County (Glasscock GCD) in 2070, as compared with 2012 aquifer levels, not to exceed 6 feet; (Reference: GMA 7 Technical Memo 16-01, 1-8-2016)

b) The Ogallala Aquifer is not relevant for joint planning purposes in all other areas of GMA 7.

NOW THEREFORE BE IT RESOLVED, that Groundwater Management Area 7 does hereby document, record, and confirm the above-described Desired Future Conditions for the Ogallala Aquifer which were adopted by vote of the following Designated Representatives of Groundwater Conservation Districts present and voting on September 22, 2016:

Ayes:

DESIGNATED REPRESENTATIVE - COKE COUNTY UWCD

DESIGNATED REPRESENTATIVE - CROCKETT COUNTY GCD

DESIGNATED REPRESENTATIVE - GLASSCOCK GCD

DESIGNATED REPRESENTATIVE - [redacted] UWCD #1
HICKORY

DESIGNATED REPRESENTATIVE - HILL COUNTRY UWCD

DESIGNATED REPRESENTATIVE - IRION COUNTY WCD

DESIGNATED REPRESENTATIVE - KIMBLE COUNTY GCD

DESIGNATED REPRESENTATIVE -KINNEY COUNTY GCD

DESIGNATED REPRESENTATIVE- LIPAN-KICKAPOO WCD

DESIGNATED REPRESENTATIVE - LONE WOLF GCD

DESIGNATED REPRESENTATIVE - MENARD COUNTY UWD

DESIGNATED REPRESENTATIVE - MIDDLE PECOS GCD

DESIGNATED REPRESENTATIVE - PLATEAU UWC & SD

DESIGNATED REPRESENTATIVE - REAL-EDWARDS CON & REC DIST

DESIGNATED REPRESENTATIVE - SANTA RITA UWCD

DESIGNATED REPRESENTATIVE - STERLING COUNTY UWCD

DESIGNATED REPRESENTATIVE - SUTTON COUNTY UWCD

DESIGNATED REPRESENTATIVE - UVALDE COUNTY WCD

DESIGNATED REPRESENTATIVE - WES-TEX GCD

Designated Representative - Hickory UWCD

Nays:

DESIGNATED REPRESENTATIVE -

DESIGNATED REPRESENTATIVE -

Appendix B

TWDB Pumping Estimates – Dockum Aquifer

Appendix B
TWDB Pumping Estimates - Dockum Aquifer

Year	County	Aquifer	Municipal	Manufacturing	Irrigation	Livestock	Total
2000	ECTOR	DOCKUM AQUIFER	1,011	12	0	14	1,037
2001	ECTOR	DOCKUM AQUIFER	0	12	0	6	18
2003	ECTOR	DOCKUM AQUIFER	321	12	0	4	337
2004	ECTOR	DOCKUM AQUIFER	452	13	0	1	466
2005	ECTOR	DOCKUM AQUIFER	452	212	0	4	668
2006	ECTOR	DOCKUM AQUIFER	504	212	0	4	720
2007	ECTOR	DOCKUM AQUIFER	495	44	0	4	543
2008	ECTOR	DOCKUM AQUIFER	501	84	0	2	587
2009	ECTOR	DOCKUM AQUIFER	534	7	0	2	543
2010	ECTOR	DOCKUM AQUIFER	567	9	0	4	580
2011	ECTOR	DOCKUM AQUIFER	615	12	0	4	631
2012	ECTOR	DOCKUM AQUIFER	578	13	0	3	594
2000	IRION	DOCKUM AQUIFER	0	0	0	1	1
2001	IRION	DOCKUM AQUIFER	0	0	0	1	1
2002	IRION	DOCKUM AQUIFER	0	0	0	1	1
2003	IRION	DOCKUM AQUIFER	0	0	0	0	0
2004	IRION	DOCKUM AQUIFER	0	0	0	0	0
2005	IRION	DOCKUM AQUIFER	0	0	0	1	1
2006	IRION	DOCKUM AQUIFER	1	0	0	1	2
2007	IRION	DOCKUM AQUIFER	1	0	0	1	2
2008	IRION	DOCKUM AQUIFER	1	0	0	1	2
2009	IRION	DOCKUM AQUIFER	1	0	0	1	2
2010	IRION	DOCKUM AQUIFER	1	0	0	1	2
2011	IRION	DOCKUM AQUIFER	1	0	0	1	2
2012	IRION	DOCKUM AQUIFER	1	0	0	1	2
2000	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2001	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2002	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2003	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2004	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2005	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2006	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2007	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2008	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2009	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2010	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2011	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2012	MIDLAND	DOCKUM AQUIFER	0	0	0	1	1
2000	MITCHELL	DOCKUM AQUIFER	954	0	5,549	42	6,545
2001	MITCHELL	DOCKUM AQUIFER	1,340	0	3,423	40	4,803
2002	MITCHELL	DOCKUM AQUIFER	1,882	0	3,670	33	5,585
2003	MITCHELL	DOCKUM AQUIFER	1,616	0	5,188	28	6,832
2004	MITCHELL	DOCKUM AQUIFER	1,609	0	5,826	24	7,459
2005	MITCHELL	DOCKUM AQUIFER	1,616	0	5,931	61	7,608
2006	MITCHELL	DOCKUM AQUIFER	1,537	0	7,306	61	8,904
2008	MITCHELL	DOCKUM AQUIFER	1,310	0	8,092	82	9,484
2009	MITCHELL	DOCKUM AQUIFER	1,278	0	11,575	75	12,928
2010	MITCHELL	DOCKUM AQUIFER	1,385	0	9,443	79	10,907
2011	MITCHELL	DOCKUM AQUIFER	1,309	0	10,146	82	11,537
2012	MITCHELL	DOCKUM AQUIFER	1,636	0	15,745	65	17,446

Appendix B
TWDB Pumping Estimates - Dockum Aquifer

Year	County	Aquifer	Municipal	Manufacturing	Irrigation	Livestock	Total
2000	NOLAN	DOCKUM AQUIFER	278	0	3,313	10	3,601
2001	NOLAN	DOCKUM AQUIFER	247	0	1,925	5	2,177
2002	NOLAN	DOCKUM AQUIFER	248	0	1,942	5	2,195
2003	NOLAN	DOCKUM AQUIFER	246	0	2,142	3	2,391
2004	NOLAN	DOCKUM AQUIFER	243	0	4,105	4	4,352
2005	NOLAN	DOCKUM AQUIFER	266	0	5,313	50	5,629
2006	NOLAN	DOCKUM AQUIFER	260	0	5,166	57	5,483
2007	NOLAN	DOCKUM AQUIFER	222	0	5,736	54	6,012
2008	NOLAN	DOCKUM AQUIFER	237	0	10,030	57	10,324
2009	NOLAN	DOCKUM AQUIFER	251	0	11,128	54	11,433
2010	NOLAN	DOCKUM AQUIFER	262	0	7,990	48	8,300
2011	NOLAN	DOCKUM AQUIFER	314	0	12,145	49	12,508
2012	NOLAN	DOCKUM AQUIFER	433	0	12,349	43	12,825
2000	REAGAN	DOCKUM AQUIFER	0	0	84	10	94
2001	REAGAN	DOCKUM AQUIFER	0	0	62	8	70
2002	REAGAN	DOCKUM AQUIFER	0	0	79	8	87
2003	REAGAN	DOCKUM AQUIFER	0	0	53	5	58
2004	REAGAN	DOCKUM AQUIFER	0	0	39	0	39
2005	REAGAN	DOCKUM AQUIFER	0	0	47	1	48
2006	REAGAN	DOCKUM AQUIFER	0	0	71	1	72
2007	REAGAN	DOCKUM AQUIFER	0	0	65	1	66
2008	REAGAN	DOCKUM AQUIFER	0	0	74	1	75
2009	REAGAN	DOCKUM AQUIFER	0	0	63	1	64
2010	REAGAN	DOCKUM AQUIFER	0	0	74	1	75
2011	REAGAN	DOCKUM AQUIFER	0	0	100	1	101
2012	REAGAN	DOCKUM AQUIFER	0	0	75	1	76
2000	SCURRY	DOCKUM AQUIFER	658	0	2,660	32	3,350
2001	SCURRY	DOCKUM AQUIFER	771	0	1,929	16	2,716
2002	SCURRY	DOCKUM AQUIFER	701	0	2,943	15	3,659
2003	SCURRY	DOCKUM AQUIFER	544	0	2,440	15	2,999
2004	SCURRY	DOCKUM AQUIFER	588	0	2,894	23	3,505
2005	SCURRY	DOCKUM AQUIFER	638	0	3,586	108	4,332
2006	SCURRY	DOCKUM AQUIFER	995	0	5,623	121	6,739
2007	SCURRY	DOCKUM AQUIFER	829	0	4,537	120	5,486
2008	SCURRY	DOCKUM AQUIFER	777	0	3,868	112	4,757
2009	SCURRY	DOCKUM AQUIFER	852	0	7,439	91	8,382
2010	SCURRY	DOCKUM AQUIFER	817	0	5,857	132	6,806
2011	SCURRY	DOCKUM AQUIFER	831	0	6,936	141	7,908
2012	SCURRY	DOCKUM AQUIFER	878	0	9,139	97	10,114
2000	STERLING	DOCKUM AQUIFER	0	0	0	8	8
2001	STERLING	DOCKUM AQUIFER	0	0	0	11	11
2002	STERLING	DOCKUM AQUIFER	0	0	0	9	9
2003	STERLING	DOCKUM AQUIFER	0	0	0	6	6
2004	STERLING	DOCKUM AQUIFER	0	0	0	6	6
2005	STERLING	DOCKUM AQUIFER	0	0	0	7	7
2006	STERLING	DOCKUM AQUIFER	1	0	0	8	9
2009	STERLING	DOCKUM AQUIFER	1	0	0	7	8
2010	STERLING	DOCKUM AQUIFER	1	0	0	6	7
2011	STERLING	DOCKUM AQUIFER	1	0	0	6	7
2012	STERLING	DOCKUM AQUIFER	1	0	0	6	7

Appendix B
TWDB Pumping Estimates - Dockum Aquifer

Year	County	Aquifer	Municipal	Manufacturing	Irrigation	Livestock	Total
2000	UPTON	DOCKUM AQUIFER	0	0	99	18	117
2001	UPTON	DOCKUM AQUIFER	0	0	68	10	78
2002	UPTON	DOCKUM AQUIFER	0	0	63	9	72
2003	UPTON	DOCKUM AQUIFER	0	0	62	6	68
2004	UPTON	DOCKUM AQUIFER	0	0	55	4	59
2005	UPTON	DOCKUM AQUIFER	0	0	52	9	61
2006	UPTON	DOCKUM AQUIFER	4	0	57	9	70
2007	UPTON	DOCKUM AQUIFER	3	0	48	9	60
2008	UPTON	DOCKUM AQUIFER	4	0	71	0	75
2009	UPTON	DOCKUM AQUIFER	5	0	62	0	67
2010	UPTON	DOCKUM AQUIFER	7	0	150	7	164
2011	UPTON	DOCKUM AQUIFER	6	0	219	7	232
2012	UPTON	DOCKUM AQUIFER	6	0	160	6	172

Appendix C

TWDB Pumping Estimates – Ogallala Aquifer

Appendix C
TWDB Pumping Estimates - Ogallala Aquifer

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2000	ECTOR	OGALLALA AQUIFER	3,358	0	0	0	2,390	8	5,756
2001	ECTOR	OGALLALA AQUIFER	5,101	0	0	0	3,284	5	8,390
2002	ECTOR	OGALLALA AQUIFER	3,173	0	0	0	3,081	4	6,258
2003	ECTOR	OGALLALA AQUIFER	0	0	0	0	913	3	916
2004	ECTOR	OGALLALA AQUIFER	0	0	0	0	337	3	340
2005	ECTOR	OGALLALA AQUIFER	0	0	0	0	432	10	442
2006	ECTOR	OGALLALA AQUIFER	91	0	0	0	8	9	108
2007	ECTOR	OGALLALA AQUIFER	76	0	0	0	80	10	166
2008	ECTOR	OGALLALA AQUIFER	86	0	0	0	0	11	97
2009	ECTOR	OGALLALA AQUIFER	965	0	0	0	0	12	977
2010	ECTOR	OGALLALA AQUIFER	614	0	0	0	302	10	926
2011	ECTOR	OGALLALA AQUIFER	429	0	0	0	142	10	581
2012	ECTOR	OGALLALA AQUIFER	629	0	0	0	40	8	677
2000	GLASSCOCK	OGALLALA AQUIFER	3	0	0	0	4,567	22	4,592
2001	GLASSCOCK	OGALLALA AQUIFER	3	0	0	0	3,317	22	3,342
2002	GLASSCOCK	OGALLALA AQUIFER	2	0	0	0	3,400	20	3,422
2003	GLASSCOCK	OGALLALA AQUIFER	2	0	0	0	5,808	16	5,826
2004	GLASSCOCK	OGALLALA AQUIFER	2	0	0	0	5,706	24	5,732
2005	GLASSCOCK	OGALLALA AQUIFER	2	0	0	0	5,697	31	5,730
2006	GLASSCOCK	OGALLALA AQUIFER	19	0	0	0	5,999	34	6,052
2007	GLASSCOCK	OGALLALA AQUIFER	16	0	0	0	4,871	46	4,933
2008	GLASSCOCK	OGALLALA AQUIFER	18	0	0	0	5,523	24	5,565
2009	GLASSCOCK	OGALLALA AQUIFER	18	0	0	0	5,906	25	5,949
2010	GLASSCOCK	OGALLALA AQUIFER	18	0	0	0	7,363	30	7,411
2011	GLASSCOCK	OGALLALA AQUIFER	21	0	0	0	6,859	34	6,914
2012	GLASSCOCK	OGALLALA AQUIFER	19	0	0	0	5,821	24	5,864
2004	MASON	OGALLALA AQUIFER	89	0	0	0	0	0	89
2005	MASON	OGALLALA AQUIFER	95	0	0	0	0	0	95
2000	MIDLAND	OGALLALA AQUIFER	1,988	109	0	0	15,234	89	17,420
2001	MIDLAND	OGALLALA AQUIFER	1,502	3	551	0	13,786	89	15,931
2002	MIDLAND	OGALLALA AQUIFER	2,068	0	1,093	0	13,029	77	16,267
2003	MIDLAND	OGALLALA AQUIFER	5,252	0	652	0	9,587	41	15,532
2004	MIDLAND	OGALLALA AQUIFER	4,803	0	740	0	9,227	56	14,826
2005	MIDLAND	OGALLALA AQUIFER	4,062	0	749	0	9,879	108	14,798
2006	MIDLAND	OGALLALA AQUIFER	4,987	0	0	0	10,836	129	15,952
2007	MIDLAND	OGALLALA AQUIFER	2,140	0	585	0	8,142	145	11,012
2008	MIDLAND	OGALLALA AQUIFER	6,407	0	585	0	10,541	94	17,627
2009	MIDLAND	OGALLALA AQUIFER	7,025	0	585	0	10,996	126	18,732
2010	MIDLAND	OGALLALA AQUIFER	2,601	1	585	0	7,841	94	11,122
2011	MIDLAND	OGALLALA AQUIFER	2,804	15	826	0	11,095	99	14,839
2012	MIDLAND	OGALLALA AQUIFER	2,680	20	484	0	10,687	83	13,954
2006	NOLAN	OGALLALA AQUIFER	6	0	0	0	0	0	6
2007	NOLAN	OGALLALA AQUIFER	5	0	0	0	0	0	5
2008	NOLAN	OGALLALA AQUIFER	5	0	0	0	0	0	5
2009	NOLAN	OGALLALA AQUIFER	6	0	0	0	0	0	6
2010	NOLAN	OGALLALA AQUIFER	7	0	0	0	0	0	7
2011	NOLAN	OGALLALA AQUIFER	8	0	0	0	0	0	8
2012	NOLAN	OGALLALA AQUIFER	7	0	0	0	0	0	7
2000	UPTON	OGALLALA AQUIFER	0	0	0	0	218	0	218
2001	UPTON	OGALLALA AQUIFER	0	0	0	0	152	0	152
2002	UPTON	OGALLALA AQUIFER	0	0	0	0	142	0	142
2003	UPTON	OGALLALA AQUIFER	0	0	0	0	139	0	139
2004	UPTON	OGALLALA AQUIFER	0	0	0	0	124	0	124

Appendix C
TWDB Pumping Estimates - Ogallala Aquifer

Year	County	Aquifer	Municipal	Manufacturing	Mining	Steam Electric Power	Irrigation	Livestock	Total
2005	UPTON	OGALLALA AQUIFER	0	0	0	0	117	0	117
2006	UPTON	OGALLALA AQUIFER	0	0	0	0	128	0	128
2007	UPTON	OGALLALA AQUIFER	0	0	0	0	109	0	109
2008	UPTON	OGALLALA AQUIFER	0	0	0	0	160	0	160
2009	UPTON	OGALLALA AQUIFER	0	0	0	0	140	0	140
2010	UPTON	OGALLALA AQUIFER	0	0	0	0	167	0	167
2011	UPTON	OGALLALA AQUIFER	0	0	0	0	243	0	243
2012	UPTON	OGALLALA AQUIFER	0	0	0	0	178	0	178

Appendix D

Region F Socioeconomic Impact Reports from TWDB

July 22, 2010

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

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

Dear Chairman Grant:

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

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

Sincerely,

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

SN/ao

Enclosure

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

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

Prepared in Support of the 2011 Region F Regional Water Plan

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

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

July 2010

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Introduction

Water shortages during drought would likely curtail or eliminate economic activity in business and industries reliant on water. For example, without water farmers cannot irrigate; refineries cannot produce gasoline, and paper mills cannot make paper. Unreliable water supplies would not only have an immediate and real impact on existing businesses and industry, but they could also adversely affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages would disrupt activity in homes, schools and government and could adversely affect public health and safety. For all of the above reasons, it is important to analyze and understand how restricted water supplies during drought could affect communities throughout the state.

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process, and rules direct TWDB staff to provide technical assistance: "*The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs*" [(§357.7 (4)(A)]. Staff of the TWDB's Water Resources Planning Division designed and conducted this report in support of the Region F Regional Water Planning Group.

This document summarizes the results of our analysis and discusses the methodology used to generate the results. Section 1 outlines the overall methodology and discusses approaches and assumptions specific to each water use category (i.e., irrigation, livestock, mining, steam-electric, municipal and manufacturing). Section 2 presents the results for each category where shortages are reported at the regional planning area level and river basin level. Results for individual water user groups are not presented, but are available upon request.

1. Methodology

Section 1 provides a general overview of how economic and social impacts were measured. In addition, it summarizes important clarifications, assumptions and limitations of the study.

1.1 Economic Impacts of Water Shortages

1.1.1 General Approach

Economic analysis as it relates to water resources planning generally falls into two broad areas. Supply side analysis focuses on costs and alternatives of developing new water supplies or implementing programs that provide additional water from current supplies. Demand side analysis concentrates on impacts or benefits of providing water to people, businesses and the environment. Analysis in this report focuses strictly on demand side impacts. When analyzing the economic impacts of water shortages as defined in Texas water planning, three potential scenarios are possible:

1) Scenario 1 involves situations where there are physical shortages of raw surface or groundwater due to drought of record conditions. For example, City A relies on a reservoir with average conservation storage of 500 acre-feet per year and a firm yield of 100 acre feet. In 2010, the city uses about 50 acre-feet per year, but by 2030 their demands are expected to increase to 200 acre-feet. Thus, in 2030 the reservoir would not have enough water to meet the city's demands,

and people would experience a shortage of 100 acre-feet assuming drought of record conditions. Under normal or average climatic conditions, the reservoir would likely be able to provide reliable water supplies well beyond 2030.

2) Scenario 2 is a situation where despite drought of record conditions, water supply sources can meet existing use requirements; however, limitations in water infrastructure would preclude future water user groups from accessing these water supplies. For example, City B relies on a river that can provide 500 acre-feet per year during drought of record conditions and other constraints as dictated by planning assumptions. In 2010, the city is expected to use an estimated 100 acre-feet per year and by 2060 it would require no more than 400 acre-feet. But the intake and pipeline that currently transfers water from the river to the city's treatment plant has a capacity of only 200 acre-feet of water per year. Thus, the city's water supplies are adequate even under the most restrictive planning assumptions, but their conveyance system is too small. This implies that at some point – perhaps around 2030 - infrastructure limitations would constrain future population growth and any associated economic activity or impacts.

3) Scenario 3 involves water user groups that rely primarily on aquifers that are being depleted. In this scenario, projected and in some cases existing demands may be unsustainable as groundwater levels decline. Areas that rely on the Ogallala aquifer are a good example. In some communities in the region, irrigated agriculture forms a major base of the regional economy. With less irrigation water from the Ogallala, population and economic activity in the region could decline significantly assuming there are no offsetting developments.

Assessing the social and economic effects of each of the above scenarios requires various levels and methods of analysis and would generate substantially different results for a number of reasons; the most important of which has to do with the time frame of each scenario. Scenario 1 falls into the general category of static analysis. This means that models would measure impacts for a small interval of time such as a drought. Scenarios 2 and 3, on the other hand imply a dynamic analysis meaning that models are concerned with changes over a much longer time period.

Since administrative rules specify that planning analysis be evaluated under drought of record conditions (a static and random event), socioeconomic impact analysis developed by the TWDB for the state water plan is based on assumptions of Scenario 1. Estimated impacts under scenario 1 are point estimates for years in which needs are reported (2010, 2020, 2030, 2040, 2050 and 2060). They are independent and distinct "what if" scenarios for a particular year and shortages are assumed to be temporary events resulting from drought of record conditions. Estimated impacts measure what would happen if water user groups experience water shortages for a period of one year.

The TWDB recognize that dynamic models may be more appropriate for some water user groups; however, combining approaches on a statewide basis poses several problems. For one, it would require a complex array of analyses and models, and might require developing supply and demand forecasts under "normal" climatic conditions as opposed to drought of record conditions. Equally important is the notion that combining the approaches would produce inconsistent results across regions resulting in a so-called "apples to oranges" comparison.

A variety tools are available to estimate economic impacts, but by far, the most widely used today are input-output models (IO models) combined with social accounting matrices (SAMs). Referred to as IO/SAM models, these tools formed the basis for estimating economic impacts for agriculture (irrigation and livestock water uses) and industry (manufacturing, mining, steam-electric and commercial business activity for municipal water uses).

Since the planning horizon extends through 2060, economic variables in the baseline are adjusted in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Future values for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category.

The following steps outline the overall process.

Step 1: *Generate IO/SAM Models and Develop Economic Baseline*

IO/SAM models were estimated using propriety software known as IMPLAN PRO™ (Impact for Planning Analysis). IMPLAN is a modeling system originally developed by the U.S. Forestry Service in the late 1970s. Today, the Minnesota IMPLAN Group (MIG Inc.) owns the copyright and distributes data and software. It is probably the most widely used economic impact model in existence. IMPLAN comes with databases containing the most recently available economic data from a variety of sources.[1] Using IMPLAN software and data, transaction tables conceptually similar to the one discussed previously were estimated for each county in the region and for the region as a whole. Each transaction table contains 528 economic sectors and allows one to estimate a variety of economic statistics including:

- **total sales** - total production measured by sales revenues;
- **intermediate sales** - sales to other businesses and industries within a given region;
- **final sales** – sales to end users in a region and exports out of a region;
- **employment** - number of full and part-time jobs (annual average) required by a given industry including self-employment;
- **regional income** - total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments; and
- **business taxes** - sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include income taxes).

TWDB analysts developed an economic baseline containing each of the above variables using year 2000 data. Since the planning horizon extends through 2060, economic variables in the baseline were allowed to change in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Projections for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category. Monetary impacts in future years are reported in constant year 2006 dollars.

It is important to stress that employment, income and business taxes are the most useful variables when comparing the relative contribution of an economic sector to a regional economy. Total sales as reported in IO/SAM models are less desirable and can be misleading because they include sales to other industries in the region for use in the production of other goods. For example, if a mill buys grain from local farmers and uses it to produce feed, sales of both the processed feed and raw corn are counted as "output" in an IO model. Thus, total sales double-count or overstate the true economic value of goods

[1]The IMPLAN database consists of national level technology matrices based on benchmark input-output accounts generated by the U.S. Bureau of Economic Analysis and estimates of final demand, final payments, industry output and employment for various economic sectors. IMPLAN regional data (i.e. states, a counties or groups of counties within a state) are divided into two basic categories: 1) data on an industry basis including value-added, output and employment, and 2) data on a commodity basis including final demands and institutional sales. State-level data are balanced to national totals using a matrix ratio allocation system and county data are balanced to state totals.

and services produced in an economy. They are not consistent with commonly used measures of output such as Gross National Product (GNP), which counts only final sales.

Another important distinction relates to terminology. Throughout this report, the term *sector* refers to economic subdivisions used in the IMPLAN database and resultant input-output models (528 individual sectors based on Standard Industrial Classification Codes). In contrast, the phrase *water use category* refers to water user groups employed in state and regional water planning including irrigation, livestock, mining, municipal, manufacturing and steam electric. Each IMPLAN sector was assigned to a specific water use category.

Step 2: *Estimate Direct and Indirect Economic Impacts of Water Needs*

Direct impacts are reductions in output by sectors experiencing water shortages. For example, without adequate cooling and process water a refinery would have to curtail or cease operation, car washes may close, or farmers may not be able to irrigate and sales revenues fall. Indirect impacts involve changes in inter-industry transactions as supplying industries respond to decreased demands for their services, and how seemingly non-related businesses are affected by decreased incomes and spending due to direct impacts. For example, if a farmer ceases operations due to a lack of irrigation water, they would likely reduce expenditures on supplies such as fertilizer, labor and equipment, and businesses that provide these goods would suffer as well.

Direct impacts accrue to immediate businesses and industries that rely on water and without water industrial processes could suffer. However, output responses may vary depending upon the severity of shortages. A small shortage relative to total water use would likely have a minimal impact, but large shortages could be critical. For example, farmers facing small shortages might fallow marginally productive acreage to save water for more valuable crops. Livestock producers might employ emergency culling strategies, or they may consider hauling water by truck to fill stock tanks. In the case of manufacturing, a good example occurred in the summer of 1999 when Toyota Motor Manufacturing experienced water shortages at a facility near Georgetown, Kentucky.[2] As water levels in the Kentucky River fell to historic lows due to drought, plant managers sought ways to curtail water use such as reducing rinse operations to a bare minimum and recycling water by funneling it from paint shops to boilers. They even considered trucking in water at a cost of 10 times what they were paying. Fortunately, rains at the end of the summer restored river levels, and Toyota managed to implement cutbacks without affecting production, but it was a close call. If rains had not replenished the river, shortages could have severely reduced output.[3]

To account for uncertainty regarding the relative magnitude of impacts to farm and business operations, the following analysis employs the concept of elasticity. Elasticity is a number that shows how a change in one variable will affect another. In this case, it measures the relationship between a percentage reduction in water availability and a percentage reduction in output. For example, an elasticity of 1.0 indicates that a 1.0 percent reduction in water availability would result in a 1.0 percent reduction in economic output. An elasticity of 0.50 would indicate that for every 1.0 percent of unavailable water, output is reduced by 0.50 percent and so on. Output elasticities used in this study are:[4]

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[2] Royal, W. "*High And Dry - Industrial Centers Face Water Shortages*." in Industry Week, Sept, 2000.

[3] The efforts described above are not planned programmatic or long-term operational changes. They are emergency measures that individuals might pursue to alleviate what they consider a temporary condition. Thus, they are not characteristic of long-term management strategies designed to ensure more dependable water supplies such as capital investments in conservation technology or development of new water supplies.

[4] Elasticities are based on one of the few empirical studies that analyze potential relationships between economic output and water shortages in the United States. The study, conducted in California, showed that a significant number of industries would suffer reduced output during water shortages. Using a survey based approach researchers posed two scenarios to different industries. In

- if water needs are 0 to 5 percent of total water demand, no corresponding reduction in output is assumed;
- if water needs are 5 to 30 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.50 percent reduction in output;
- if water needs are 30 to 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 0.75 percent reduction in output; and
- if water needs are greater than 50 percent of total water demand, for each additional one percent of water need that is not met, there is a corresponding 1.0 percent (i.e., a proportional reduction).

In some cases, elasticities are adjusted depending upon conditions specific to a given water user group.

Once output responses to water shortages were estimated, direct impacts to total sales, employment, regional income and business taxes were derived using regional level economic multipliers estimating using IO/SAM models. The formula for a given IMPLAN sector is:

$$D_{i,t} = Q_{i,t} *, S_{i,t} * E_Q * RFD_i * DM_{i(Q, L, I, T)}$$

where:

$D_{i,t}$ = direct economic impact to sector *i* in period *t*

$Q_{i,t}$ = total sales for sector *i* in period *t* in an affected county

$RFD_{i,}$ = ratio of final demand to total sales for sector *i* for a given region

$S_{i,t}$ = water shortage as percentage of total water use in period *t*

E_Q = elasticity of output and water use

$DM_{i(L, I, T)}$ = direct output multiplier coefficients for labor (L), income (I) and taxes (T) for sector *i*.

Secondary impacts were derived using the same formula used to estimate direct impacts; however, indirect multiplier coefficients are used. Methods and assumptions specific to each water use sector are discussed in Sections 1.1.2 through 1.1.4.

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the first scenario, they asked how a 15 percent cutback in water supply lasting one year would affect operations. In the second scenario, they asked how a 30 percent reduction lasting one year would affect plant operations. In the case of a 15 percent shortage, reported output elasticities ranged from 0.00 to 0.76 with an average value of 0.25. For a 30 percent shortage, elasticities ranged from 0.00 to 1.39 with average of 0.47. For further information, see, California Urban Water Agencies, *"Cost of Industrial Water Shortages,"* Spectrum Economics, Inc. November, 1991.

General Assumptions and Clarification of the Methodology

As with any attempt to measure and quantify human activities at a societal level, assumptions are necessary and every model has limitations. Assumptions are needed to maintain a level of generality and simplicity such that models can be applied on several geographic levels and across different economic sectors. In terms of the general approach used here several clarifications and cautions are warranted:

1. Shortages as reported by regional planning groups are the starting point for socioeconomic analyses.

2. Estimated impacts are point estimates for years in which needs are reported (i.e., 2010, 2020, 2030, 2040, 2050 and 2060).They are independent and distinct "what if" scenarios for each particular year and water shortages are assumed to be temporary events resulting from severe drought conditions combined with infrastructure limitations. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals and resultant impacts are measured. Given, that reported figures are not cumulative in nature, it is inappropriate to sum impacts over the entire planning horizon. Doing so, would imply that the analysis predicts that drought of record conditions will occur every ten years in the future, which is not the case. Similarly, authors of this report recognize that in many communities needs are driven by population growth, and in the future total population will exceed the amount of water available due to infrastructure limitations, regardless of whether or not there is a drought. This implies that infrastructure limitations would constrain economic growth. However, since needs as defined by planning rules are based upon water supply and demand under the assumption of drought of record conditions, it improper to conduct economic analysis that focuses on growth related impacts over the planning horizon. Figures generated from such an analysis would presume a 50-year drought of record, which is unrealistic. Estimating lost economic activity related to constraints on population and commercial growth due to lack of water would require developing water supply and demand forecasts under "normal" or "most likely" future climatic conditions.

3. While useful for planning purposes, this study is not a benefit-cost analysis. Benefit cost analysis is a tool widely used to evaluate the economic feasibility of specific policies or projects as opposed to estimating economic impacts of unmet water needs. Nevertheless, one could include some impacts measured in this study as part of a benefit cost study if done so properly. Since this is not a benefit cost analysis, future impacts are not weighted differently. In other words, estimates are not discounted. If used as a measure of economic benefits, one should incorporate a measure of uncertainty into the analysis. In this type of analysis, a typical method of discounting future values is to assign probabilities of the drought of record recurring again in a given year, and weight monetary impacts accordingly. This analysis assumes a probability of one.

4. IO multipliers measure the strength of backward linkages to supporting industries (i.e., those who sell inputs to an affected sector). However, multipliers say nothing about forward linkages consisting of businesses that purchase goods from an affected sector for further processing. For example, ranchers in many areas sell most of their animals to local meat packers who process animals into a form that consumers ultimately see in grocery stores and restaurants. Multipliers do not capture forward linkages to meat packers, and since meat packers sell livestock purchased from ranchers as "final sales," multipliers for the ranching sector do fully account for all losses to a region's economy. Thus, as mentioned previously, in some cases closely linked sectors were moved from one water use category to another.

5. Cautions regarding interpretations of direct and secondary impacts are warranted. IO/SAM multipliers are based on "fixed-proportion production functions," which basically means that input use - including labor - moves in lockstep fashion with changes in levels of output. In a

scenario where output (i.e., sales) declines, losses in the immediate sector or supporting sectors could be much less than predicted by an IO/SAM model for several reasons. For one, businesses will likely expect to continue operating so they might maintain spending on inputs for future use; or they may be under contractual obligations to purchase inputs for an extended period regardless of external conditions. Also, employers may not lay-off workers given that experienced labor is sometimes scarce and skilled personnel may not be readily available when water shortages subside. Lastly people who lose jobs might find other employment in the region. As a result, direct losses for employment and secondary losses in sales and employment should be considered an upper bound. Similarly, since projected population losses are based on reduced employment in the region, they should be considered an upper bound as well.

6. IO models are static. Models and resultant multipliers are based upon the structure of the U.S. and regional economies in 2006. In contrast, water shortages are projected to occur well into the future. Thus, the analysis assumes that the general structure of the economy remains the same over the planning horizon, and the farther out into the future we go, this assumption becomes less reliable.

7. Impacts are annual estimates. If one were to assume that conditions persisted for more than one year, figures should be adjusted to reflect the extended duration. The drought of record in most regions of Texas lasted several years.

8. Monetary figures are reported in constant year 2006 dollars.

1.1.2 Impacts to Agriculture

Irrigated Crop Production

The first step in estimating impacts to irrigation required calculating gross sales for IMPLAN crop sectors. Default IMPLAN data do not distinguish irrigated production from dry-land production. Once gross sales were known other statistics such as employment and income were derived using IMPLAN direct multiplier coefficients. Gross sales for a given crop are based on two data sources:

1) county-level statistics collected and maintained by the TWDB and the USDA Farm Services Agency (FSA) including the number of irrigated acres by crop type and water application per acre, and

2) regional-level data published by the Texas Agricultural Statistics Service (TASS) including prices received for crops (marketing year averages), crop yields and crop acreages.

Crop categories used by the TWDB differ from those used in IMPLAN datasets. To maintain consistency, sales and other statistics are reported using IMPLAN crop classifications. Table 1 shows the TWDB crops included in corresponding IMPLAN sectors, and Table 2 summarizes acreage and estimated annual water use for each crop classification (five-year average from 2003-2007). Table 3 displays average (2003-2007) gross revenues per acre for IMPLAN crop categories.

Table 1: Crop Classifications Used in TWDB Water Use Survey and Corresponding IMPLAN Crop Sectors

IMPLAN Category	TWDB Category
Oilseeds	Soybeans and "other oil crops"
Grains	Grain sorghum, corn, wheat and "other grain crops"
Vegetable and melons	"Vegetables" and potatoes
Tree nuts	Pecans
Fruits	Citrus, vineyard and other orchard
Cotton	Cotton
Sugarcane and sugar beets	Sugarcane and sugar beets
All "other" crops	"Forage crops", peanuts, alfalfa, hay and pasture, rice and "all other crops"

Table 2: Summary of Irrigated Crop Acreage and Water Demand for the Region F Water Planning Area (average 2003-2007)

Sector	Acres (1000s)	Distribution of acres	Water use (1000s of AF)	Distribution of water use
Oilseeds	<1	<1%	<1	<1%
Grains	45	20%	62	17%
Vegetable and melons	5	2%	9	<1%
Tree nuts	6	3%	13	<1%
Fruits	<1	<1%	1	<1%
Cotton	104	47%	154	42%
All "other" crops	61	28%	123	34%
Total	221	100%	363	100%

Source: Water demand figures are a 5- year average (2003-2007) of the TWDB's annual Irrigation Water Use Estimates. Statistics for irrigated crop acreage are based upon annual survey data collected by the TWDB and the Farm Service Agency. Values do not include acreage or water use for the TWDB categories classified by the Farm Services Agency as "failed acres," "golf course" or "waste water."

Table 3: Average Gross Sales Revenues per Acre for Irrigated Crops for the Region F Water Planning Area (2003-2007)		
IMPLAN Sector	**Gross revenues per acre**	**Crops included in estimates**
Oilseeds	$177	Irrigated figure is based on five-year (2003-2007) average weighted by acreage for "irrigated soybeans" and "irrigated 'other' oil crops."
Grains	$199	Based on five-year (2003-2007) average weighted by acreage for "irrigated grain sorghum," "irrigated corn", "irrigated wheat" and "irrigated 'other' grain crops."
Vegetable and melons	$6,053	Based on five-year (2003-2007) average weighted by acreage for "irrigated shallow and deep root vegetables", "irrigated Irish potatoes" and "irrigated melons."
Tree nuts	$3,451	Based on five-year (2003-2007) average weighted by acreage for "irrigated pecans."
Fruits	$5,902	Based on five-year (2003-2007) average weighted by acreage for "irrigated citrus", "irrigated vineyards" and "irrigated 'other' orchard."
Cotton	$488	Based on five-year (2003-2007) average weighted by acreage for "irrigated cotton."
All other crops	$335	Irrigated figure is based on five-year (2003-2007) average weighted by acreage for "irrigated 'forage' crops", "irrigated peanuts", "irrigated alfalfa", "irrigated 'hay' and pasture" and "irrigated 'all other' crops."

*Figures are rounded. Source: Based on data from the Texas Agricultural Statistics Service, Texas Water Development Board, and Texas A&M University.

An important consideration when estimating impacts to irrigation was determining which crops are affected by water shortages. One approach is the so-called rationing model, which assumes that farmers respond to water supply cutbacks by fallowing the lowest value crops in the region first and the highest valued crops last until the amount of water saved equals the shortage.[5] For example, if farmer A grows vegetables (higher value) and farmer B grows wheat (lower value) and they both face a proportionate cutback in irrigation water, then farmer B will sell water to farmer A. Farmer B will fallow her irrigated acreage before farmer A fallows anything. Of course, this assumes that farmers can and do transfer enough water to allow this to happen. A different approach involves constructing farm-level profit maximization models that conform to widely-accepted economic theory that farmers make decisions based on marginal net returns. Such models have good predictive capability, but data requirements and complexity are high. Given that a detailed analysis for each region would require a substantial amount of farm-level data and analysis, the following investigation assumes that projected shortages are distributed equally across predominant crops in the region. Predominant in this case are crops that comprise at least one percent of total acreage in the region.

The following steps outline the overall process used to estimate direct impacts to irrigated agriculture:

1. *Distribute shortages across predominant crop types in the region*. Again, unmet water needs were distributed equally across crop sectors that constitute one percent or more of irrigated acreage.

2. *Estimate associated reductions in output for affected crop sectors*. Output reductions are based on elasticities discussed previously and on estimated values per acre for different crops. Values per acre stem from the same data used to estimate output for the year 2006 baseline. Using multipliers, we then generate estimates of forgone income, jobs, and tax revenues based on reductions in gross sales and final demand.

Livestock

The approach used for the livestock sector is basically the same as that used for crop production. As is the case with crops, livestock categorizations used by the TWDB differ from those used in IMPLAN datasets, and TWDB groupings were assigned to a given IMPLAN sector (Table 4). Then we:

1) *Distribute projected water needs equally among predominant livestock sectors and estimate lost output*: As is the case with irrigation, shortages are assumed to affect all livestock sectors equally; however, the category of "other" is not included given its small size. If water needs were small relative to total demands, we assume that producers would haul in water by truck to fill stock tanks. The cost per acre-foot ($24,000) is based on 2008 rates charged by various water haulers in Texas, and assumes that the average truck load is 6,500 gallons at a hauling distance of 60 miles.

3) *Estimate reduced output in forward processors for livestock sectors*. Reductions in output for livestock sectors are assumed to have a proportional impact on forward processors in the region such as meat packers. In other words, if the cows were gone, meat-packing plants or fluid milk manufacturers) would likely have little to process. This is not an unreasonable premise. Since the

[5] The rationing model was initially proposed by researchers at the University of California at Berkeley, and was then modified for use in a study conducted by the U.S. Environmental Protection Agency that evaluated how proposed water supply cutbacks recommended to protect water quality in the Bay/Delta complex in California would affect farmers in the Central Valley. See, Zilberman, D., Howitt, R. and Sunding, D. "*Economic Impacts of Water Quality Regulations in the San Francisco Bay and Delta*." Western Consortium for Public Health. May 1993.

1950s, there has been a major trend towards specialized cattle feedlots, which in turn has decentralized cattle purchasing from livestock terminal markets to direct sales between producers and slaughterhouses. Today, the meat packing industry often operates large processing facilities near high concentrations of feedlots to increase capacity utilization.[6] As a result, packers are heavily dependent upon nearby feedlots. For example, a recent study by the USDA shows that on average meat packers obtain 64 percent of cattle from within 75 miles of their plant, 82 percent from within 150 miles and 92 percent from within 250 miles.[7]

Table 4: Description of Livestock Sectors

IMPLAN Category	TWDB Category
Cattle ranching and farming	Cattle, cow calf, feedlots and dairies
Poultry and egg production	Poultry production.
Other livestock	Livestock other than cattle and poultry (i.e., horses, goats, sheep, hogs)
Milk manufacturing	Fluid milk manufacturing, cheese manufacturing, ice cream manufacturing etc.
Meat packing	Meat processing present in the region from slaughter to final processing

1.1.3 Impacts to Municipal Water User Groups

Disaggregation of Municipal Water Demands

Estimating the economic impacts for the municipal water user groups is complicated for a number of reasons. For one, municipal use comprises a range of consumers including commercial businesses, institutions such as schools and government and households. However, reported water needs are not distributed among different municipal water users. In other words, how much of a municipal need is commercial and how much is residential (domestic)?

The amount of commercial water use as a percentage of total municipal demand was estimated based on "GED" coefficients (gallons per employee per day) published in secondary sources.[8] For example, if year 2006 baseline data for a given economic sector (e.g., amusement and recreation services) shows employment at 30 jobs and the GED coefficient is 200, then average daily water use by that sector is (30 x 200 = 6,000 gallons) or 6.7 acre-feet per year. Water not attributed to commercial use is considered

[6] Ferreira, W.N. *"Analysis of the Meat Processing Industry in the United States."* Clemson University Extension Economics Report ER211, January 2003.

[7] Ward, C.E. *"Summary of Results from USDA's Meatpacking Concentration Study."* Oklahoma Cooperative Extension Service, OSU Extension Facts WF-562.

[8] Sources for GED coefficients include: Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G. Cushing, K.K., and Mann, A. "*Waste Not, Want Not: The Potential for Urban Water Conservation in California*." Pacific Institute. November 2003. U.S. Bureau of the Census. 1982 Census of Manufacturers: Water Use in Manufacturing. USGPO, Washington D.C. See also: *"U.S. Army Engineer Institute for Water Resources, IWR Report 88-R-6.,"* Fort Belvoir, VA. See also, Joseph, E. S., 1982, "*Municipal and Industrial Water Demands of the Western United States*." Journal of the Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, v. 108, no. WR2, p. 204-216. See also, Baumann, D. D., Boland, J. J., and Sims, J. H., 1981, *"Evaluation of Water Conservation for Municipal and Industrial Water Supply."* U.S. Army Corps of Engineers, Institute for Water Resources, Contract no. 82-C1.

domestic, which includes single and multi-family residential consumption, institutional uses and all use designated as "county-other." Based on our analysis, commercial water use is about 5 to 35 percent of municipal demand. Less populated rural counties occupy the lower end of the spectrum, while larger metropolitan counties are at the higher end.

After determining the distribution of domestic versus commercial water use, we developed methods for estimating impacts to the two groups.

Domestic Water Uses

Input output models are not well suited for measuring impacts of shortages for domestic water uses, which make up the majority of the municipal water use category. To estimate impacts associated with domestic water uses, municipal water demand and needs are subdivided into residential, and commercial and institutional use. Shortages associated with residential water uses are valued by estimating proxy demand functions for different water user groups allowing us to estimate the marginal value of water, which would vary depending upon the level of water shortages. The more severe the water shortage, the more costly it becomes. For instance, a 2 acre-foot shortage for a group of households that use 10 acre-feet per year would not be as severe as a shortage that amounted to 8 acre-feet. In the case of a 2 acre-foot shortage, households would probably have to eliminate some or all outdoor water use, which could have implicit and explicit economic costs including losses to the horticultural and landscaping industry. In the case of an 8 acre-foot shortage, people would have to forgo all outdoor water use and most indoor water consumption. Economic impacts would be much higher in the latter case because people, and would be forced to find emergency alternatives assuming alternatives were available.

To estimate the value of domestic water uses, TWDB staff developed marginal loss functions based on constant elasticity demand curves. This is a standard and well-established method used by economists to value resources such as water that have an explicit monetary cost.

A constant price elasticity of demand is estimated using a standard equation:

$$w = kc^{(-\varepsilon)}$$

where:

- w is equal to average monthly residential water use for a given water user group measured in thousands of gallons;
- k is a constant intercept;
- c is the average cost of water per 1,000 gallons; and
- ε is the price elasticity of demand.

Price elasticities (-0.30 for indoor water use and -0.50 for outdoor use) are based on a study by Bell et al.[9] that surveyed 1,400 water utilities in Texas that serve at least 1,000 people to estimate demand elasticity for several variables including price, income, weather etc. Costs of water and average use per month per household are based on data from the Texas Municipal League's annual water and wastewater rate surveys - specifically average monthly household expenditures on water and wastewater

[9] Bell, D.R. and Griffin, R.C. "*Community Water Demand in Texas as a Century is Turned*." Research contract report prepared for the Texas Water Development Board. May 2006.

in different communities across the state. After examining variance in costs and usage, three different categories of water user groups based on population (population less than 5,000, cities with populations ranging from 5,000 to 99,999 and cities with populations exceeding 100,000) were selected to serve as proxy values for municipal water groups that meet the criteria (Table 5).[10]

Table 5: Water Use and Costs Parameters Used to Estimated Water Demand Functions (average monthly costs per acre-foot for delivered water and average monthly use per household)

Community Population	Water	Wastewater	Total monthly cost	Avg. monthly use (gallons)
Less than or equal to 5,000	$1,335	$1,228	$2,563	6,204
5,000 to 100,000	$1,047	$1,162	$2,209	7,950
Great than or equal to 100,000	$718	$457	$1,190	8,409

Source: Based on annual water and wastewater rate surveys published by the Texas Municipal League.

As an example, Table 6 shows the economic impact per acre-foot of domestic water needs for municipal water user groups with population exceeding 100,000 people. There are several important assumptions incorporated in the calculations:

1) Reported values are net of the variable costs of treatment and distribution such as expenses for chemicals and electricity since using less water involves some savings to consumers and utilities alike; and for outdoor uses we do not include any value for wastewater.

2) Outdoor and "non-essential" water uses would be eliminated before indoor water consumption was affected, which is logical because most water utilities in Texas have drought contingency plans that generally specify curtailment or elimination of outdoor water use during droughts.[11] Determining how much water is used for outdoor purposes is based on several secondary sources. The first is a major study sponsored by the American Water Works Association, which surveyed cities in states including Colorado, Oregon, Washington, California, Florida and Arizona. On average across all cities surveyed 58 percent of single family residential water use was for outdoor activities. In cities with climates comparable to large metropolitan areas of Texas, the average was 40 percent.[12] Earlier findings of the U.S. Water Resources Council showed a national

[10] Ideally, one would want to estimate demand functions for each individual utility in the state. However, this would require an enormous amount of time and resources. For planning purposes, we believe the values generated from aggregate data are more than sufficient.

[11] In Texas, state law requires retail and wholesale water providers to prepare and submit plans to the Texas Commission on Environmental Quality (TCEQ). Plans must specify demand management measures for use during drought including curtailment of "non-essential water uses." Non-essential uses include, but are not limited to, landscape irrigation and water for swimming pools or fountains. For further information see the Texas Environmental Quality Code §288.20.

[12] See, Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W., Dziegielewski, D., Nelson, J.O. "*Residential End Uses of Water.*" Research sponsored by the American Water Works Association and completed by Aquacraft, Inc. and Planning and Management Consultants, Ltd. (PMCL@CDM).

average of 33 percent. Similarly, the United States Environmental Protection Agency (USEPA) estimated that landscape watering accounts for 32 percent of total residential and commercial water use on annual basis.[13] A study conducted for the California Urban Water Agencies (CUWA) calculated average annual values ranging from 25 to 35 percent.[14] Unfortunately, there does not appear to be any comprehensive research that has estimated non-agricultural outdoor water use in Texas. As an approximation, an average annual value of 30 percent based on the above references was selected to serve as a rough estimate in this study.

3) As shortages approach 100 percent values become immense and theoretically infinite at 100 percent because at that point death would result, and willingness to pay for water is immeasurable. Thus, as shortages approach 80 percent of monthly consumption, we assume that households and non-water intensive commercial businesses (those that use water only for drinking and sanitation would have water delivered by tanker truck or commercial water delivery companies. Based on reports from water companies throughout the state, we estimate that the cost of trucking in water is around $21,000 to $27,000 per acre-feet assuming a hauling distance of between 20 to 60 miles. This is not an unreasonable assumption. The practice was widespread during the 1950s drought and recently during droughts in this decade. For example, in 2000 at the heels of three consecutive drought years Electra - a small town in North Texas - was down to its last 45 days worth of reservoir water when rain replenished the lake, and the city was able to refurbish old wells to provide supplemental groundwater. At the time, residents were forced to limit water use to 1,000 gallons per person per month - less than half of what most people use - and many were having water delivered to their homes by private contractors.[15] In 2003 citizens of Ballinger, Texas, were also faced with a dwindling water supply due to prolonged drought. After three years of drought, Lake Ballinger, which supplies water to more than 4,300 residents in Ballinger and to 600 residents in nearby Rowena, was almost dry. Each day, people lined up to get water from a well in nearby City Park. Trucks hauling trailers outfitted with large plastic and metal tanks hauled water to and from City Park to Ballinger.[16]

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[13] U.S. Environmental Protection Agency. *"Cleaner Water through Conservation."* USEPA Report no. 841-B-95-002. April, 1995.

[14] Planning and Management Consultants, Ltd. *"Evaluating Urban Water Conservation Programs: A Procedures Manual."* Prepared for the California Urban Water Agencies. February 1992.

[15] Zewe, C. *"Tap Threatens to Run Dry in Texas Town."* July 11, 2000. CNN Cable News Network.

[16] Associated Press, *"Ballinger Scrambles to Finish Pipeline before Lake Dries Up."* May 19, 2003.

Table 6: Economic Losses Associated with Domestic Water Shortages in Communities with Populations Exceeding 100,000 people				
Water shortages as a percentage of total monthly household demands	**No. of gallons remaining per household per day**	**No of gallons remaining per person per day**	**Economic loss (per acre-foot)**	**Economic loss (per gallon)**
1%	278	93	$748	$0.00005
5%	266	89	$812	$0.0002
10%	252	84	$900	$0.0005
15%	238	79	$999	$0.0008
20%	224	75	$1,110	$0.0012
25%	210	70	$1,235	$0.0015
30%[a]	196	65	$1,699	$0.0020
35%	182	61	$3,825	$0.0085
40%	168	56	$4,181	$0.0096
45%	154	51	$4,603	$0.011
50%	140	47	$5,109	$0.012
55%	126	42	$5,727	$0.014
60%	112	37	$6,500	$0.017
65%	98	33	$7,493	$0.02
70%	84	28	$8,818	$0.02
75%	70	23	$10,672	$0.03
80%	56	19	$13,454	$0.04
85%	42	14	$18,091 ($24,000)[b]	$0.05 ($0.07)[b]
90%	28	9	$27,363 ($24,000)	$0.08 ($0.07)
95%	14	5	$55,182 ($24,000)	$0.17 ($0.07)
99%	3	0.9	$277,728 ($24,000)	$0.85 ($0.07)
99.9%	1	0.5	$2,781,377 ($24,000)	$8.53 ($0.07)
100%	0	0	Infinite ($24,000)	Infinite ($0.07)

[a] The first 30 percent of needs are assumed to be restrictions of outdoor water use; when needs reach 30 percent of total demands all outdoor water uses would be restricted. Needs greater than 30 percent include indoor use

[b] As shortages approach 100 percent the value approaches infinity assuming there are not alternatives available; however, we assume that communities would begin to have water delivered by tanker truck at an estimated cost of $24,000 per acre-foot when shortages breached 85 percent.

Commercial Businesses

Effects of water shortages on commercial sectors were estimated in a fashion similar to other business sectors meaning that water shortages would affect the ability of these businesses to operate. This is particularly true for "water intensive" commercial sectors that are need large amounts of water (in addition to potable and sanitary water) to provide their services. These include:

- car-washes,
- laundry and cleaning facilities,
- sports and recreation clubs and facilities including race tracks,
- amusement and recreation services,
- hospitals and medical facilities,
- hotels and lodging places, and
- eating and drinking establishments.

A key assumption is that commercial operations would not be affected until water shortages were at least 50 percent of total municipal demand. In other words, we assume that residential water consumers would reduce water use including all non-essential uses before businesses were affected.

An example will illustrate the breakdown of municipal water needs and the overall approach to estimating impacts of municipal needs. Assume City A experiences an unexpected shortage of 50 acre-feet per year when their demands are 200 acre-feet per year. Thus, shortages are only 25 percent of total municipal use and residents of City A could eliminate needs by restricting landscape irrigation. City B, on the other hand, has a deficit of 150 acre-feet in 2020 and a projected demand of 200 acre-feet. Thus, total shortages are 75 percent of total demand. Emergency outdoor and some indoor conservation measures could eliminate 50 acre-feet of projected needs, yet 50 acre-feet would still remain. To eliminate" the remaining 50 acre-feet water intensive commercial businesses would have to curtail operations or shut down completely.

Three other areas were considered when analyzing municipal water shortages: 1) lost revenues to water utilities, 2) losses to the horticultural and landscaping industries stemming for reduction in water available for landscape irrigation, and 3) lost revenues and related economic impacts associated with reduced water related recreation.

Water Utility Revenues

Estimating lost water utility revenues was straightforward. We relied on annual data from the "*Water and Wastewater Rate Survey*" published annually by the Texas Municipal League to calculate an average value per acre-foot for water and sewer. For water revenues, average retail water and sewer rates multiplied by total water needs served as a proxy. For lost wastewater, total unmet needs were adjusted for return flow factor of 0.60 and multiplied by average sewer rates for the region. Needs reported as "county-other" were excluded under the presumption that these consist primarily of self-supplied water uses. In addition, 15 percent of water demand and needs are considered non-billed or "unaccountable" water that comprises things such as leakages and water for municipal government functions (e.g., fire departments). Lost tax receipts are based on current rates for the "miscellaneous gross receipts tax, "which the state collects from utilities located in most incorporated cities or towns in Texas. We do not include lost water utility revenues when aggregating impacts of municipal water shortages to regional and state levels to prevent double counting.

Horticultural and Landscaping Industry

The horticultural and landscaping industry, also referred to as the "green Industry," consists of businesses that produce, distribute and provide services associated with ornamental plants, landscape and garden supplies and equipment. Horticultural industries often face big losses during drought. For example, the recent drought in the Southeast affecting the Carolinas and Georgia horticultural and landscaping businesses had a harsh year. Plant sales were down, plant mortality increased, and watering costs increased. Many businesses were forced to close locations, lay off employees, and even file for bankruptcy. University of Georgia economists put statewide losses for the industry at around $3.2 billion during the 3-year drought that ended in 2008.[17] Municipal restrictions on outdoor watering play a significant role. During drought, water restrictions coupled with persistent heat has a psychological effect on homeowners that reduces demands for landscaping products and services. Simply put, people were afraid to spend any money on new plants and landscaping.

In Texas, there do not appear to be readily available studies that analyze the economic effects of water shortages on the industry. However, authors of this report believe negative impacts do and would result in restricting landscape irrigation to municipal water consumers. The difficulty in measuring them is two-fold. First, as noted above, data and research for these types of impacts that focus on Texas are limited; and second, economic data provided by IMPLAN do not disaggregate different sectors of the green industry to a level that would allow for meaningful and defensible analysis.[18]

Recreational Impacts

Recreational businesses often suffer when water levels and flows in rivers, springs and reservoirs fall significantly during drought. During droughts, many boat docks and lake beaches are forced to close, leading to big losses for lakeside business owners and local communities. Communities adjacent to popular river and stream destinations such as Comal Springs and the Guadalupe River also see their business plummet when springs and rivers dry up. Although there are many examples of businesses that have suffered due to drought, dollar figures for drought-related losses to the recreation and tourism industry are not readily available, and very difficult to measure without extensive local surveys. Thus, while they are important, economic impacts are not measured in this study.

Table 7 summarizes impacts of municipal water shortages at differing levels of magnitude, and shows the ranges of economic costs or losses per acre-foot of shortage for each level.

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[17] Williams, D. *"Georgia landscapers eye rebound from Southeast drought."* Atlanta Business Chronicle, Friday, June 19, 2009

[18] Economic impact analyses prepared by the TWDB for 2006 regional water plans did include estimates for the horticultural industry. However, year 2000 and prior IMPLAN data were disaggregated to a finer level. In the current dataset (2006), the sector previously listed as "Landscaping and Horticultural Services" (IMPLAN Sector 27) is aggregated into "Services to Buildings and Dwellings" (IMPLAN Sector 458).

Table 7: Impacts of Municipal Water Shortages at Different Magnitudes of Shortages		
Water shortages as percent of total municipal demands	Impacts	Economic costs per acre-foot*
0-30%	✓ Lost water utility revenues ✓ Restricted landscape irrigation and non-essential water uses	$730 - $2,040
30-50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use	$2,040 - $10,970
>50%	✓ Lost water utility revenues ✓ Elimination of landscape irrigation and non-essential water uses ✓ Rationing of indoor use ✓ Restriction or elimination of commercial water use ✓ Importing water by tanker truck	$10,970 - varies
*Figures are rounded		

1.1.4 Industrial Water User Groups

Manufacturing

Impacts to manufacturing were estimated by distributing water shortages among industrial sectors at the county level. For example, if a planning group estimates that during a drought of record water supplies in County A would only meet 50 percent of total annual demands for manufactures in the county, we reduced output for each sector by 50 percent. Since projected manufacturing demands are based on TWDB Water Uses Survey data for each county, we only include IMPLAN sectors represented in the TWBD survey database. Some sectors in IMPLAN databases are not part of the TWDB database given that they use relatively small amounts of water - primarily for on-site sanitation and potable purposes. To maintain consistency between IMPLAN and TWDB databases, Standard Industrial Classification (SIC) codes both databases were cross referenced in county with shortages. Non-matches were excluded when calculating direct impacts.

Mining

The process of mining is very similar to that of manufacturing. We assume that within a given county, shortages would apply equally to relevant mining sectors, and IMPLAN sectors are cross referenced with TWDB data to ensure consistency.

In Texas, oil and gas extraction and sand and gravel (aggregates) operations are the primary mining industries that rely on large volumes of water. For sand and gravel, estimated output reductions are straightforward; however, oil and gas is more complicated for a number of reasons. IMPLAN does not necessarily report the physical extraction of minerals by geographic local, but rather the sales revenues reported by a particular corporation.

For example, at the state level revenues for IMPLAN sector 19 (oil and gas extraction) and sector 27 (drilling oil and gas wells) totals $257 billion. Of this, nearly $85 billion is attributed to Harris County. However, only a very small fraction (less than one percent) of actual production takes place in the county. To measure actual potential losses in well head capacity due to water shortages, we relied on county level production data from the Texas Railroad Commission (TRC) and average well-head market prices for crude and gas to estimate lost revenues in a given county. After which, we used to IMPLAN ratios to estimate resultant losses in income and employment.

Other considerations with respect to mining include:

1) Petroleum and gas extraction industry only uses water in significant amounts for secondary recovery. Known in the industry as enhanced or water flood extraction, secondary recovery involves pumping water down injection wells to increase underground pressure thereby pushing oil or gas into other wells. IMPLAN output numbers do not distinguish between secondary and non-secondary recovery. To account for the discrepancy, county-level TRC data that show the proportion of barrels produced using secondary methods were used to adjust IMPLAN data to reflect only the portion of sales attributed to secondary recovery.

2) A substantial portion of output from mining operations goes directly to businesses that are classified as manufacturing in our schema. Thus, multipliers measuring backward linkages for a given manufacturer might include impacts to a supplying mining operation. Care was taken not to double count in such situations if both a mining operation and a manufacturer were reported as having water shortages.

Steam-electric

At minimum without adequate cooling water, power plants cannot safely operate. As water availability falls below projected demands, water levels in lakes and rivers that provide cooling water would also decline. Low water levels could affect raw water intakes and outfalls at electrical generating units in several ways. For one, power plants are regulated by thermal emission guidelines that specify the maximum amount of heat that can go back into a river or lake via discharged cooling water. Low water levels could result in permit compliance issues due to reduced dilution and dispersion of heat and subsequent impacts on aquatic biota near outfalls.[19] However, the primary concern would be a loss of head (i.e., pressure) over intake structures that would decrease flows through intake tunnels. This would affect safety related pumps, increase operating costs and/or result in sustained shut-downs. Assuming plants did shutdown, they would not be able to generate electricity.

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[19] Section 316 (b) of the Clean Water Act requires that thermal wastewater discharges do not harm fish and other wildlife.

Among all water use categories steam-electric is unique and cautions are needed when applying methods used in this study. Measured changes to an economy using input-output models stem directly from changes in sales revenues. In the case of water shortages, one assumes that businesses will suffer lost output if process water is in short supply. For power generation facilities this is true as well. However, the electric services sector in IMPLAN represents a corporate entity that may own and operate several electrical generating units in a given region. If one unit became inoperable due to water shortages, plants in other areas or generation facilities that do not rely heavily on water such as gas powered turbines might be able to compensate for lost generating capacity. Utilities could also offset lost production via purchases on the spot market.[20] Thus, depending upon the severity of the shortages and conditions at a given electrical generating unit, energy supplies for local and regional communities could be maintained. But in general, without enough cooling water, utilities would have to throttle back plant operations, forcing them to buy or generate more costly power to meet customer demands.

Measuring impacts end users of electricity is not part of this study as it would require extensive local and regional level analysis of energy production and demand. To maintain consistency with other water user groups, impacts of steam-electric water shortages are measured in terms of lost revenues (and hence income) and jobs associated with shutting down electrical generating units.

1.2 Social Impacts of Water Shortages

As the name implies, the effects of water shortages can be social or economic. Distinctions between the two are both semantic and analytical in nature – more so analytic in the sense that social impacts are harder to quantify. Nevertheless, social effects associated with drought and water shortages are closely tied to economic impacts. For example, they might include:

- demographic effects such as changes in population,
- disruptions in institutional settings including activity in schools and government,
- conflicts between water users such as farmers and urban consumers,
- health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations),
- mental and physical stress (e.g., anxiety, depression, domestic violence),
- public safety issues from forest and range fires and reduced fire fighting capability,
- increased disease caused by wildlife concentrations,
- loss of aesthetic and property values, and
- reduced recreational opportunities.[21]

[20] Today, most utilities participate in large interstate "power pools" and can buy or sell electricity "on the grid" from other utilities or power marketers. Thus, assuming power was available to buy, and assuming that no contractual or physical limitations were in place such as transmission constraints; utilities could offset lost power that resulted from waters shortages with purchases via the power grid.

[21] Based on information from the website of the National Drought Mitigation Center at the University of Nebraska Lincoln. Available online at: http://www.drought.unl.edu/risk/impacts.htm. See also, Vanclay, F. "*Social Impact Assessment*." in Petts, J. (ed) International Handbook of Environmental Impact Assessment. 1999.

Social impacts measured in this study focus strictly on demographic effects including changes in population and school enrollment. Methods are based on demographic projection models developed by the Texas State Data Center and used by the TWDB for state and regional water planning. Basically, the social impact model uses results from the economic component of the study and assesses how changes in labor demand would affect migration patterns in a region. Declines in labor demand as measured using adjusted IMPLAN data are assumed to affect net economic migration in a given regional water planning area. Employment losses are adjusted to reflect the notion that some people would not relocate but would seek employment in the region and/or public assistance and wait for conditions to improve. Changes in school enrollment are simply the proportion of lost population between the ages of 5 and 17.

2. Results

Section 2 presents the results of the analysis at the regional level. Included are baseline economic data for each water use category, and estimated economics impacts of water shortages for water user groups with reported deficits. According to the 2011 *Region F Regional Water Plan*, during severe drought irrigation, livestock municipal, manufacturing, mining and steam-electric water user groups would experience water shortages in the absence of new water management strategies.

2.1 Overview of Regional Economy

On an annual basis, the Region F economy generates $20.8 billion worth of gross state product for Texas ($19.1 billion in income and $1.7 billion in business taxes) and supports nearly 227,000 jobs (Table 8). Generating about $9.8 billion in gross state product, agriculture, manufacturing, and mining are the region's primary base economic sectors.[22] Municipal sectors also generate substantial amounts of income and are major employers in the region; however, many businesses that make up the municipal category such as restaurants and retail stores are non-basic industries meaning they exist to provide services to people who work would in base industries. In other words, without base industries, many jobs categorized as municipal would not exist.

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[22] Base industries are those that supply markets outside of the region. These industries are crucial to the local economy and are called the economic base of a region. Appendix A shows how IMPLAN's 529 sectors were allocated to water use category, and shows economic data for each sector.

Table 8: The Region F Economy by Water User Group ($millions)*						
Water Use Category	Total sales	Intermediate sales	Final sales	Jobs	Income	Business taxes
Irrigation	$131.11	$21.48	$109.67	2,267	$68.24	$1.79
Livestock	$801.61	$432.80	$368.82	11,083	$78.45	$11.11
Manufacturing	$8,793.15	$1,386.66	$7,406.49	36,089	$2,613.94	$51.57
Mining	$11,507.80	$5,279.12	$6,228.68	27,668	$6,415.53	$563.76
Steam-electric	$376.64	$105.96	$270.68	932	$261.54	$44.63
Municipal	$15,709.07	$3,801.30	$11,907.77	148,786	$9,682.07	$981.89
Regional total	$37,319.38	$11,027.32	$26,292.11	226,825	$19,119.77	$1,654.75

[a] Appendix 1 displays data for individual IMPLAN sectors that make up each water use category. Based on data from the Texas Water Development Board, and year 2006 data from the Minnesota IMPLAN Group, Inc.

2.2 Impacts of Agricultural Water Shortages

According to the 2011 *Region F Regional Water Plan*, during severe drought most counties in the region would experiences shortages of irrigation water ranging anywhere from about 5 to 90 percent of total annual irrigation demands. Shortages of these magnitudes would reduce gross state product (income plus state and local business taxes) by about $30 to 35 million depending upon the decade Table 9).

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

*Changes to income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.3 Impacts of Municipal Water Shortages

Water shortages are projected to occur in a significant number of communities throughout the region, and deficits range anywhere from 1 to 100 percent of total annual water demands. At the regional level, the estimated economic value of domestic water shortages totals $164 million in 2010 and $446 million in 2060 (Table 10). Due to curtailment of commercial business activity, municipal shortages would also reduce gross state product (income plus taxes) by $40 million in 2010 and $433 million in 2060.

Table 10: Economic Impacts of Water Shortages for Municipal Water User Groups ($millions)

Decade	Monetary value of domestic water shortages	Lost income from reduced commercial business activity*	Lost state and local taxes from reduced commercial business activity	Lost jobs from reduced commercial business activity	Lost water utility revenues
2010	$164.31	$35.84	1,165	$3.58	$22.60
2020	$244.46	$36.34	1,180	$3.64	$38.89
2030	$275.39	$119.12	3,208	$9.52	$48.62
2040	$363.08	$366.53	9,367	$27.34	$62.99
2050	$432.97	$386.74	9,940	$29.00	$67.58
2060	$446.11	$403.41	10,360	$30.22	$72.94

*Changes to income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.4 Impacts of Manufacturing Water Shortages

Manufacturing water shortages are projected to occur in the counties of Coleman, Ector, Howard, Kimble, Runnels, and Tom Green. Projected shortages would reduce gross state product (income plus taxes) by an estimated $891 million in 2020 and $1,356 million in 2060 (Table 11).

Table 11: Economic Impacts of Water Shortages for Manufacturing Water User Groups ($millions)			
Decade	Lost income due to reduced manufacturing output*	Lost state and local business tax revenues due to reduced manufacturing output	Lost jobs due to reduced manufacturing output
2010	$829.61	$62.12	15,723
2020	$936.77	$69.97	17,705
2030	$994.28	$75.07	19,076
2040	$1,092.03	$82.10	20,836
2050	$1,166.59	$87.70	22,261
2060	$1,261.31	$94.74	24,041

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.5 Impacts of Mining Water Shortages

Mining water shortages are projected to occur in Coleman, Coke, and Howard counties, and would primarily affect oil extraction. Combined shortages for each county would result in estimated losses of gross state product totaling $13.5 million dollars in 2010 and $11.0 million 2060 (Table 12).

Table 12: Economic Impacts of Water Shortages for Mining Water User Groups ($millions)			
Decade	Lost income due to reduced mining output*	Lost state and local business tax revenues due to reduced mining output	Lost jobs due to reduced mining output
2010	$12.50	$0.94	78
2020	$16.04	$1.21	101
2030	$2.26	$0.14	13
2040	$4.75	$0.33	29
2050	$6.70	$0.49	41
2060	$9.83	$0.73	61

*Changes to Income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.6 Impacts of Steam-electric Water Shortages

Water shortages for electrical generating units are projected in Coke, Ector, Mitchell, Tom Green and Ward counties resulting in estimated losses of gross state product totaling $607 million dollars in 2010, and $2,017 billion in 2060 (Table 13).

Table 13: Economic Impacts of Water Shortages for Steam-electric Water User Groups ($millions)

Decade	Lost income due to reduced electrical generation*	Lost state and local business tax revenues due to reduced electrical generation	Lost jobs due to reduced electrical generation
2010	$530.83	$76.19	1,805
2020	$691.34	$99.23	2,350
2030	$1,045.50	$150.07	3,554
2040	$1,232.24	$176.87	4,189
2050	$1,468.65	$210.80	4,993
2060	$1,763.75	$253.16	5,996

*Changes to income and business taxes are collectively equivalent to a decrease in gross state product, which is analogous to gross domestic product measured at the state rather than national level. Appendix 2 shows results by water user group.

2.7 Social Impacts of Water Shortages

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

Table 15: Social Impacts of Water Shortages (2010-2060)

Year	Population Losses	Declines in School Enrollment
2010	25,050	7,065
2020	26,239	7,444
2030	31,670	8,389
2040	41,980	7,759
2050	45,362	8,378
2060	49,236	9,106

2.8 Distribution of Impacts by Major River Basin

Administrative rules require that impacts are presented by both planning region and major river basin. To meet rule requirements, impacts were allocated among basins based on the distribution of water shortages in relevant basins. For example, if 50 percent of water shortages in River Basin A and 50 percent occur in River Basin B, then impacts were split equally among the two basins. Table 16 displays the results.

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

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

Appendix 1: Economic Data for Individual IMPLAN Sectors

Economic Data for Agricultural Water User Groups ($millions)

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

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

Economic Data for Mining and Steam-electric Water User Groups ($millions)

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

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

Economic Data for Manufacturing Water User Groups ($millions)

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

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

Economic Data for Municipal Water User Groups ($millions)

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

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

Appendix 2: Impacts by Water User Group

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

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

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

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

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

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

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

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

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

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

APPENDIX B

GAM Run 16-026 MAG Version 2

GAM Run 16-026 MAG Version 2: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 7

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
(512) 463-6641
September 21, 2018

STATE OF TEXAS
IAN C. JONES
GEOLOGY
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9/24/2018

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GAM Run 16-026 MAG Version 2: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 7

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Texas Water Development Board
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(512) 463-6641
September 21, 2018

EXECUTIVE SUMMARY:

We have prepared estimates of the modeled available groundwater for the relevant aquifers of Groundwater Management Area 7—the Capitan Reef Complex, Dockum, Edwards-Trinity (Plateau), Ellenburger-San Saba, Hickory, Ogallala, Pecos Valley, Rustler, and Trinity aquifers. The estimates are based on the desired future conditions for these aquifers adopted by the groundwater conservation districts in Groundwater Management Area 7 on September 22, 2016 and March 22, 2018. The explanatory reports and other materials submitted to the Texas Water Development Board (TWDB) were determined to be administratively complete on June 22, 2018.

The original version of GAM Run 16-026 MAG inadvertently included modeled available groundwater estimates for areas declared not relevant by the groundwater management area and areas that had no desired future conditions for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers. GAM Run 16-026 MAG Version 2 (this report) contains updates to reported total modeled available groundwater estimates and to Tables 5 and 6 that reflect only relevant portions of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers.

The modeled available groundwater values are summarized by decade for the groundwater conservation districts (Tables 1, 3, 5, 7, 9, 11, 13) and for use in the regional water planning process (Tables 2, 4, 6, 8, 10, 12, 14). The modeled available groundwater estimates are 26,164 acre-feet per year in the Capitan Reef Complex Aquifer; 2,324 acre-feet per year in the Dockum Aquifer; 474,464 acre-feet per year in the undifferentiated Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers; 22,616 acre-feet per year in the Ellenburger-San Saba Aquifer; 49,936 acre-feet per year in the Hickory Aquifer; 6,570 to 8,019 acre-feet per year in the Ogallala Aquifer; and 7,040 acre-feet per year in the Rustler Aquifer. The modeled available groundwater estimates were extracted from results of model runs using the groundwater availability models for the Capitan Reef Complex Aquifer (Jones, 2016); the High Plains Aquifer System (Deeds and Jigmond, 2015); the minor aquifers of the Llano Uplift Area (Shi and others, 2016), and the Rustler Aquifer (Ewing and others, 2012). In addition, the alternative 1-layer model for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers (Hutchison and others, 2011) was used for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers, except for Kinney and Val Verde counties. In these two counties, the alternative Kinney County model (Hutchison and others, 2011) and the model associated with a hydrogeological study for Val Verde County and the City of Del Rio (EcoKai Environmental, Inc. and Hutchison, 2014), respectively, were used to estimate modeled available groundwater. The Val Verde County/Del Rio model covers Val Verde County. This model was used to simulate multiple pumping scenarios indicating the effects of a proposed wellfield. The model indicated the effects of varied pumping rates and wellfield locations. These model runs were used by Groundwater Management Area 7 as the basis for the desired future conditions for Val Verde County.

REQUESTOR:

Mr. Joel Pigg, chair of Groundwater Management Area 7 districts.

DESCRIPTION OF REQUEST:

In letters dated November 22, 2016 and March 26, 2018, Dr. William Hutchison on behalf of Groundwater Management Area 7 provided the TWDB with the desired future conditions for the Capitan, Dockum, Edwards-Trinity (Plateau), Ellenburger-San Saba, Hickory, Ogallala, Pecos Valley, Rustler, and Trinity aquifers in Groundwater Management Area 7. Groundwater Management Area 7 provided additional clarifications through emails to the TWDB on March 23, 2018 and June 12, 2018 for the use of model extents (Dockum, Ellenburger-San Saba, Hickory, Ogallala, Rustler aquifers), the use of aquifer extents (Capitan Reef Complex, Edwards-Trinity [Plateau], Pecos Valley, and Trinity aquifers), and desired future conditions for the Edwards-Trinity (Plateau) Aquifer of Kinney and Val Verde counties.

The final adopted desired future conditions as stated in signed resolutions for the aquifers in Groundwater Management Area 7 are reproduced below:

Capitan Reef [Complex] Aquifer

Total net drawdown of the Capitan Reef [Complex] Aquifer not to exceed 56 feet in Pecos County (Middle Pecos [Groundwater Conservation District]) in 2070 as compared with 2006 aquifer levels (Reference: Scenario 4, GMA 7 Technical Memorandum 15-06, 4-8-2015).

Dockum Aquifer

Total net drawdown of the Dockum Aquifer not to exceed 14 feet in Reagan County (Santa Rita [Groundwater Conservation District]) in 2070, as compared with 2012 aquifer levels.

Total net drawdown of the Dockum Aquifer not to exceed 52 feet in Pecos County (Middle Pecos [Groundwater Conservation District]) in 2070, as compared with 2012 aquifer levels.

Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers

Average drawdown for [the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers] in the following [Groundwater Management Area] 7 counties not to exceed drawdowns from 2010 to 2070 [...].

County	[...] Average Drawdowns from 2010 to 2070 [feet]
Coke	0
Crockett	10
Ector	4
Edwards	2
Gillespie	5
Glasscock	42
Irion	10
Kimble	1
Menard	1
Midland	12
Pecos	14
Reagan	42
Real	4
Schleicher	8
Sterling	7
Sutton	6

Taylor	0
Terrell	2
Upton	20
Uvalde	2

Total net drawdown *[of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers]* in Kinney County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an annual average flow of 23.9 [cubic feet per second] and an annual median flow of 23.9 [cubic feet per second] at Las Moras Springs [...].

Total net drawdown [of the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers] in Val Verde County in 2070, as compared with 2010 aquifer levels, shall be consistent with maintenance of an average annual flow of 73-75 [million gallons per day] at San Felipe Springs.

Minor Aquifers of the Llano Uplift Area

Total net drawdowns of [Ellenburger-San Saba Aquifer] levels in 2070, as compared with 2010 aquifer levels, shall not exceed the number of feet set forth below, respectively, for the following counties and districts:

County	[Groundwater Conservation District]	Drawdown in 2070 (feet)
Gillespie	Hill Country [Underground Water Conservation District]	8
Mason	Hickory [Underground Water Conservation District] no. 1	14
McCulloch	Hickory [Underground Water Conservation District] no. 1	29
Menard	Menard County [Underground Water District] and Hickory [Underground Water Conservation District] no. 1	46
Kimble	Kimble County [Groundwater Conservation District] and Hickory	18

	[Underground Water Conservation District] no. 1	
San Saba	Hickory [Underground Water Conservation District] no. 1	5

Total net drawdown of [Hickory Aquifer] levels in 2070, as compared with 2010 aquifer levels, shall not exceed the number of feet set forth below, respectively, for the following counties and districts:

County	[Groundwater Conservation District]	Drawdown in 2070 (feet)
Concho	Hickory [Underground Water Conservation District No. 1]	53
Gillespie	Hill Country UWCD	9
Mason	Hickory [Underground Water Conservation District No. 1]	17
McCulloch	Hickory [Underground Water Conservation District No. 1]	29
Menard	Menard UWD and Hickory [Underground Water Conservation District No. 1]	46
Kimble	Kimble County [Groundwater Conservation District] and Hickory [Underground Water Conservation District No. 1]	18
San Saba	Hickory [Underground Water Conservation District No. 1]	6

Ogallala Aquifer

Total net [drawdown] of the Ogallala Aquifer in Glasscock County (Glasscock [Groundwater Conservation District]) in 2070, as compared with 2012 aquifer levels, not to exceed 6 feet [...].

Rustler Aquifer

Total net drawdown of the Rustler Aquifer in Pecos County (Middle Pecos GCD) in 2070 not to exceed 94 feet as compared with 2009 aquifer levels.

Additionally, districts in Groundwater Management Area 7 voted to declare that the following aquifers or parts of aquifers are non-relevant for the purposes of joint planning:

- The Blaine, Igneous, Lipan, Marble Falls, and Seymour aquifers.
- The Edwards-Trinity (Plateau) Aquifer in Hickory Underground Water Conservation District No. 1, the Lipan-Kickapoo Water Conservation District, Lone Wolf Groundwater Conservation District, and Wes-Tex Groundwater Conservation District.
- The Ellenburger-San Saba Aquifer in Llano County.
- The Hickory Aquifer in Llano County.
- The Dockum Aquifer outside of Santa Rita Groundwater Conservation District and Middle Pecos Groundwater Conservation District.
- The Ogallala Aquifer outside of Glasscock County.

In response to a several requests for clarifications from the TWDB in 2017 and 2018, the Groundwater Management Area 7 Chair, Mr. Joel Pigg, and Groundwater Management Area 7 consultant, Dr. William R. Hutchison, indicated the following preferences for verifying the desired future condition of the aquifers and calculating modeled available groundwater volumes in Groundwater Management Area 7:

Capitan Reef Complex Aquifer

Calculate modeled available groundwater values based on the official aquifer boundaries.

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers

Calculate modeled available groundwater values based on the official aquifer boundaries.

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

Kinney County

Use the modeled available groundwater values and model assumptions from GAM Run 10-043 MAG Version 2 (Shi, 2012) to maintain annual average springflow of 23.9 cubic feet per second and a median flow of 24.4 cubic feet per second at Las Moras Springs from 2010 to 2060.

Val Verde County

There is no associated drawdown as a desired future condition. The desired future condition is based solely on simulated springflow conditions at San Felipe Spring of 73 to 75 million gallons per day. Pumping scenarios—50,000 acre-feet per year—in three well field locations, and monthly hydrologic conditions for the historic period 1969 to 2012 meet the desired future conditions set by Groundwater Management Area 7 (EcoKai and Hutchison, 2014; Hutchison 2018b).

Minor Aquifers of the Llano Uplift Area

Calculate modeled available groundwater values based on the spatial extent of the Ellenburger-San Saba and Hickory aquifers in the groundwater availability model for the aquifers of the Llano Uplift Area and use the same model assumptions used in Groundwater Management Area 7 Technical Memorandum 16-02 (Hutchison 2016g).

Drawdown calculations do not take into consideration the occurrence of dry cells where water levels are below the base of the aquifer.

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

Dockum Aquifer

Calculate modeled available groundwater values based on the spatial extent of the groundwater availability model for the Dockum Aquifer.

Modeled available groundwater analysis excludes pass-through cells.

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

Ogallala Aquifer

Calculate modeled available groundwater values based on the official aquifer boundary and use the same model assumptions used in Groundwater Management Area Technical Memorandum 16-01 (Hutchison, 2016f).

Modeled available groundwater analysis excludes pass-through cells.

Well pumpage decreases as the saturated thickness of the aquifer decreases below a 30-foot threshold.

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

Rustler Aquifer

Use 2008 as the baseline year and run the model from 2009 through 2070 (end of 2008/beginning of 2009 as initial conditions), as used in the submitted predictive model run.

Use 2008 recharge conditions throughout the predictive period.

Calculate modeled available groundwater values based on the spatial extent of the groundwater availability model for the Rustler Aquifer.

General-head boundary heads decline at a rate of 1.5 feet per year.

Use the same model assumptions used in Groundwater Management Area 7 Technical Memorandum 15-05 (Hutchison, 2016d).

Assume that modeled drawdown verifications within 1 foot achieve the desired future conditions.

METHODS:

As defined in Chapter 36 of the Texas Water Code (TWC, 2011), "modeled available groundwater" is the estimated average amount of water that may be produced annually to achieve a desired future condition. Groundwater conservation districts are required to consider modeled available groundwater, along with several other factors, when issuing permits in order to manage groundwater production to achieve the desired future condition(s). The other factors districts must consider include annual precipitation and production patterns, the estimated amount of pumping exempt from permitting, existing permits, and a reasonable estimate of actual groundwater production under existing permits.

For relevant aquifers with desired future conditions based on water-level drawdown, water levels simulated at the end of the predictive simulations were compared to specified baseline water levels. In the case of the High Plains Aquifer System (Dockum and Ogallala aquifers) and the minor aquifers of the Llano Uplift area (Ellenburger-San Saba and Hickory aquifers), baseline water levels represent water levels at the end of the calibrated transient model are the initial water level conditions in the predictive simulation—water levels at the end of the preceding year. In the case of the Capitan Reef Complex, Edwards-Trinity (Plateau), Pecos Valley, and Trinity, and Rustler aquifers, the baseline water levels may occur in a specified year, early in the predictive simulation. These baseline years are 2006 in the groundwater availability model for the Capitan Reef Complex Aquifer, 2010 in the alternative model for the Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers, 2012 in the groundwater availability model for the High Plains Aquifer System, 2010 in the groundwater availability model for the minor aquifers of the Llano Uplift area, and 2009 in the groundwater availability model for the Rustler Aquifer. The predictive model runs used average pumping rates from the historical period for the respective model except in the aquifer or area of interest. In those areas, pumping rates are varied until they produce drawdowns consistent with the adopted desired future conditions. Pumping rates or modeled available groundwater are reported in 10-year intervals.

Water-level drawdown averages were calculated for the relevant portions of each aquifer. Drawdown for model cells that became dry during the simulation—when the water level dropped below the base of the cell—were excluded from the averaging. In Groundwater Management Area 7, dry cells only occur during the predictive period in the Ogallala Aquifer of Glasscock County. Consequently, estimates of modeled available groundwater decrease over time as continued simulated pumping predicts the development of increasing numbers of dry model cells in areas of the Ogallala Aquifer in Glasscock County. The calculated water-level drawdown averages were compared with the desired future conditions to verify that the pumping scenario achieved the desired future conditions.

In Kinney and Val Verde counties, the desired future conditions are based on discharge from selected springs. In these cases, spring discharge is estimated based on simulated average spring discharge over a historical period maintaining all historical hydrologic conditions—such as recharge and river stage—except pumping. In other words, we assume that past average hydrologic conditions—the range of fluctuation—will continue in the future. In the cases of Kinney and Val Verde counties, simulated spring discharge is based on hydrologic variations that took place over the periods 1950 through 2005 and 1968 through 2013, respectively. The desired future condition for the Edwards-Trinity (Plateau) Aquifer in Kinney County is similar to the one adopted in 2010 and the associated modeled available groundwater is based on a specific model run—GAM Run 10-043 (Shi, 2012).

Modeled available groundwater values for the Ellenburger-San Saba and Hickory aquifers were determined by extracting pumping rates by decade from the model results using

ZONBUDUSG Version 1.01 (Panday and others, 2013). For the remaining relevant aquifers in Groundwater Management Area 7 modeled available groundwater values were determined by extracting pumping rates by decade from the model results using ZONEBUDGET Version 3.01 (Harbaugh, 2009). Decadal modeled available groundwater for the relevant aquifers are reported by groundwater conservation district and county (Figure 1; Tables 1, 3, 5, 7, 9, 11, 13), and by county, regional water planning area, and river basin (Figures 2 and 3; Tables 2, 4, 6, 8, 10, 12, 14).

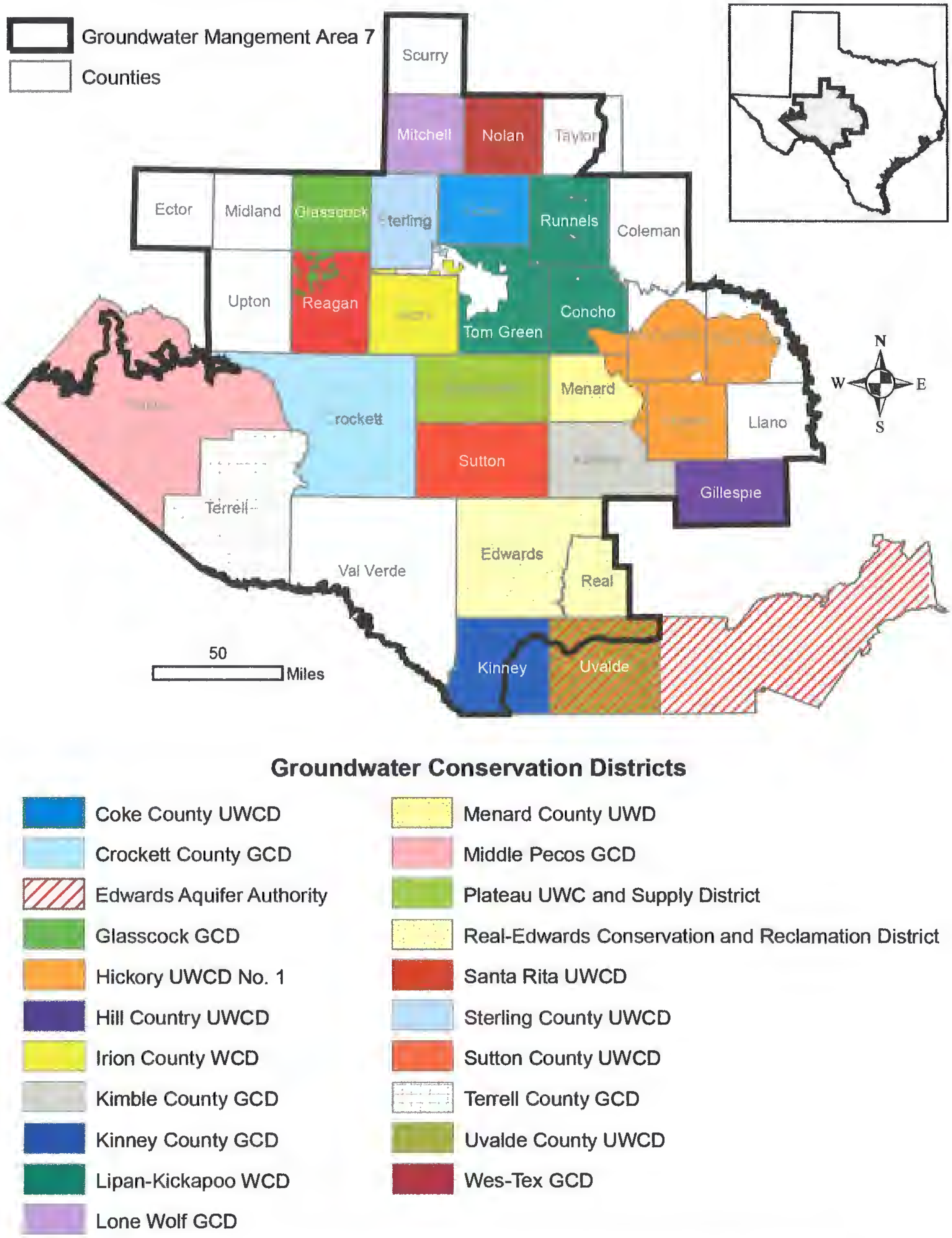

FIGURE 1. MAP SHOWING THE GROUNDWATER CONSERVATION DISTRICTS (GCD) IN GROUNDWATER MANAGEMENT AREA 7. NOTE: THE BOUNDARIES OF THE EDWARDS AQUIFER AUTHORITY OVERLAP WITH THE UVALDE COUNTY UNDERGROUND WATER CONSERVATION DISTRICT (UWCD).

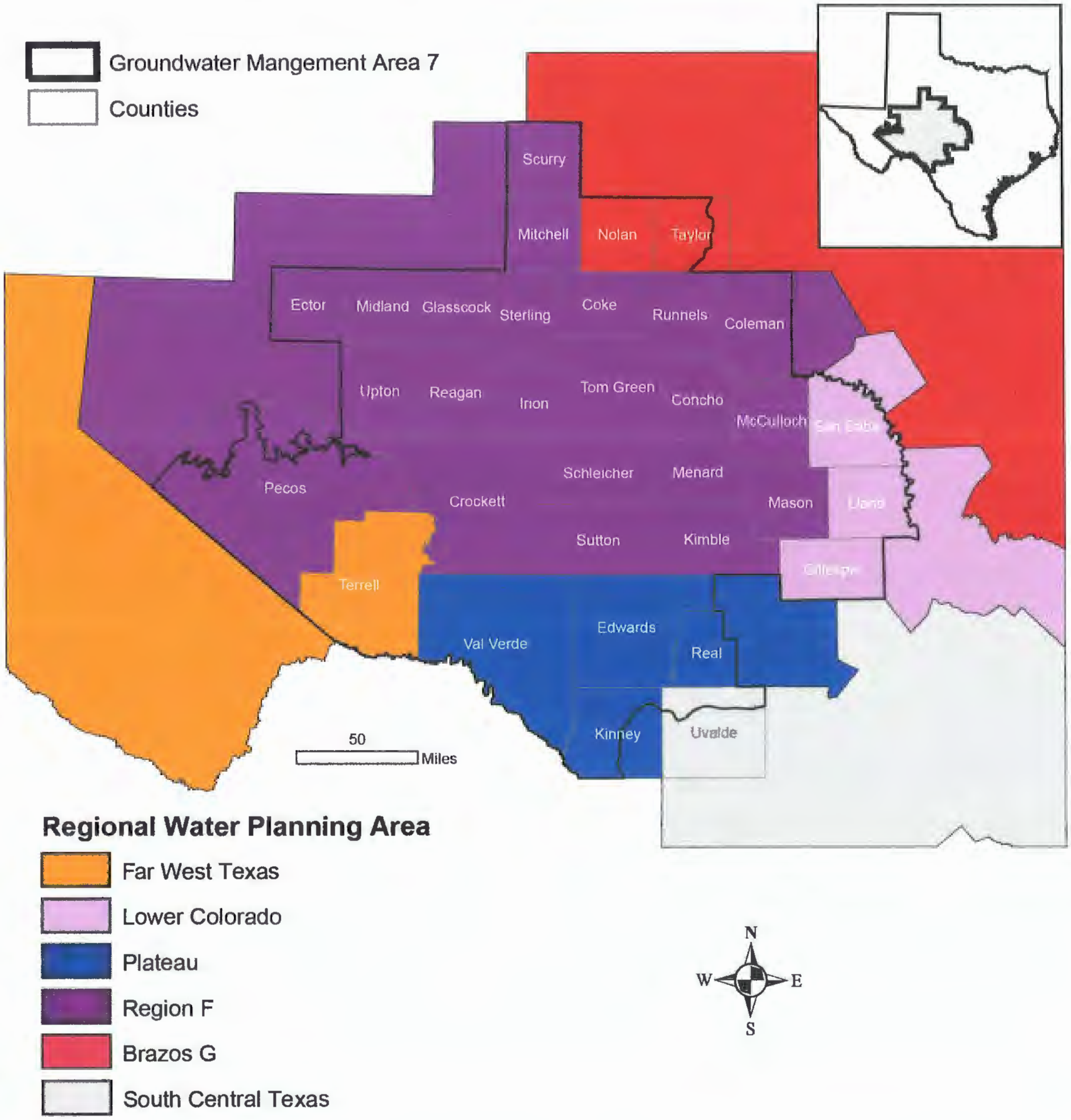

FIGURE 2. MAP SHOWING REGIONAL WATER PLANNING AREAS IN GROUNDWATER MANAGEMENT AREA 7.

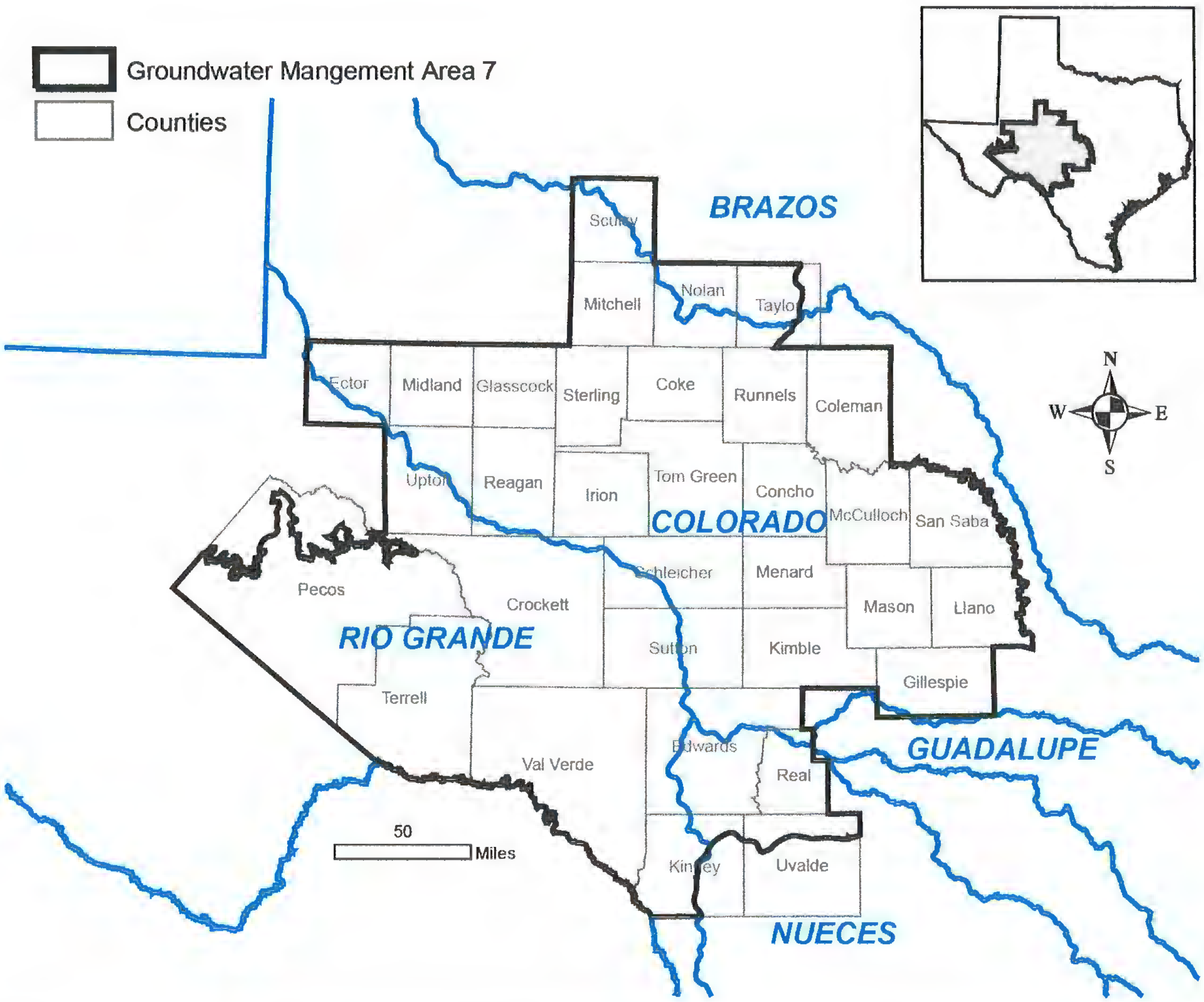

FIGURE 3. **MAP SHOWING RIVER BASINS IN GROUNDWATER MANAGEMENT AREA 7. THESE INCLUDE PARTS OF THE BRAZOS, COLORADO, GUADALUPE, NUECES, AND RIO GRANDE RIVER BASINS.**

PARAMETERS AND ASSUMPTIONS:

Capitan Reef Complex Aquifer

Version 1.01 of the groundwater availability model of the eastern arm of the Capitan Reef Complex Aquifer was used. See Jones (2016) for assumptions and limitations of the groundwater availability model. See Hutchison (2016h) for details on the assumptions used for predictive simulations.

The model has five layers: Layer 1, the Edwards-Trinity (Plateau) and Pecos Valley aquifers; Layer 2, the Dockum Aquifer and the Dewey Lake Formation; Layer 3, the Rustler Aquifer; Layer 4, a confining unit made up of the Salado and Castile formations, and the overlying portion of the Artesia Group; and Layer 5, the Capitan Reef Complex Aquifer, part of the Artesia Group, and the Delaware Mountain Group. Layers 1 through 4 are intended to act solely as boundary conditions facilitating groundwater inflow and outflow relative to the Capitan Reef Complex Aquifer (Layer 5).

The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

The model was run for the interval 2006 through 2070 for a 64-year predictive simulation. Drawdowns were calculated by subtracting 2006 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7.

During predictive simulations, there were no cells where water levels were below the base elevation of the cell ("dry" cells). Therefore, all drawdowns were included in the averaging.

Drawdown averages and modeled available groundwater volumes are based on the official aquifer boundary within Groundwater Management Area 7.

Dockum and Ogallala Aquifers

Version 1.01 of the groundwater availability model for the High Plains Aquifer System by Deeds and Jigmond (2015) was used to construct the predictive model simulation for this analysis. See Hutchison (2016f) for details of the initial assumptions.

The model has four layers which represent the Ogallala and Pecos Valley Alluvium aquifers (Layer 1), the Edwards-Trinity (High Plains) and Edwards-Trinity (Plateau) aquifers (Layer 2), the Upper Dockum Aquifer (Layer 3), and the Lower Dockum Aquifer (Layer 4). Pass-through cells exist in layers 2 and 3 where the Dockum Aquifer was absent but provided pathway for flow between the Lower Dockum and the Ogallala or Edwards-Trinity (High Plains) aquifers vertically. These pass-through cells were excluded from the calculations of drawdowns and modeled available groundwater.

The model was run with MODFLOW-NWT (Niswonger and others, 2011). The model uses the Newton formulation and the upstream weighting package, which automatically reduces pumping as heads drop in a particular cell, as defined by the user. This feature may simulate the declining production of a well as saturated thickness decreases. Deeds and Jigmond (2015) modified the MODFLOW-NWT code to use a saturated thickness of 30 feet as the threshold—instead of percent of the saturated thickness—when pumping reductions occur during a simulation. It is important for groundwater management areas to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

The model was run for the interval 2013 through 2070 for a 58-year predictive simulation. Drawdowns were calculated by subtracting 2012 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7.

During predictive simulations, there were no cells where water levels were below the base elevation of the cell ("dry" cells). Therefore, all drawdowns were included in the averaging. Modeled available groundwater analysis excludes pass-through cells.

Drawdown averages and modeled available groundwater volumes are based on the model boundaries within Groundwater Management Area 7 for the Dockum Aquifer and official aquifer boundaries for the Ogallala Aquifer.

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

The single-layer alternative groundwater flow model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers used for this analysis. This model is an update to the previously developed groundwater availability model documented in Anaya and Jones (2009). See Hutchison and others (2011a) and Anaya and Jones (2009) for assumptions and limitations of the model. See Hutchison (2016e; 2018c) for details on the assumptions used for predictive simulations.

The groundwater model has one layer representing the Pecos Valley Aquifer and the Edwards-Trinity (Plateau) Aquifer. In the relatively narrow area where both aquifers are present, the model is a lumped representation of both aquifers.

The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

The model was run for the interval 2006 through 2070 for a 65-year predictive simulation. Drawdowns were calculated by subtracting 2010 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7. Comparison of 2010 simulated and measured water levels indicate a root mean squared error of 84 feet or 3 percent of the range in water-level elevations.

Drawdowns for cells with water levels below the base elevation of the cell ("dry" cells) were included in the averaging.

Drawdown averages and modeled available groundwater volumes are based on the official aquifer boundaries within Groundwater Management Area 7.

Edwards-Trinity (Plateau) Aquifer of Kinney County

All parameters and assumptions for the Edwards-Trinity (Plateau) Aquifer of Kinney County in Groundwater Management Area 7 are described in GAM Run 10-043 MAG Version 2 (Shi, 2012). This report assumes a planning period from 2010 to 2070.

The Kinney County Groundwater Conservation District model developed by Hutchison and others (2011b) was used for this analysis. The model was calibrated to water level and spring flux collected from 1950 to 2005.

The model has four layers representing the following hydrogeologic units (from top to bottom): Carrizo-Wilcox Aquifer (layer 1), Upper Cretaceous Unit (layer 2), Edwards (Balcones Fault Zone) Aquifer/Edwards portion of the Edwards-Trinity (Plateau) Aquifer (layer 3), and Trinity portion of the Edwards-Trinity (Plateau) Aquifer (layer 4).

The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

The model was run for the interval 2006 through 2070 for a 65-year predictive simulation. Drawdowns were calculated by subtracting 2010 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7.

Modeled available groundwater volumes are based on the official aquifer boundaries within Groundwater Management Area 7 in Kinney County.

Edwards-Trinity (Plateau) Aquifer of Val Verde County

The single-layer numerical groundwater flow model for the Edwards-Trinity (Plateau) Aquifer of Val Verde County was used for this analysis. This model is based on the previously developed alternative groundwater model of the Kinney County area documented in Hutchison and others (2011b). See EcoKai (2014) for assumptions and limitations of the model. See Hutchison (2016e; 2018b) for details on the assumptions used for predictive simulations, including recharge and pumping assumptions.

The groundwater model has one layer representing the Edwards-Trinity (Plateau) Aquifer of Val Verde County.

The model was run with MODFLOW-2005 (Harbaugh, 2005).

The model was run for a 45-year predictive simulation representing hydrologic conditions of the interval 1968 through 2013. Simulated spring discharge from San Felipe Springs was then averaged over duration of the simulation. The resultant pumping rate that met the desired future conditions was applied to the predictive period—2010 through 2070—based on the assumption that average conditions over the predictive period are the same as those over the historic period represented by the model run.

Modeled available groundwater volumes are based on the official aquifer boundaries within Groundwater Management Area 7 in Val Verde County.

Rustler Aquifer

Version 1.01 of the groundwater availability model for the Rustler Aquifer by Ewing and others (2012) was used to construct the predictive model simulation for this analysis. See Hutchison (2016d) for details of the initial assumptions, including recharge conditions.

The model has two layers, the top one representing the Rustler Aquifer, and the other representing the Dewey Lake Formation and the Dockum Aquifer.

The model was run with MODFLOW-NWT (Niswonger and others, 2011).

The model was run for the interval 2009 through 2070 for a 61-year predictive simulation. Drawdowns were calculated by subtracting 2009 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7. During predictive simulations, there were no cells where water levels were below the base elevation of the cell ("dry" cells). Therefore, all drawdowns were included in the averaging.

Drawdown averages and modeled available groundwater volumes are based on the model boundaries within Groundwater Management Area 7.

Minor aquifers of the Llano Uplift Area

We used version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift Area. See Shi and others (2016) for assumptions and limitations of the model. See Hutchison (2016g) for details of the initial assumptions.

The model contains eight layers: Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits (Layer 1), confining units (Layer 2), Marble Falls Aquifer and equivalent units (Layer 3), confining units (Layer 4), Ellenburger-San Saba Aquifer and equivalent units (Layer 5), confining units (Layer 6), Hickory Aquifer and equivalent units (Layer 7), and Precambrian units (Layer 8).

The model was run with MODFLOW-USG beta (development) version (Panday and others, 2013). Perennial rivers and reservoirs were simulated using the MODFLOW-USG river package. Springs were simulated using the MODFLOW-USG drain package.

Drawdown averages and modeled available groundwater volumes are based on the model boundaries within Groundwater Management Area 7.

The model was run for the interval 2011 through 2070 for a 60-year predictive simulation. Drawdowns were calculated by subtracting 2010 simulated water levels from 2070 simulated water levels, which were then averaged over the portion of the aquifer in Groundwater Management Area 7. During predictive simulations, there were no cells where water levels were below the base elevation of the cell ("dry" cells). Therefore, all drawdowns were included in the averaging.

RESULTS:

The modeled available groundwater estimates are 26,164 acre-feet per year in the Capitan Reef Complex Aquifer, 474,464 acre-feet per year in the undifferentiated Edwards-Trinity (Plateau), Pecos Valley, and Trinity aquifers, 22,616 acre-feet per year in the Ellenburger-San Saba Aquifer, 49,936 acre-feet per year in the Hickory Aquifer, 6,570 to 7,925 acre-feet per year in the Ogallala Aquifer, 2,324 acre-feet per year in the Dockum Aquifer, and 7,040 acre-feet per year in the Rustler Aquifer.

The modeled available groundwater for the respective aquifers has been summarized by aquifer, county, and groundwater conservation district (Tables 1, 3, 5, 7, 9, 11, and 13). The modeled available groundwater is also summarized by county, regional water planning area, river basin, and aquifer for use in the regional water planning process (Tables 2, 4, 6, 8, 10, 12, and 14). The modeled available groundwater for the Ogallala Aquifer that achieves the desired future conditions adopted by districts in Groundwater Management Area 7 decreases from 7,925 to 6,570 acre-feet per year between 2020 and 2070 (Tables 9 and 10). This decline is attributable to the occurrence of increasing numbers of cells where water levels were below the base elevation of the cell ("dry" cells) in parts of Glasscock County. Please note that MODFLOW-NWT automatically reduces pumping as water levels decline.

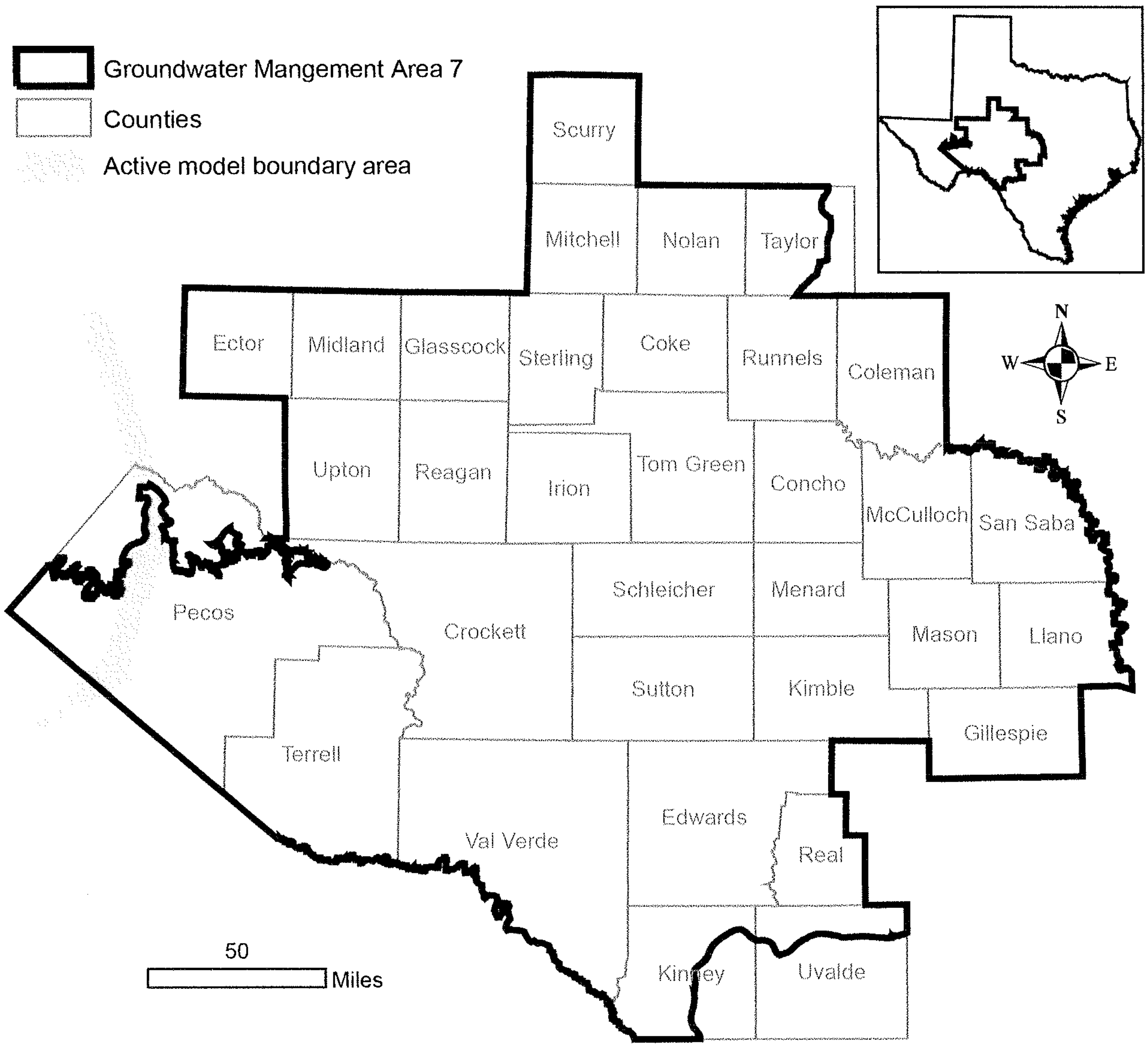

FIGURE 4. MAP SHOWING THE AREAS COVERED BY THE CAPITAN REEF COMPLEX AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE EASTERN ARM OF THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 7.

TABLE 1. MODELED AVAILABLE GROUNDWATER FOR THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2006 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR. GCD IS THE ABBREVIATION FOR GROUNDWATER CONSERVATION DISTRICT.

District	County	Year							
		2006	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Middle Pecos GCD	Pecos	26,164	26,164	26,164	26,164	26,164	26,164	26,164	26,164
	Total	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**
GMA 7		**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**

TABLE 2. MODELED AVAILABLE GROUNDWATER FOR THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Pecos	F	Rio Grande	26,164	26,164	26,164	26,164	26,164	26,164
		Total	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**
GMA 7			**26,164**	**26,164**	**26,164**	**26,164**	**26,164**	**26,164**

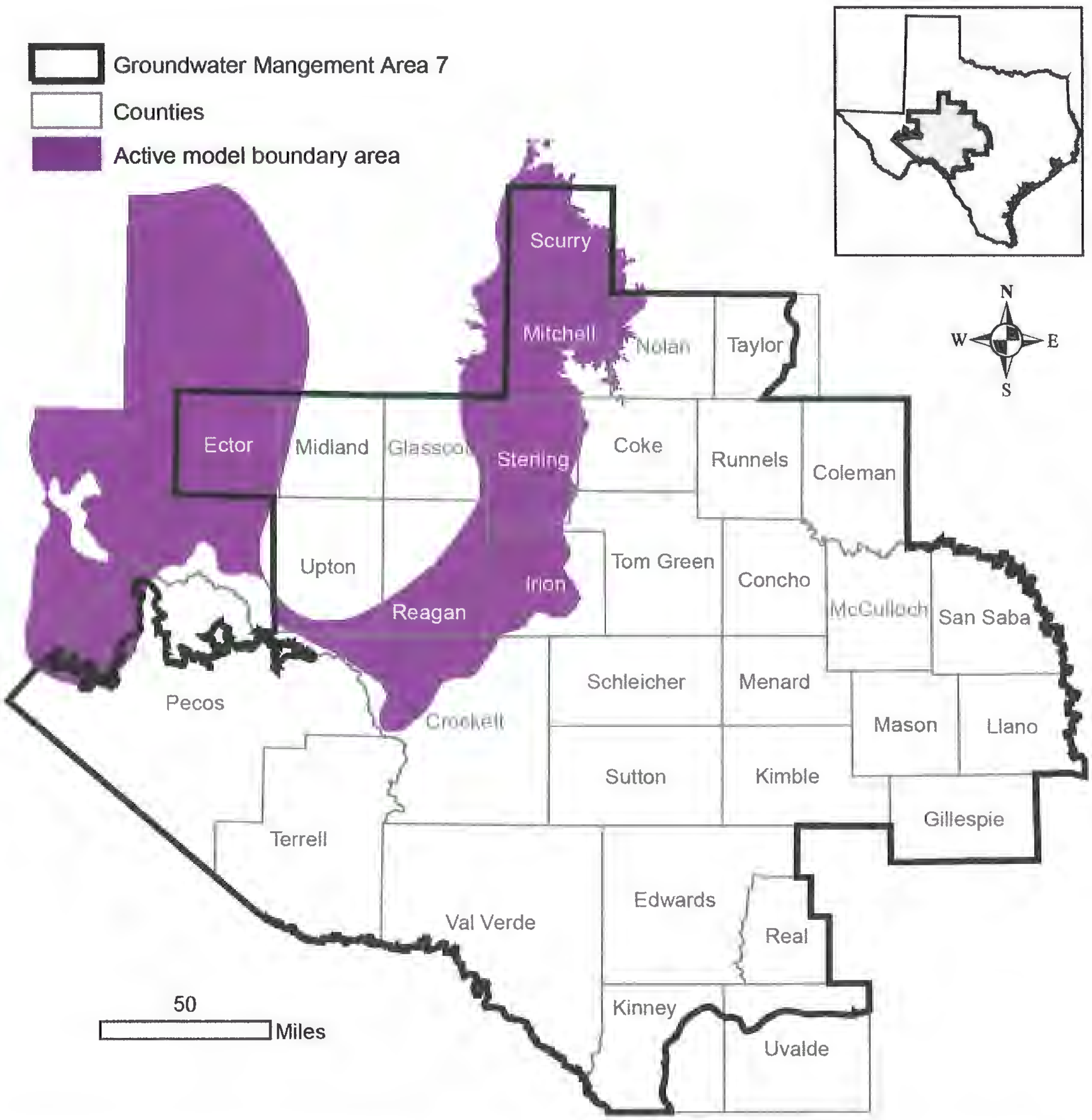

FIGURE 5. MAP SHOWING AREAS COVERED BY THE DOCKUM AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE HIGH PLAINS AQUIFER SYSTEM IN GROUNDWATER MANAGEMENT AREA 7.

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE DOCKUM AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2013 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR. GCD AND UWCD ARE THE ABBREVIATIONS FOR GROUNDWATER CONSERVATION DISTRICT AND UNDERGROUND WATER CONSERVATION DISTRICT, RESPECTIVELY.

District	County	Year						
		2013	2020	2030	2040	2050	2060	2070
Middle Pecos GCD	Pecos	2,022	2,022	2,022	2,022	2,022	2,022	2,022
	Total	**2,022**	**2,022**	**2,022**	**2,022**	**2,022**	**2,022**	**2,022**
Santa Rita UWCD	Reagan	302	302	302	302	302	302	302
	Total	**302**	**302**	**302**	**302**	**302**	**302**	**302**
GMA 7		**2324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**

Note: The modeled available groundwater for Santa Rita Underground Water Conservation District excludes parts of Reagan County that fall within Glasscock Groundwater Conservation District. The year 2013 is used because the 2012 desired future condition baseline year for the Dockum Aquifer is an initial condition in the predictive model run.

TABLE 4. MODELED AVAILABLE GROUNDWATER FOR THE DOCKUM AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Pecos	F	Rio Grande	2,022	2,022	2,022	2,022	2,022	2,022
		Total	**2,022**	**2,022**	**2,022**	**2,022**	**2,022**	**2,022**
Reagan	F	Colorado	302	302	302	302	302	302
		Rio Grande	0	0	0	0	0	0
		Total	**302**	**302**	**302**	**302**	**302**	**302**
GMA 7			**2,324**	**2,324**	**2,324**	**2,324**	**2,324**	**2,324**

Note: The modeled available groundwater for Reagan County excludes parts of Reagan County that fall outside of Santa Rita Underground Water Conservation District.

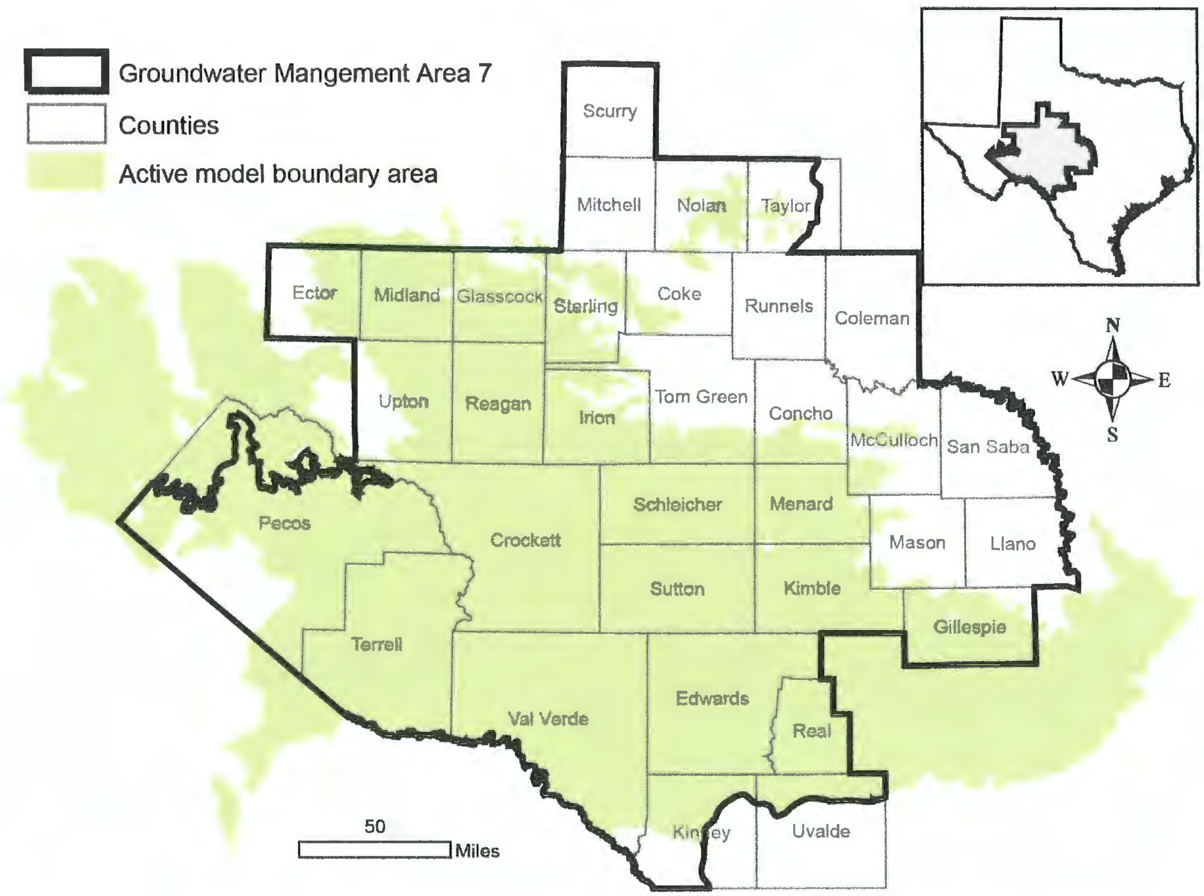

FIGURE 6. **MAP SHOWING THE AREAS COVERED BY THE UNDIFFERENTIATED EDWARDS-TRINITY (PLATEAU), PECOS VALLEY, AND TRINITY AQUIFERS IN THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFERS IN GROUNDWATER MANAGEMENT AREA 7.**

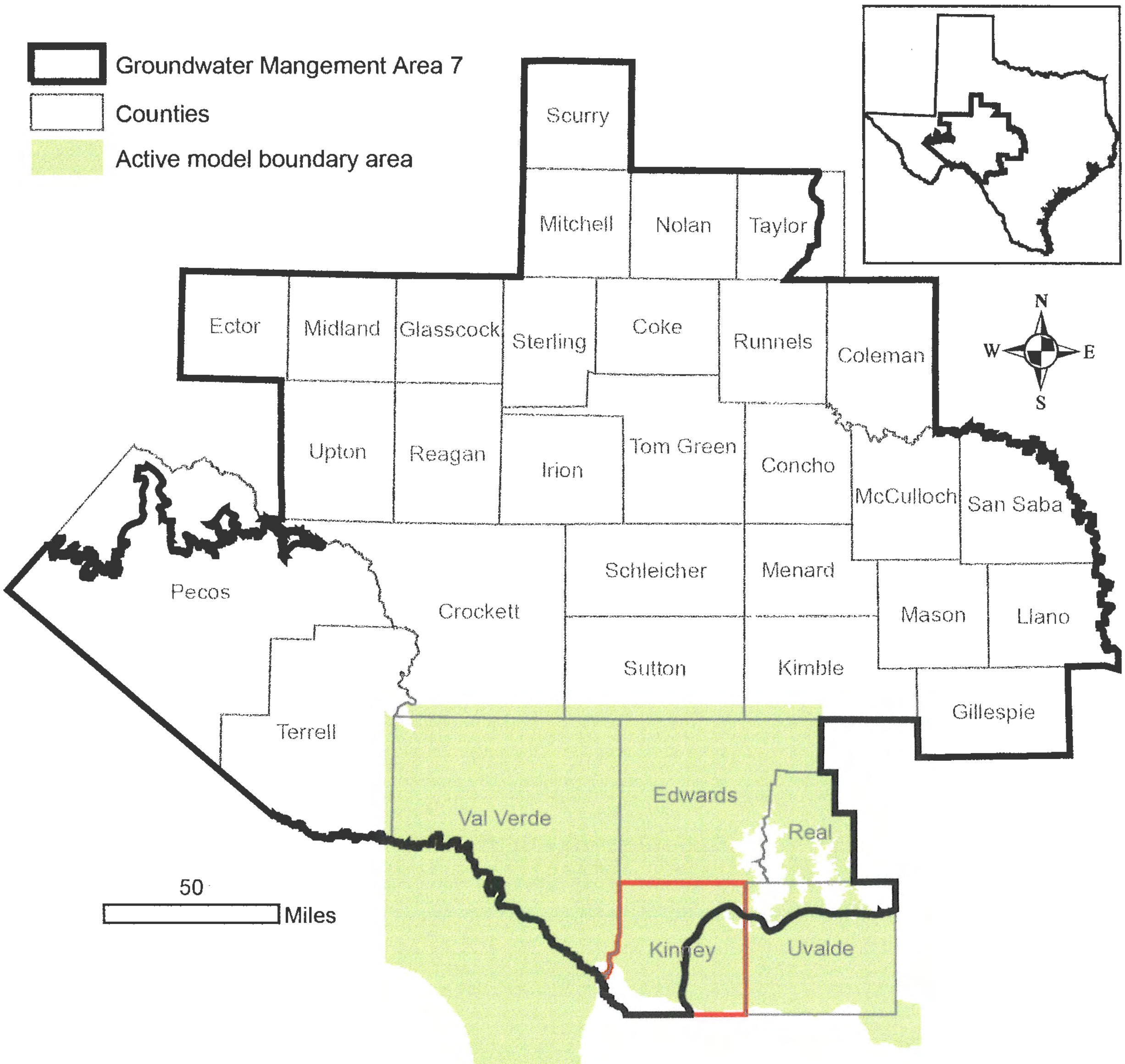

FIGURE 7. MAP SHOWING THE AREAS COVERED BY THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN THE ALTERNATIVE MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN KINNEY COUNTY.

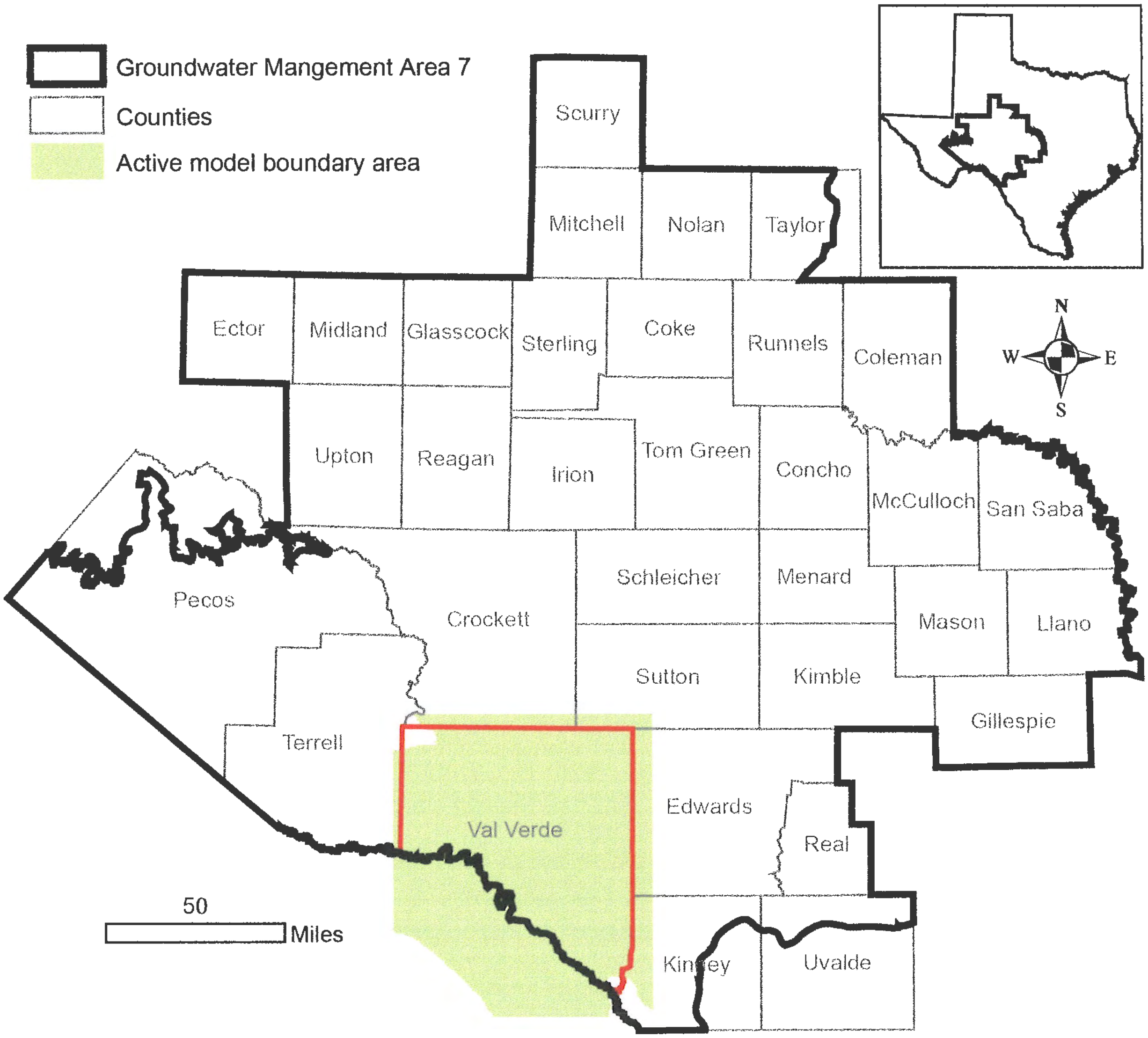

FIGURE 8. **MAP SHOWING THE AREAS COVERED BY THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN THE GROUNDWATER FLOW MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN VAL VERDE COUNTY.**

TABLE 5. MODELED AVAILABLE GROUNDWATER FOR THE UNDIFFERENTIATED EDWARDS-TRINITY (PLATEAU), PECOS VALLEY, AND TRINITY AQUIFERS IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY, FOR EACH DECADE BETWEEN 2006 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR. UWCD IS ABBREVIATION FOR UNDERGROUND WATER CONSERVATION DISTRICT, WCD IS WATER CONSERVATION DISTRICT, UWD IS UNDERGROUND WATER DISTRICT, UWC IS UNDERGROUND WATER CONSERVATION, AND C AND R DISTRICT IS CONSERVATION AND RECLAMATION DISTRICT.

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
Coke County UWCD	Coke	997	997	997	997	997	997	997
	Total	**997**	**997**	**997**	**997**	**997**	**997**	**997**
Crockett County GCD	Crockett	4,675	4,675	4,675	4,675	4,675	4,675	4,675
	Total	**4,675**	**4,675**	**4,675**	**4,675**	**4,675**	**4,675**	**4,675**
Glasscock GCD	Glasscock	65,186	65,186	65,186	65,186	65,186	65,186	65,186
	Reagan	40,835	40,835	40,835	40,835	40,835	40,835	40,835
	Total	**106,021**	**106,021**	**106,021**	**106,021**	**106,021**	**106,021**	**106,021**
Hill Country UWCD	Gillespie	4,979	4,979	4,979	4,979	4,979	4,979	4,979
	Total	**4,979**	**4,979**	**4,979**	**4,979**	**4,979**	**4,979**	**4,979**
Irion County WCD*	Irion	3,289	3,289	3,289	3,289	3,289	3,289	3,289
	Total	**3,289**	**3,289**	**3,289**	**3,289**	**3,289**	**3,289**	**3,289**
Kimble County GCD	Kimble	1,282	1,282	1,282	1,282	1,282	1,282	1,282
	Total	**1,282**	**1,282**	**1,282**	**1,282**	**1,282**	**1,282**	**1,282**
Kinney County GCD	Kinney	70,341	70,341	70,341	70,341	70,341	70,341	70,341
	Total	**70,341**	**70,341**	**70,341**	**70,341**	**70,341**	**70,341**	**70,341**

TABLE 5. (CONTINUED).

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
Menard County UWD	Menard	2,217	2,217	2,217	2,217	2,217	2,217	2,217
	Total	**2,217**	**2,217**	**2,217**	**2,217**	**2,217**	**2,217**	**2,217**
Middle Pecos GCD	Pecos	117,309	117,309	117,309	117,309	117,309	117,309	117,309
	Total	**117,309**	**117,309**	**117,309**	**117,309**	**117,309**	**117,309**	**117,309**
Plateau UWC and Supply District	Schleicher	8,034	8,034	8,034	8,034	8,034	8,034	8,034
	Total	**8,034**	**8,034**	**8,034**	**8,034**	**8,034**	**8,034**	**8,034**
Real-Edwards C and R District	Edwards	5,676	5,676	5,676	5,676	5,676	5,676	5,676
	Real	7,523	7,523	7,523	7,523	7,523	7,523	7,523
	Total	**13,199**	**13,199**	**13,199**	**13,199**	**13,199**	**13,199**	**13,199**
Santa Rita UWCD	Reagan	27,398	27,398	27,398	27,398	27,398	27,398	27,398
	Total	**27,398**	**27,398**	**27,398**	**27,398**	**27,398**	**27,398**	**27,398**
Sterling County UWCD	Sterling	2,495	2,495	2,495	2,495	2,495	2,495	2,495
	Total	**2,495**	**2,495**	**2,495**	**2,495**	**2,495**	**2,495**	**2,495**
Sutton County UWCD	Sutton	6,400	6,400	6,400	6,400	6,400	6,400	6,400
	Total	**6,400**	**6,400**	**6,400**	**6,400**	**6,400**	**6,400**	**6,400**
Terrell County GCD	Terrell	1,420	1,420	1,420	1,420	1,420	1,420	1,420
	Total	**1,420**	**1,420**	**1,420**	**1,420**	**1,420**	**1,420**	**1,420**
Uvalde County UWCD	Uvalde	1,993	1,993	1,993	1,993	1,993	1,993	1,993
	Total	**1,993**	**1,993**	**1,993**	**1,993**	**1,993**	**1,993**	**1,993**

TABLE 5. (CONTINUED).

District	County	Year						
		2010	2020	2030	2040	2050	2060	2070
No district		102,415	102,415	102,415	102,415	102,415	102,415	102,415
GMA 7		**474,464**	**474,464**	**474,464**	**474,464**	**474,464**	**474,464**	**474,464**

*The modeled available groundwater for Irion County WCD only includes the portion of the district that falls within Irion County.

TABLE 6. MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE UNDIFFERENTIATED EDWARDS-TRINITY (PLATEAU), PECOS VALLEY, AND TRINITY AQUIFERS IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Coke	F	Colorado	997	997	997	997	997	997
		Total	**997**	**997**	**997**	**997**	**997**	**997**
Crockett	F	Colorado	20	20	20	20	20	20
		Rio Grande	5,427	5,427	5,427	5,427	5,427	5,427
		Total	**5,447**	**5,447**	**5,447**	**5,447**	**5,447**	**5,447**
Ector	F	Colorado	4,925	4,925	4,925	4,925	4,925	4,925
		Rio Grande	617	617	617	617	617	617
		Total	**5,542**	**5,542**	**5,542**	**5,542**	**5,542**	**5,542**
Edwards	J	Colorado	2,305	2,305	2,305	2,305	2,305	2,305
		Nueces	1,631	1,631	1,631	1,631	1,631	1,631
		Rio Grande	1,740	1,740	1,740	1,740	1,740	1,740
		Total	**5,676**	**5,676**	**5,676**	**5,676**	**5,676**	**5,676**
Gillespie	K	Colorado	4,843	4,843	4,843	4,843	4,843	4,843
		Guadalupe	136	136	136	136	136	136
		Total	**4,979**	**4,979**	**4,979**	**4,979**	**4,979**	**4,979**
Glasscock	F	Colorado	65,186	65,186	65,186	65,186	65,186	65,186
		Total	**65,186**	**65,186**	**65,186**	**65,186**	**65,186**	**65,186**

TABLE 6. (CONTINUED).

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Irion	F	Colorado	3,289	3,289	3,289	3,289	3,289	3,289
		Total	**3,289**	**3,289**	**3,289**	**3,289**	**3,289**	**3,289**
Kimble*	F	Colorado	1,282	1,282	1,282	1,282	1,282	1,282
		Total	**1,282**	**1,282**	**1,282**	**1,282**	**1,282**	**1,282**
Kinney	J	Nueces	12	12	12	12	12	12
		Rio Grande	70,329	70,329	70,329	70,329	70,329	70,329
		Total	**70,341**	**70,341**	**70,341**	**70,341**	**70,341**	**70,341**
Menard*	F	Colorado	2,217	2,217	2,217	2,217	2,217	2,217
		Total	**2,217**	**2,217**	**2,217**	**2,217**	**2,217**	**2,217**
Midland	F	Colorado	23,233	23,233	23,233	23,233	23,233	23,233
		Total	**23,233**	**23,233**	**23,233**	**23,233**	**23,233**	**23,233**
Pecos	F	Rio Grande	117,309	117,309	117,309	117,309	117,309	117,309
		Total	**117,309**	**117,309**	**117,309**	**117,309**	**117,309**	**117,309**
Reagan	F	Colorado	68,205	68,205	68,205	68,205	68,205	68,205
		Rio Grande	28	28	28	28	28	28
		Total	**68,233**	**68,233**	**68,233**	**68,233**	**68,233**	**68,233**
Real	J	Colorado	277	277	277	277	277	277
		Guadalupe	3	3	3	3	3	3
		Nueces	7,243	7,243	7,243	7,243	7,243	7,243
		Total	**7,523**	**7,523**	**7,523**	**7,523**	**7,523**	**7,523**

TABLE 6. (CONTINUED).

County	RWPA	River Basin	Year					
			2020	**2030**	**2040**	**2050**	**2060**	**2070**
Schleicher	F	Colorado	6,403	6,403	6,403	6,403	6,403	6,403
		Rio Grande	1,631	1,631	1,631	1,631	1,631	1,631
		Total	**8,034**	**8,034**	**8,034**	**8,034**	**8,034**	**8,034**
Sterling	F	Colorado	2,495	2,495	2,495	2,495	2,495	2,495
		Total	**2,495**	**2,495**	**2,495**	**2,495**	**2,495**	**2,495**
Sutton	F	Colorado	388	388	388	388	388	388
		Rio Grande	6,022	6,022	6,022	6,022	6,022	6,022
		Total	**6,410**	**6,410**	**6,410**	**6,410**	**6,410**	**6,410**
Taylor	G	Brazos	331	331	331	331	331	331
		Colorado	158	158	158	158	158	158
		Total	**489**	**489**	**489**	**489**	**489**	**489**
Terrell	E	Rio Grande	1,420	1,420	1,420	1,420	1,420	1,420
		Total	**1,420**	**1,420**	**1,420**	**1,420**	**1,420**	**1,420**
Upton	F	Colorado	21,243	21,243	21,243	21,243	21,243	21,243
		Rio Grande	1,126	1,126	1,126	1,126	1,126	1,126
		Total	**22,369**	**22,369**	**22,369**	**22,369**	**22,369**	**22,369**
Uvalde	L	Nueces	1,993	1,993	1,993	1,993	1,993	1,993
		Total	**1,993**	**1,993**	**1,993**	**1,993**	**1,993**	**1,993**
Val Verde	J	Rio Grande	50,000	50,000	50,000	50,000	50,000	50,000
		Total	**50,000**	**50,000**	**50,000**	**50,000**	**50,000**	**50,000**
GMA 7			**474,464**	**474,464**	**474,464**	**474,464**	**474,464**	**474,464**

*The modeled available groundwater for Kimble and Menard counties excludes the parts of the counties that fall within Hickory Underground Water Conservation District No. 1.

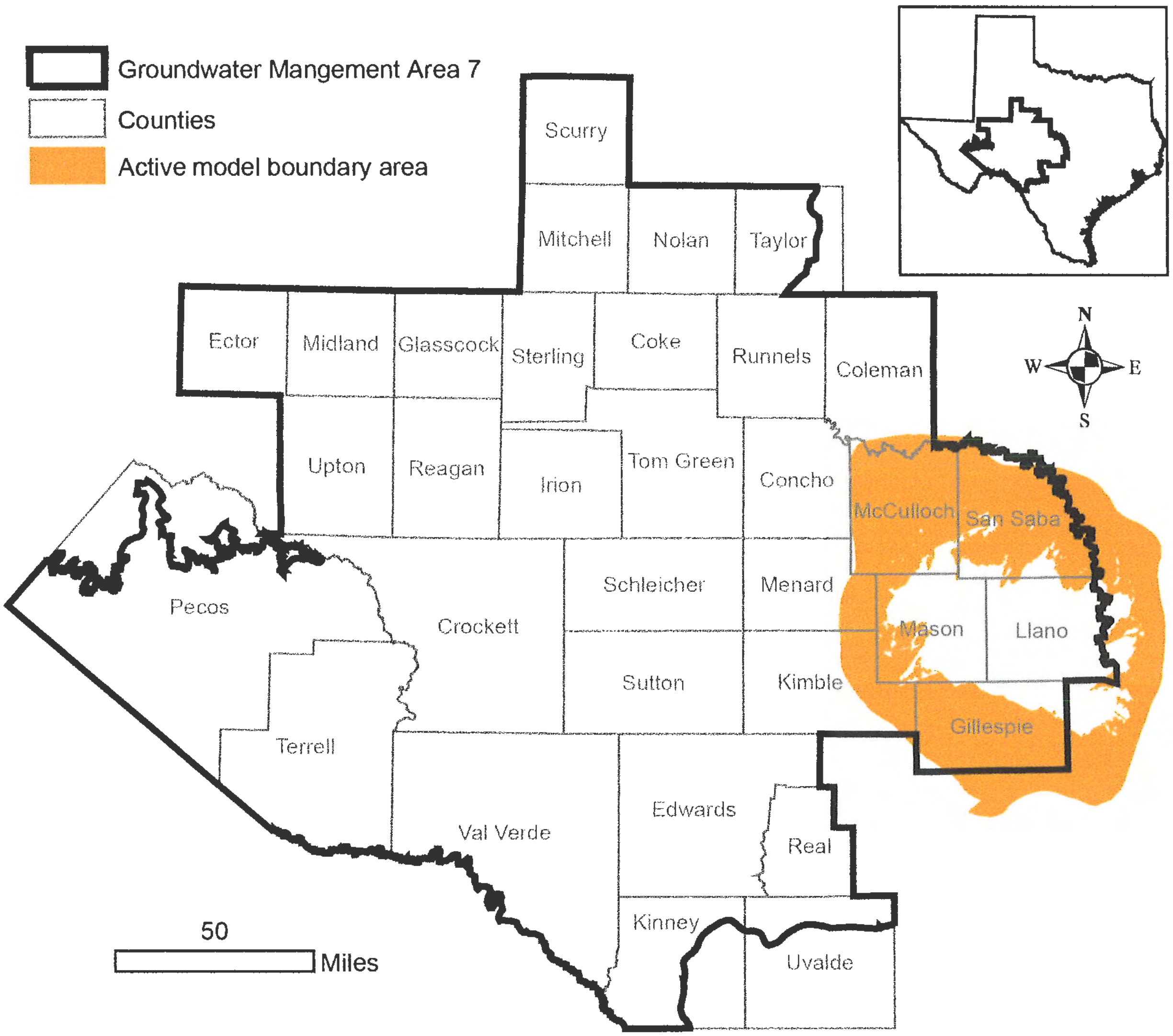

FIGURE 9. MAP SHOWING THE AREAS COVERED BY THE ELLENBURGER-SAN SABA AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT AREA IN GROUNDWATER MANAGEMENT AREA 7.

TABLE 7. MODELED AVAILABLE GROUNDWATER FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2011 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR. UWCD IS THE ABBREVIATION FOR UNDERGROUND WATER CONSERVATION DISTRICT AND UWD IS UNDERGROUND WATER DISTRICT.

District	County	Year						
		2011	2020	2030	2040	2050	2060	2070
Hickory UWCD No. 1	Kimble	344	344	344	344	344	344	344
	Mason	3,237	3,237	3,237	3,237	3,237	3,237	3,237
	McCulloch	3,466	3,466	3,466	3,466	3,466	3,466	3,466
	Menard	282	282	282	282	282	282	282
	San Saba	5,559	5,559	5,559	5,559	5,559	5,559	5,559
	Total	**12,887**	**12,887**	**12,887**	**12,887**	**12,887**	**12,887**	**12,887**
Hill Country UWCD	Gillespie	6,294	6,294	6,294	6,294	6,294	6,294	6,294
	Total	**6,294**	**6,294**	**6,294**	**6,294**	**6,294**	**6,294**	**6,294**
Kimble County GCD	Kimble	178	178	178	178	178	178	178
	Total	**178**	**178**	**178**	**178**	**178**	**178**	**178**
Menard County UWD	Menard	27	27	27	27	27	27	27
	Total	**27**	**27**	**27**	**27**	**27**	**27**	**27**
No District	McCulloch	898	898	898	898	898	898	898
	San Saba	2,331	2,331	2,331	2,331	2,331	2,331	2,331
	Total	**3,229**	**3,229**	**3,229**	**3,229**	**3,229**	**3,229**	**3,229**
GMA 7		**22,616**	**22,616**	**22,616**	**22,616**	**22,616**	**22,616**	**22,616**

Note: The year 2011 is used because the 2010 desired future condition baseline year for the Ellenburger-San Saba Aquifer is an initial condition in the predictive model run.

TABLE 8. MODELED AVAILABLE GROUNDWATER FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Gillespie	K	Colorado	6,294	6,294	6,294	6,294	6,294	6,294
		Total	**6,294**	**6,294**	**6,294**	**6,294**	**6,294**	**6,294**
Kimble	F	Colorado	521	521	521	521	521	521
		Total	**521**	**521**	**521**	**521**	**521**	**521**
Mason	F	Colorado	3,237	3,237	3,237	3,237	3,237	3,237
		Total	**3,237**	**3,237**	**3,237**	**3,237**	**3,237**	**3,237**
McCulloch	F	Colorado	4,364	4,364	4,364	4,364	4,364	4,364
		Total	**4,364**	**4,364**	**4,364**	**4,364**	**4,364**	**4,364**
Menard	F	Colorado	309	309	309	309	309	309
		Total	**309**	**309**	**309**	**309**	**309**	**309**
San Saba	K	Colorado	7,890	7,890	7,890	7,890	7,890	7,890
		Total	**7,890**	**7,890**	**7,890**	**7,890**	**7,890**	**7,890**
GMA 7			**22,616**	**22,616**	**22,616**	**22,616**	**22,616**	**22,616**

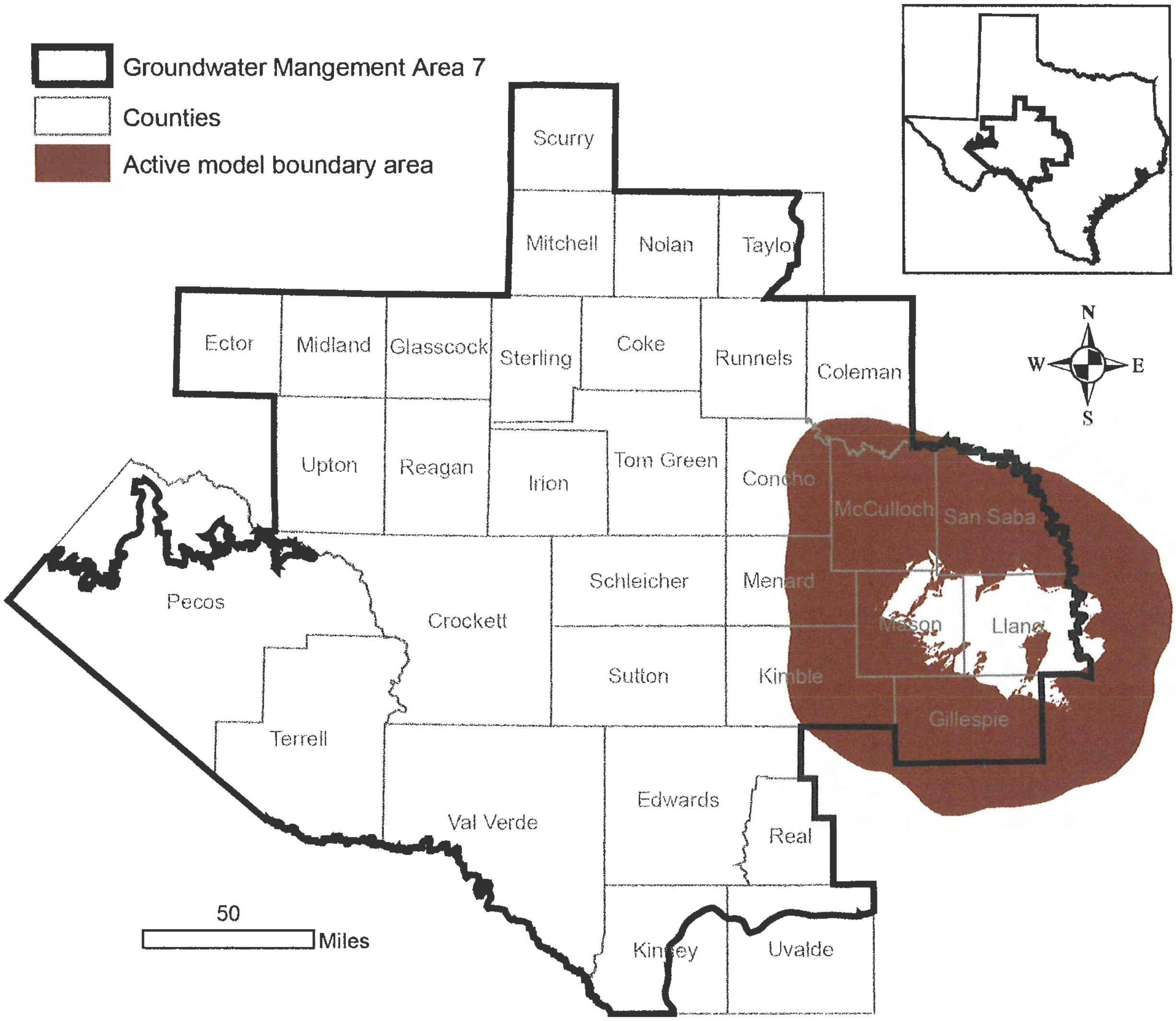

FIGURE 10. **MAP SHOWING AREAS COVERED BY THE HICKORY AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT AREA IN GROUNDWATER MANAGEMENT AREA 7.**

TABLE 9. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2011 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR. UWCD IS THE ABBREVIATION FOR UNDERGROUND WATER CONSERVATION DISTRICT AND UWD IS UNDERGROUND WATER DISTRICT.

District	County	Year						
		2011	2020	2030	2040	2050	2060	2070
Hickory UWCD No. 1	Concho	13	13	13	13	13	13	13
	Kimble	42	42	42	42	42	42	42
	Mason	13,212	13,212	13,212	13,212	13,212	13,212	13,212
	McCulloch	21,950	21,950	21,950	21,950	21,950	21,950	21,950
	Menard	2,600	2,600	2,600	2,600	2,600	2,600	2,600
	San Saba	7,027	7,027	7,027	7,027	7,027	7,027	7,027
	Total	**44,843**	**44,843**	**44,843**	**44,843**	**44,843**	**44,843**	**44,843**
Hill Country UWCD	Gillespie	1,751	1,751	1,751	1,751	1,751	1,751	1,751
	Total	**1,751**	**1,751**	**1,751**	**1,751**	**1,751**	**1,751**	**1,751**
Kimble County GCD	Kimble	123	123	123	123	123	123	123
	Total	**123**	**123**	**123**	**123**	**123**	**123**	**123**
Lipan-Kickapoo WCD	Concho	13	13	13	13	13	13	13
	Total	**13**	**13**	**13**	**13**	**13**	**13**	**13**
Menard County UWD	Menard	126	126	126	126	126	126	126
	Total	**126**	**126**	**126**	**126**	**126**	**126**	**126**
No District	McCulloch	2,427	2,427	2,427	2,427	2,427	2,427	2,427
	San Saba	652	652	652	652	652	652	652
	Total	**3,080**	**3,080**	**3,080**	**3,080**	**3,080**	**3,080**	**3,080**
GMA 7		**49,936**	**49,936**	**49,936**	**49,936**	**49,936**	**49,936**	**49,936**

Note: The year 2011 is used because the 2010 desired future condition baseline year for the Hickory Aquifer is an initial condition in the predictive model run.

TABLE 10. MODELED AVAILABLE GROUNDWATER FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Concho	F	Colorado	27	27	27	27	27	27
		Total	**27**	**27**	**27**	**27**	**27**	**27**
Gillespie	K	Colorado	1,751	1,751	1,751	1,751	1,751	1,751
		Total	**1,751**	**1,751**	**1,751**	**1,751**	**1,751**	**1,751**
Kimble	F	Colorado	165	165	165	165	165	165
		Total	**165**	**165**	**165**	**165**	**165**	**165**
Mason	F	Colorado	13,212	13,212	13,212	13,212	13,212	13,212
		Total	**13,212**	**13,212**	**13,212**	**13,212**	**13,212**	**13,212**
McCulloch	F	Colorado	24,377	24,377	24,377	24,377	24,377	24,377
		Total	**24,377**	**24,377**	**24,377**	**24,377**	**24,377**	**24,377**
Menard	F	Colorado	2,725	2,725	2,725	2,725	2,725	2,725
		Total	**2,725**	**2,725**	**2,725**	**2,725**	**2,725**	**2,725**
San Saba	K	Colorado	7,680	7,680	7,680	7,680	7,680	7,680
		Total	**7,680**	**7,680**	**7,680**	**7,680**	**7,680**	**7,680**
GMA 7			**49,936**	**49,936**	**49,936**	**49,936**	**49,936**	**49,936**

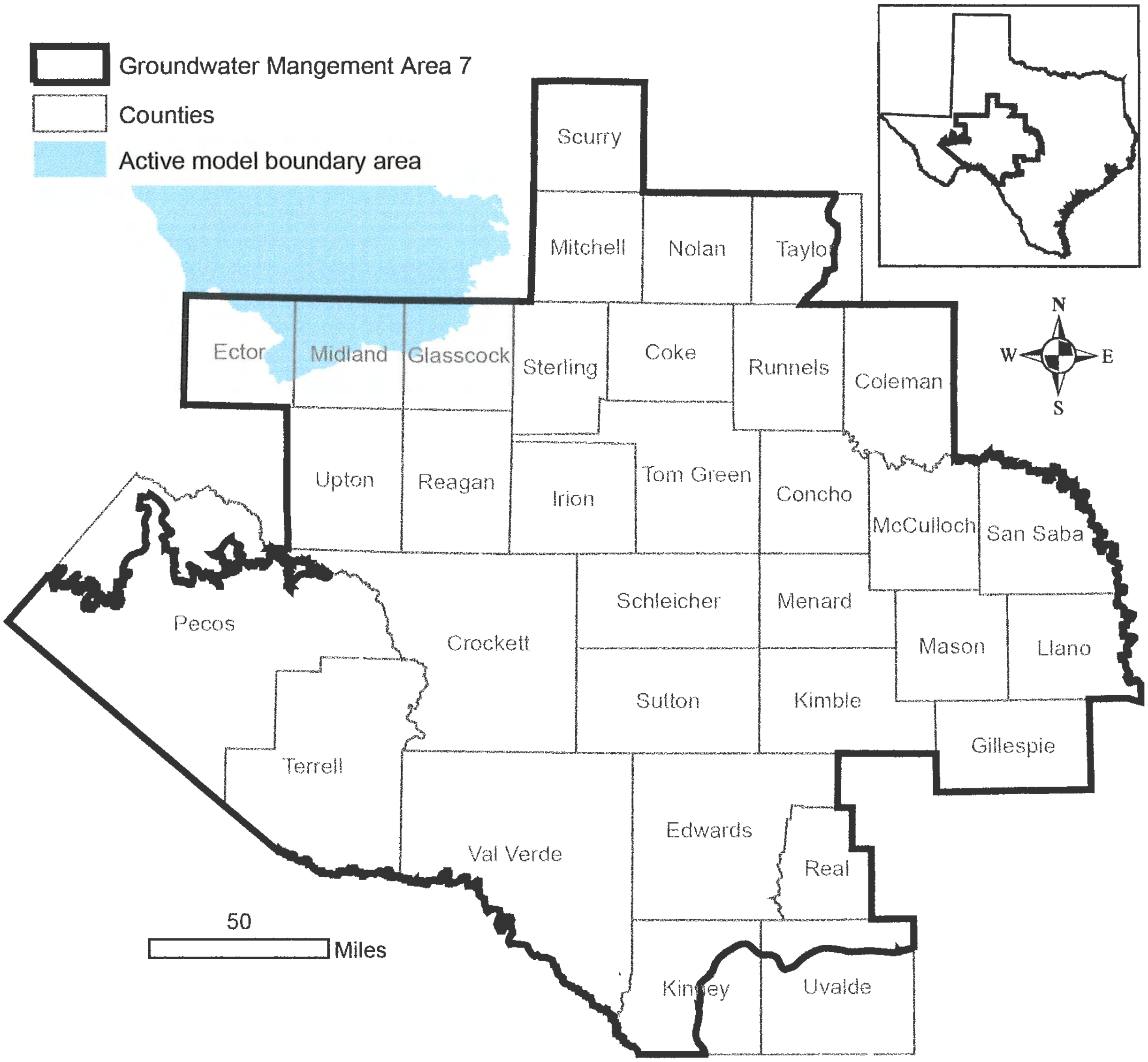

FIGURE 11. **MAP SHOWING THE AREAS COVERED BY THE OGALLALA AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE HIGH PLAINS AQUIFER SYSTEM IN GROUNDWATER MANAGEMENT AREA 7.**

TABLE 11. MODELED AVAILABLE GROUNDWATER FOR THE OGALLALA AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2013 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year						
		2013	2020	2030	2040	2050	2060	2070
Glasscock GCD	Glasscock	8,019	7,925	7,673	7,372	7,058	6,803	6,570
	Total	**8,019**	**7,925**	**7,673**	**7,372**	**7,058**	**6,803**	**6,570**
GMA 7		**8,019**	**7,925**	**7,673**	**7,372**	**7,058**	**6,803**	**6,570**

Note: The year 2013 is used because the 2012 desired future condition baseline year for the Ogallala Aquifer is an initial condition in the predictive model run.

TABLE 12. MODELED AVAILABLE GROUNDWATER FOR THE OGALLALA AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	2030	2040	2050	2060	2070
Glasscock	F	Colorado	7,925	7,673	7,372	7,058	6,803	6,570
		Total	**7,925**	**7,673**	**7,372**	**7,058**	**6,803**	**6,570**
GMA 7			**7,925**	**7,673**	**7,372**	**7,058**	**6,803**	**6,570**

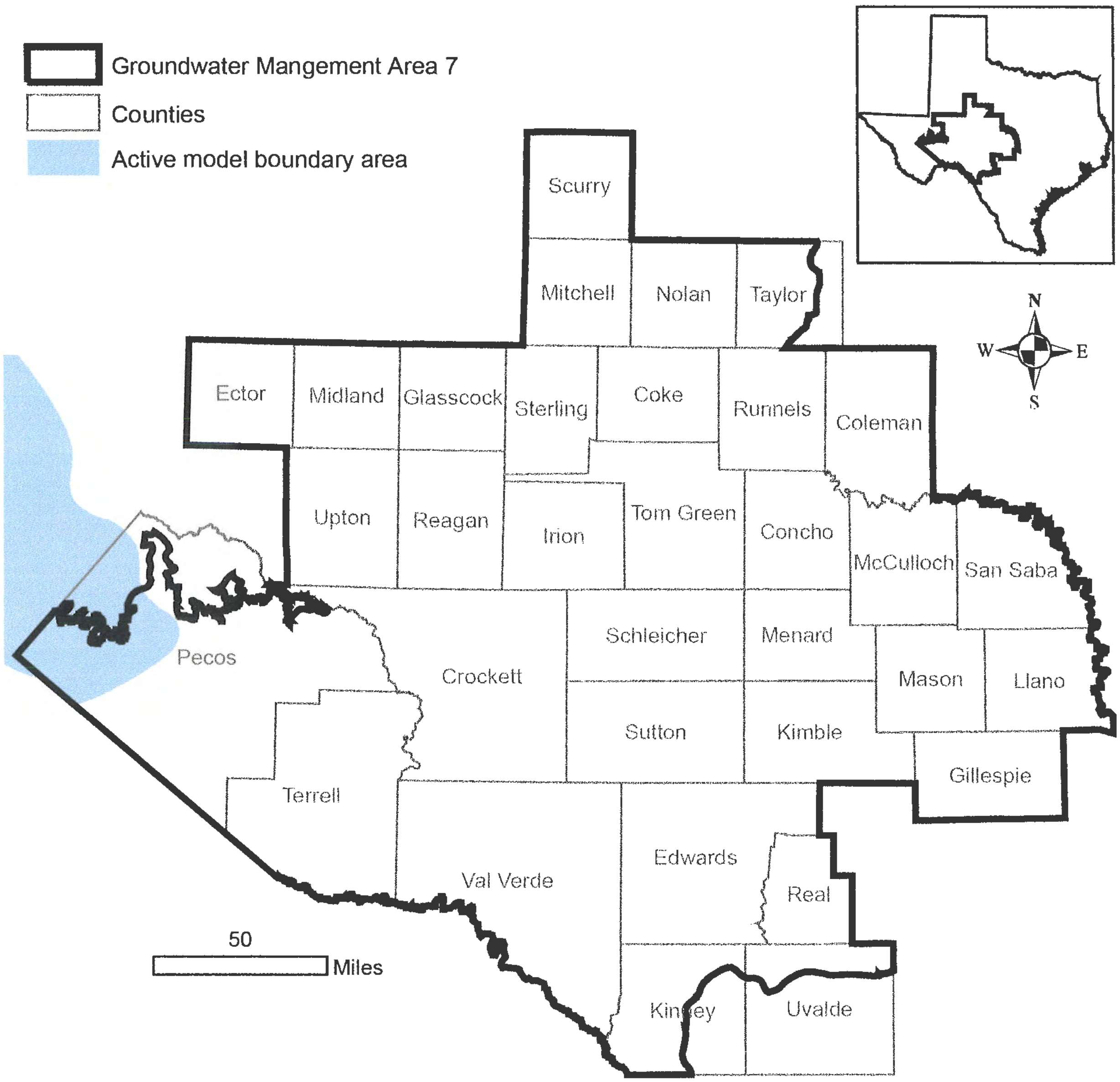

FIGURE 12. **MAP SHOWING AREAS COVERED BY THE RUSTLER AQUIFER IN THE GROUNDWATER AVAILABILITY MODEL FOR THE RUSTLER AQUIFER IN GROUNDWATER MANAGEMENT AREA 7.**

TABLE 13. MODELED AVAILABLE GROUNDWATER FOR THE RUSTLER AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY DISTRICT AND COUNTY FOR EACH DECADE BETWEEN 2009 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

District	County	Year							
		2009	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Middle Pecos GCD	Pecos	7,040	7,040	7,040	7,040	7,040	7,040	7,040	7,040
	Total	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**

TABLE 14. MODELED AVAILABLE GROUNDWATER FOR THE RUSTLER AQUIFER IN GROUNDWATER MANAGEMENT AREA 7 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. RESULTS ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Year					
			2020	**2030**	**2040**	**2050**	**2060**	**2070**
Pecos	F	Rio Grande	7,040	7,040	7,040	7,040	7,040	7,040
		Rio Grande	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**	**7,040**

LIMITATIONS:

The groundwater model used in completing this analysis is the best available scientific tool that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historical groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historical pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and streamflow are specific to a particular historical time period.

Because the application of the groundwater model was designed to address regional scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations relating to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor groundwater pumping and groundwater levels in the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

Model "Dry" Cells

The predictive model run for this analysis results in water levels in some model cells dropping below the base elevation of the cell during the simulation. In terms of water level, the cells have gone dry. However, as noted in the model assumptions the transmissivity of the cell remains constant and will produce water.

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APPENDIX C

Estimated Historical Water Use and 2017 State Water Plan Datasets

Estimated Historical Groundwater Use And 2017 State Water Plan Datasets:

Lone Wolf Groundwater Conservation District

by Stephen Allen
Texas Water Development Board
Groundwater Division
Groundwater Technical Assistance Section
stephen.allen@twdb.texas.gov
(512) 463-7317
May 3, 2019

GROUNDWATER MANAGEMENT PLAN DATA:

This package of water data reports (part 1 of a 2-part package of information) is being provided to groundwater conservation districts to help them meet the requirements for approval of their five-year groundwater management plan. Each report in the package addresses a specific numbered requirement in the Texas Water Development Board's groundwater management plan checklist. The checklist can be viewed and downloaded from this web address:

http://www.twdb.texas.gov/groundwater/docs/GCD/GMPChecklist0113.pdf

The five reports included in this part are:

1. Estimated Historical Groundwater Use (checklist item 2)

   from the TWDB Historical Water Use Survey (WUS)

2. Projected Surface Water Supplies (checklist item 6)
3. Projected Water Demands (checklist item 7)
4. Projected Water Supply Needs (checklist item 8)
5. Projected Water Management Strategies (checklist item 9)

   from the 2017 Texas State Water Plan (SWP)

Part 2 of the 2-part package is the groundwater availability model (GAM) report for the District (checklist items 3 through 5). The District should have received, or will receive, this report from the Groundwater Availability Modeling Section. Questions about the GAM can be directed to Dr. Shirley Wade, shirley.wade@twdb.texas.gov, (512) 936-0883.

DISCLAIMER:

The data presented in this report represents the most up-to-date WUS and 2017 SWP data available as of 5/3/2019. Although it does not happen frequently, either of these datasets are subject to change pending the availability of more accurate WUS data or an amendment to the 2017 SWP. District personnel must review these datasets and correct any discrepancies in order to ensure approval of their groundwater management plan.

The WUS dataset can be verified at this web address:

http://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/

The 2017 SWP dataset can be verified by contacting Sabrina Anderson (sabrina.anderson@twdb.texas.gov or 512-936-0886).

The values presented in the data tables of this report are county-based. In cases where groundwater conservation districts cover only a portion of one or more counties the data values are modified with an apportioning multiplier to create new values that more accurately represent conditions within district boundaries. The multiplier used in the following formula is a land area ratio: (data value * (land area of district in county / land area of county)). For two of the four SWP tables (Projected Surface Water Supplies and Projected Water Demands) only the county-wide water user group (WUG) data values (county other, manufacturing, steam electric power, irrigation, mining and livestock) are modified using the multiplier. WUG values for municipalities, water supply corporations, and utility districts are not apportioned; instead, their full values are retained when they are located within the district, and eliminated when they are located outside (we ask each district to identify these entity locations).

The remaining SWP tables (Projected Water Supply Needs and Projected Water Management Strategies) are not modified because district-specific values are not statutorily required. Each district needs only "consider" the county values in these tables.

In the WUS table every category of water use (including municipal) is apportioned. Staff determined that breaking down the annual municipal values into individual WUGs was too complex.

TWDB recognizes that the apportioning formula used is not perfect but it is the best available process with respect to time and staffing constraints. If a district believes it has data that is more accurate it can add those data to the plan with an explanation of how the data were derived. Apportioning percentages that the TWDB used are listed above each applicable table.

For additional questions regarding this data, please contact Stephen Allen (stephen.allen@twdb.texas.gov or 512-463-7317).

Estimated Historical Water Use
TWDB Historical Water Use Survey (WUS) Data

Groundwater and surface water historical use estimates are currently unavailable for calendar year 2017. TWDB staff anticipates the calculation and posting of these estimates at a later date.

MITCHELL COUNTY *100% (multiplier)* All values are in acre-feet

Year	Source	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
2016	GW	1,352	2	0	5	11,943	89	13,391
	SW	0	0	0	3,175	0	266	3,441
2015	GW	1,429	4	7	3	13,236	87	14,766
	SW	50	0	0	2,837	0	260	3,147
2014	GW	1,540	4	53	2	15,137	102	16,838
	SW	45	0	0	3,210	0	307	3,562
2013	GW	1,407	2	159	2	13,463	85	15,118
	SW	72	0	0	3,226	0	254	3,552
2012	GW	1,812	1	24	2	15,745	82	17,666
	SW	46	0	0	3,195	0	244	3,485
2011	GW	1,571	0	1	3	10,146	102	11,823
	SW	97	0	0	3,173	0	308	3,578
2010	GW	1,387	0	229	3	9,443	99	11,161
	SW	75	0	122	3,177	0	298	3,672
2009	GW	1,180	0	254	7	11,575	94	13,110
	SW	79	0	135	3,237	0	280	3,731
2008	GW	1,214	0	278	13	8,092	103	9,700
	SW	72	0	148	2,883	0	310	3,413
2007	GW	1,367	0	0	26	9,870	80	11,343
	SW	26	0	0	12	0	241	279
2006	GW	1,483	0	0	17	7,306	77	8,883
	SW	26	0	0	12	0	232	270
2005	GW	1,745	0	0	17	5,931	76	7,769
	SW	75	0	0	12	0	228	315
2004	GW	1,560	0	0	0	5,826	30	7,416
	SW	42	0	0	567	0	272	881
2003	GW	1,065	0	0	0	5,188	30	6,283
	SW	40	0	0	2,295	0	271	2,606
2002	GW	1,385	0	0	0	3,670	35	5,090
	SW	52	0	0	3,450	0	316	3,818
2001	GW	926	0	0	0	3,423	42	4,391
	SW	80	0	0	2,338	0	374	2,792

Projected Surface Water Supplies
TWDB 2017 State Water Plan Data

MITCHELL COUNTY *100% (multiplier)* All values are in acre-feet

RWPG	WUG	WUG Basin	Source Name	2020	2030	2040	2050	2060	2070
F	IRRIGATION, MITCHELL	COLORADO	COLORADO RUN-OF-RIVER	14	14	14	14	14	14
F	LIVESTOCK, MITCHELL	COLORADO	COLORADO LIVESTOCK LOCAL SUPPLY	381	381	381	381	381	381
F	STEAM ELECTRIC POWER, MITCHELL	COLORADO	COLORADO CITY-CHAMPION LAKE/RESERVOIR SYSTEM	0	0	0	0	0	0
	Sum of Projected Surface Water Supplies (acre-feet)			**395**	**395**	**395**	**395**	**395**	**395**

Projected Water Demands
TWDB 2017 State Water Plan Data

Please note that the demand numbers presented here include the plumbing code savings found in the Regional and State Water Plans.

MITCHELL COUNTY *100% (multiplier)* All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
F	COLORADO CITY	COLORADO	1,287	1,417	1,427	1,438	1,451	1,466
F	COUNTY-OTHER, MITCHELL	COLORADO	843	852	857	861	868	875
F	IRRIGATION, MITCHELL	COLORADO	11,519	11,460	11,404	11,348	11,292	11,236
F	LIVESTOCK, MITCHELL	COLORADO	413	413	413	413	413	413
F	LORAINE	COLORADO	73	72	71	72	72	73
F	MINING, MITCHELL	COLORADO	593	738	632	493	375	290
F	STEAM ELECTRIC POWER, MITCHELL	COLORADO	4,847	4,670	4,493	4,317	4,140	3,994
		Sum of Projected Water Demands (acre-feet)	**19,575**	**19,622**	**19,297**	**18,942**	**18,611**	**18,347**

Projected Water Supply Needs
TWDB 2017 State Water Plan Data

Negative values (in red) reflect a projected water supply need, positive values a surplus.

MITCHELL COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
F	COLORADO CITY	COLORADO	0	0	0	0	0	0
F	COUNTY-OTHER, MITCHELL	COLORADO	0	0	0	0	0	0
F	IRRIGATION, MITCHELL	COLORADO	0	0	0	0	0	0
F	LIVESTOCK, MITCHELL	COLORADO	0	0	0	0	0	0
F	LORAINE	COLORADO	0	0	0	0	0	0
F	MINING, MITCHELL	COLORADO	0	0	0	0	0	0
F	STEAM ELECTRIC POWER, MITCHELL	COLORADO	-4,847	-4,670	-4,493	-4,317	-4,140	-3,994
	Sum of Projected Water Supply Needs (acre-feet)		**-4,847**	**-4,670**	**-4,493**	**-4,317**	**-4,140**	**-3,994**

Projected Water Management Strategies
TWDB 2017 State Water Plan Data

MITCHELL COUNTY

WUG, Basin (RWPG) — All values are in acre-feet

Water Management Strategy	Source Name [Origin]	2020	2030	2040	2050	2060	2070
COLORADO CITY, COLORADO (F)							
MUNICIPAL CONSERVATION - COLORADO CITY	DEMAND REDUCTION [MITCHELL]	28	31	32	32	32	33
		28	**31**	**32**	**32**	**32**	**33**
COUNTY-OTHER, MITCHELL, COLORADO (F)							
MUNICIPAL CONSERVATION - MITCHELL COUNTY OTHER	DEMAND REDUCTION [MITCHELL]	26	27	28	28	29	29
WATER AUDITS AND LEAK - MITCHELL COUNTY OTHER	DEMAND REDUCTION [MITCHELL]	42	43	43	43	43	44
		68	**70**	**71**	**71**	**72**	**73**
IRRIGATION, MITCHELL, COLORADO (F)							
IRRIGATION CONSERVATION - MITCHELL COUNTY	DEMAND REDUCTION [MITCHELL]	230	229	228	228	228	228
		230	**229**	**228**	**228**	**228**	**228**
LORAINE, COLORADO (F)							
MUNICIPAL CONSERVATION - LORAINE	DEMAND REDUCTION [MITCHELL]	3	4	4	4	4	4
		3	**4**	**4**	**4**	**4**	**4**
MINING, MITCHELL, COLORADO (F)							
MINING CONSERVATION - MITCHELL COUNTY	DEMAND REDUCTION [MITCHELL]	42	52	44	35	26	20
REUSE - MITCHELL COUNTY MINING, DIRECT NON-POTABLE SALES FROM COLORADO CITY	DIRECT REUSE [MITCHELL]	250	250	250	250	250	250
		292	**302**	**294**	**285**	**276**	**270**
STEAM ELECTRIC POWER, MITCHELL, COLORADO (F)							
SEP CONSERVATION - ALTERNATIVE COOLING TECHNOLOGIES - MITCHELL COUNTY	DEMAND REDUCTION [MITCHELL]	1,127	1,030	933	837	740	674
SUBORDINATION - LAKE COLORADO CITY AND CHAMPION LAKE SYSTEM	COLORADO CITY-CHAMPION LAKE/RESERVOIR SYSTEM [RESERVOIR]	3,720	3,640	3,560	3,480	3,400	3,320
		4,847	**4,670**	**4,493**	**4,317**	**4,140**	**3,994**
Sum of Projected Water Management Strategies (acre-feet)		**5,468**	**5,306**	**5,122**	**4,937**	**4,752**	**4,602**

APPENDIX D

GAM Run 19-004: Lone Wolf GCD

Groundwater Management Plan

GAM Run 19-004: Lone Wolf Groundwater Conservation District Groundwater Management Plan

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
512-463-6641
March 5, 2019

STATE OF TEXAS
IAN C. JONES
GEOLOGY
No. 477
LICENSED
PROFESSIONAL GEOSCIENTIST

2/27/19

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GAM RUN 19-004: LONE WOLF GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
512-463-6641
March 5, 2019

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2011), states that, in developing its groundwater management plan, a groundwater conservation district shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board (TWDB) in conjunction with any available site-specific information provided by the district for review and comment to the Executive Administrator.

The TWDB provides data and information to the Lone Wolf Groundwater Conservation District in two parts. Part 1 is the Estimated Historical Water Use/State Water Plan dataset report, which will be provided to you separately by the TWDB Groundwater Technical Assistance Department. Please direct questions about the water data report to Mr. Stephen Allen at 512-463-7317 or stephen.allen@twdb.texas.gov. Part 2 is the required groundwater availability modeling information and this information includes:

1. the annual amount of recharge from precipitation, if any, to the groundwater resources within the district;
2. for each aquifer within the district, the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers; and
3. the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

The groundwater management plan for the Lone Wolf Groundwater Conservation District should be adopted by the district on or before July 18, 2019 and submitted to the Executive Administrator of the TWDB on or before August 17, 2019. The current management plan for the Lone Wolf Groundwater Conservation District expires on October 16, 2019.

We used one groundwater availability model to estimate the management plan information for the aquifer within the Lone Wolf Groundwater Conservation District. Information for the Dockum Aquifer is from version 1.01 of the groundwater availability model for the High Plains Aquifer System (Deeds and Jigmond, 2015).

This report replaces the results of GAM Run 13-015 (Seiter-Weatherford, 2013). Table 1 summarizes the groundwater availability model data required by statute and Figure 1 shows the area of the model from which the values in the table were extracted. If, after review of the figures, the Lone Wolf Groundwater Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB at your earliest convenience.

METHODS:

In accordance with the provisions of the Texas State Water Code, Section 36.1071, Subsection (h), the groundwater availability model mentioned above was used to estimate information for the Lone Wolf Groundwater Conservation District management plan. A water budget was extracted for the historical model periods for the Dockum Aquifer (1980 through 2012) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface-water outflow, inflow to the district, and outflow from the district for the aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

High Plains Aquifer System

- We used version 1.01 of the groundwater availability model for the High Plains Aquifer System for this analysis. See Deeds and Jigmond (2015) for assumptions and limitations of the model.
- The model has four layers representing the Ogallala Aquifer (Layer 1), the Edwards-Trinity (High Plains) Aquifer (Layer 2), and the Dockum Aquifer (Layers 3 and 4). Within the Lone Wolf Groundwater Conservation District, only the Dockum Aquifer is present.
- The model was run with MODFLOW-NWT (Niswonger and others, 2011).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifers according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Dockum Aquifer, located within Lone Wolf Groundwater Conservation District and averaged over the historical calibration periods, as shown in Table 1.

1. Precipitation recharge—the areally distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.
2. Surface-water outflow—the total water discharging from the aquifer (outflow) to surface-water features such as streams, reservoirs, and springs.
3. Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.
4. Flow between aquifers—the net vertical flow between the aquifer and adjacent aquifers or confining units. This flow is controlled by the relative water levels in each aquifer and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs.

The information needed for the district's management plan is summarized in Table 1. It is important to note that sub-regional water budgets are not exact. This is due to the size of the model cells and the approach used to extract data from the model. To avoid double accounting, a model cell that straddles a political boundary, such as a district or county boundary, is assigned to one side of the boundary based on the location of the centroid of the model cell. For example, if a cell contains two counties, the cell is assigned to the county where the centroid of the cell is located.

TABLE 1. SUMMARIZED INFORMATION FOR THE DOCKUM AQUIFER FOR LONE WOLF GROUNDWATER CONSERVATION DISTRICT'S GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Dockum Aquifer	18,108
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Dockum Aquifer	11,998
Estimated annual volume of flow into the district within each aquifer in the district	Dockum Aquifer	2,726
Estimated annual volume of flow out of the district within each aquifer in the district	Dockum Aquifer	373
Estimated net annual volume of flow between each aquifer in the district	Flow into the Dockum Aquifer from overlying units	440

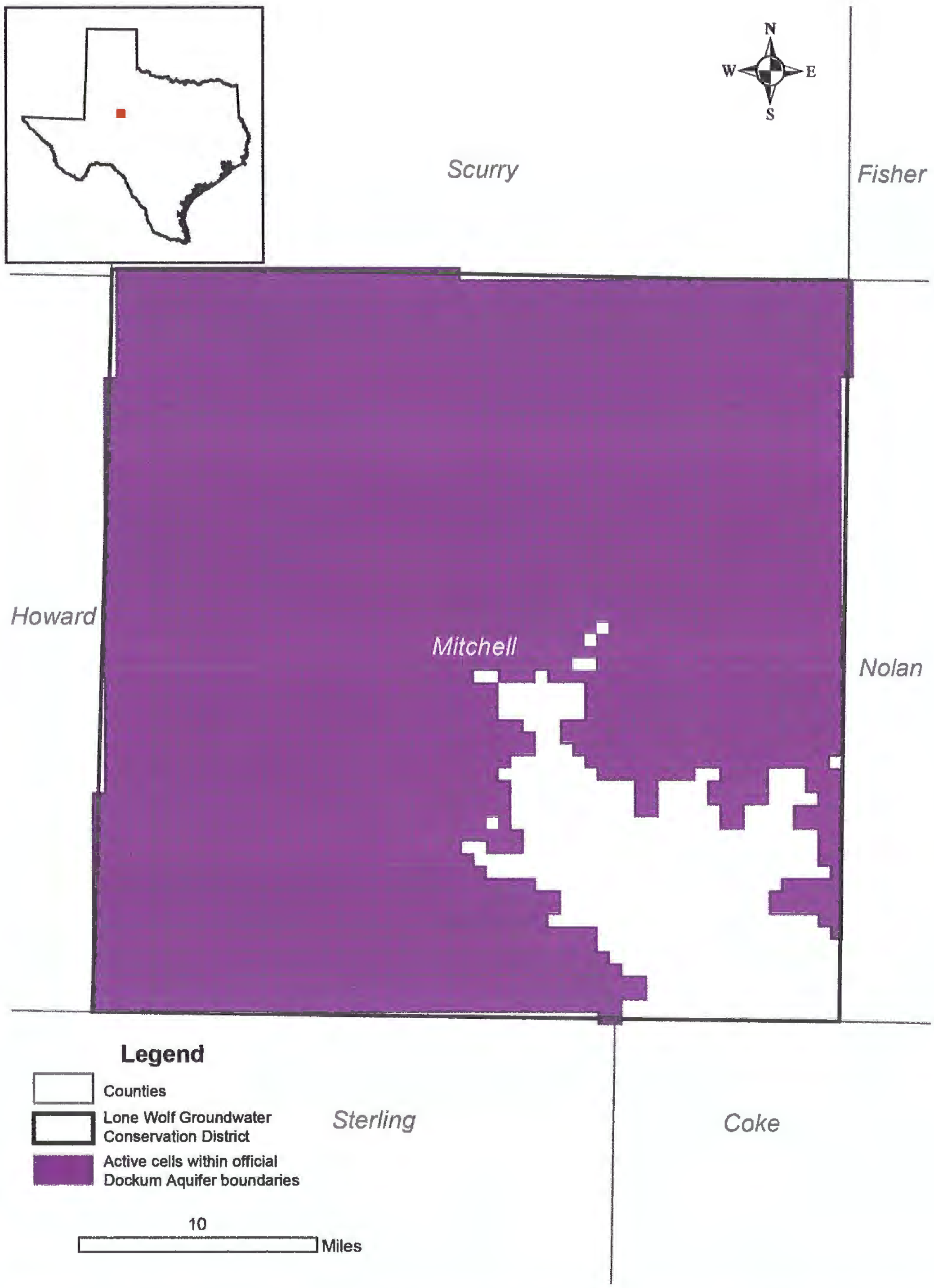

FIGURE 1. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE DOCKUM AQUIFER FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE AQUIFER SYSTEM EXTENT WITHIN THE DISTRICT BOUNDARY).

LIMITATIONS:

The groundwater models used in completing this analysis are the best available scientific tools that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historical groundwater flow conditions includes the assumptions about the location in the aquifer where historical pumping was placed. Understanding the amount and location of historical pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and interaction with streams are specific to particular historical time periods.

Because the application of the groundwater models was designed to address regional-scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations related to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historical precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

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APPENDIX E

Lone Wolf GCD Drought Contingency and Emergency Demand Management Plan

DROUGHT CONTINGENCY AND EMERGENCY WATER DEMAND MANAGEMENT PLAN

A. INTRODUCTION

The goal of this Plan is to cause a reduction in water use in response to drought or emergency conditions so that water availability can be preserved. Since emergency conditions can occur rapidly, responses must also be enacted quickly. This Plan has been prepared in advance considering conditions that will initiate and terminate the actions set forth herein.

The Lone Wolf Groundwater Conservation District Board of Directors (Board) will monitor usage patterns and public education efforts and will make recommendations on future conservation efforts, demand management procedures or any changes to this Plan. The Board will develop public awareness notices, information sheets, and other material that will serve as a constant reminder that water should be conserved at all times, not just during a drought or emergency. This Board will also review and evaluate any needed amendments or major changes to this Plan due to changes in the aquifer or other relevant circumstances. This review and evaluation will be done every other year unless conditions necessitate more frequent amendments.

The Plan will be implemented according to the three stages of rationing as imposed by the Board. Section C describes the conditions that will trigger these stages.

B. PUBLIC INVOLVEMENT

Opportunity for the public to provide input into the preparation of the Plan was provided by the Board by scheduling and providing public notice of a public meeting to accept input on the Plan. In the adoption of this Plan, the Board considered all comments from landowners.

C. TRIGGER CONDITIONS

The Board is responsible for monitoring water supply and demand conditions on a quarterly basis (or more frequently as conditions warrant) and shall determine when conditions warrant initiation or termination of each stage of the Plan. The Board will monitor drawdown reports, water supply and/or rainfall as needed to determine when trigger conditions are reached. The triggering conditions described below take into consideration: The vulnerability of the water source under drought of record conditions, the production, and distribution capacities of the aquifer and usage based upon historical patterns.

a. **Stage I- Mild Conditions**: Stage I water conservation measures may be implemented when the following condition exist:
   The Texas Palmer Drought Index shows that the area has reached a level of Mild Drought Conditions.

b. **Stage II- Moderate Conditions**: Stage II water conservation measures may be implemented when the following condition exist:
   The Texas Palmer Drought Index shows that the area has reached a level of Moderate Drought Conditions.

c. **Stage III- Severe Conditions:** Stage III water conservation measures may be implemented when one or more of the following conditions exist:
    i. The Texas Palmer Drought Index shows that the area has reached a level of Severe Drought Conditions.
    ii. Natural or man-made contamination of the water supply source(s).
    iii. The declaration by the State or Federal Government of a state of disaster due to drought condition in a county or counties served by the District.
    iv. Other unforeseen events which could cause imminent health or safety risks to the public.

D. STAGE LEVELS OF WATER ALLOCATIONS

The stage levels of water conservation are to be placed in effect by the triggers in Section C. The District may institute monitoring and enforce penalties for violations of the Drought Plan for each of the Stages listed below. The water conservation measures are summarized below.

d. **Stage I- Mild Conditions**
    i. Alternate day, time of day or duration restriction for outside water usage allowed. (District will notify public water utilities and landowners which restrictions are in effect)
    ii. The public water utilities will reduce flushing operations.
    iii. Reduction of water use will be encouraged through local media notices or other methods.

e. **Stage II- Moderate Conditions**
    i. All outside water use is prohibited (except for a livestock or other exemption or variance granted under this section).
    ii. Public service announcements as conditions change via local media (TV, radio, newspapers, etc.).

f. **Stage III- Severe Conditions**
    i. All outside watering prohibited.
    ii. District shall continue enforcement and educational efforts.

E. INITIATION AND TERMINATION PROCEDURES

Once a trigger condition occurs, the District, or its designated responsible representative, shall, based on recommendations from the Board, decide upon the appropriate stage of conservation to be initiated. The initiation may be delayed if there is a reasonable possibility the aquifer's performance will not be compromised by the condition. If water conservation is to be instituted, notice will be made via public local media (TV, radio, newspapers, etc.).

The notice shall contain the following information:

a. The date water conservation shall begin,
b. The expected duration,
c. The stage (level) of water conservations to be employed, the penalty for violations of the water conservation program, and the affected area or areas.

If the water conservation program extends 30 days the Board President or General Manager shall present the reasons at the next scheduled Board Meeting and shall request the concurrence of the Board to extend the conservation period.

When the trigger condition no longer exists, the responsible official may terminate the water conservation provided that such an action is based on sound judgment. The end of conservation shall be given to landowners via local media (TV, radio, newspapers, etc.). A water conservation period may not exceed 60 days without extension by action of the Board.

F. PENALTIES FOR VIOLATIONS

a. **First Violation-** The Violator will be notified by written notice of their specific violation and their need to comply with district rules. The notice will show the amount of penalty to be assessed for continued violations.
b. **Second Violation-** The District may assess a penalty of up to $2,500.
c. **Subsequent Violations-** The District may assess a penalty of up to $10,000 for violations continuing after Second Violation. Each day a violation exists shall be considered a separate, subsequent violation. The District may also install a flow restricting devise in the violator's well to limit the amount of water that will pass through the well in a 24 hour period. The costs of this procedure will be for the actual work and equipment and shall be paid by the customer.

These provisions apply to all landowners/ operators within the District. Municipal water supplies are responsible for ensuring their customers comply with the provisions. Municipal water supplies shall be deemed to be the violator if a customer of the supplier violates this Plan.

G. EXEMPTIONS OR WAIVERS

The Board may, in writing, grant temporary variance for existing water uses otherwise prohibited under this Plan if it is determined that failure to grant such variance would cause an emergency condition adversely affecting the health or sanitation of the public or the person requesting such variance and if one or more of the following conditions are met:

a. Compliance with this Plan cannot be technically accomplished during the duration of the water supply shortage or other condition for which the Plan is in effect.
b. Alternative methods can be implemented which will achieve the same level of reeducation in water use.

Persons requesting an exemption from the provisions of this Ordinance shall file a petition for variance with the Board within 5 days after the Plan or particular drought response stage has been invoked or after a condition justifying the variance first occurs. All petitions for variances shall be reviewed by the Board and shall include the following:

a. Name and address of the petitioner(s).
b. Purpose of water use.
c. Specific provision(s) of the Plan from which the petitioner is requesting relief.

d. Detailed statement as to how the specific provision of the Plan adversely affects the petitioner or what damage or harm will occur to the petitioner or others if petitioner complies with this Plan.
e. Description of the relief requested.
f. Period of time for which the variance is sought.
g. Alternative water use restrictions or other measures the petitioner is taking or proposes to take to meet the intent of this Plan and the compliance date.
h. Other pertinent information, as requested by the Board.

Variances granted by the Board shall be subject to the following conditions, unless specifically waived or modified by the Board:

a. Variances granted shall include a timetable for compliance.
b. Variances granted shall expire when the water conservation is no longer in effect, unless the petitioner has failed to meet specified requirements. No variances allowed for a condition requiring water conservation will continue beyond the termination of water conservation under Section E. Any variances for subsequent water conservation must be repetitioned. The fact that a variance has been granted in response to a petition will have no relevance to the Board's decision on any subsequent petition.

No variance shall be retroactive or otherwise justify any violation of this Plan occurring prior to the issuance of the variance.

H. SEVERABILITY

If any one or more of the provisions contained in these rules are for any reason held to be invalid, illegal, or unenforceable in any respect, the invalidity, illegality, or unenforceability may not affect any other rules or provisions of these rules, and these rules must be construed as if such invalid, illegal or unenforceable rules or provision had never been contained in these rules.

I. IMPLEMENTATION

The Board established the DROUGHT CONTINGENCY AND EMERGENCY WATER DEMAND MANAGEMENT PLAN by Resolution. This Board will review the procedures in this Plan every other year or more frequently if necessary. Modifications may be required to accommodate system growth, changes in water use demand, available water supply, and/or other circumstances.

This Plan was adopted by the Lone Wolf Groundwater Conservation District Board at the properly noticed public meeting held on April 1, 2008.

APPENDIX F

Resolution Adopting Management Plan

LONE WOLF GROUNDWATERCONSERVATION DISTRICT

139 West 2nd Street
Colorado City, Texas 79512

RESOLUTION
LWGCD MANAGEMENT PLAN
2019-2024

WHEREAS, the Lone Wolf Groundwater Conservation District (District) was created by Acts of the 77th Texas Legislature (2001), H.B. 2529 in accordance with Article 16, Section 59 of the Constitution of Texas and Chapters 35 and 36 of the Texas Water Code, as amended; and

WHEREAS, the District is required by S. B. 1 through Chapter 36.1071 of the Texas Water Code to develop and adopt a Management Plan; and

WHEREAS, the District is required by S. B. 1 to review and readopt the plan with or without revisions at least once every five years and to submit the adopted Management Plan to the Executive Administrator of the Texas Water Development Board for review and approval; and

WHEREAS, the District's Management Plan shall be certified by the Executive Administrator once the plan is determined to be administratively complete; and

WHEREAS, the District Board of Directors has determined this Management Plan addresses the requirements of Chapter 36.1071.

NOW, THEREFORE, be it resolved, that the Board of Directors of the Lone Wolf Groundwater Conservation District, following notice and public hearing, hereby adopts this Management Plan; and

BE IT FURTHER RESOLVED, that this Management Plan shall become effective immediately upon adoption by the District.

Adopted this 9th day of July, 2019.

David Stubblefield
Board Chairman

Attest:

Bobby Lemons
Board Vice Chairman

APPENDIX G

Evidence of Notice and Hearing

AFFIDAVIT OF PUBLICATION

BEFORE ME, the undersigned notary public, this day personally appeared

Sheila Plagens

Publisher

Colorado City Record

a newspaper having general circulation in Mitchell County, Texas, who being by me duly sworn, deposes and says that the foregoing attached notice was published in said newspaper on the following date(s), to wit:

Thur., May 16th, 2019

Signed: Sheila Plagens
Signature of Affiant

SUBSCRIBED AND SWORN TO this

the 4th day of June, 2019.

Alichia Moon
Notary Public in and for the State of Texas

Seal:

NOTARY PUBLIC STATE OF TEXAS
ALICHIA MOON
Notary Public, State of Texas
Expires 12/26/2022
I.D.# 13183543-3

LONE WOLF GROUNDWATER CONSERVATION DISTRICT

PUBLIC NOTICE

The Lone Wolf Groundwater Conservation District will hold a Public Hearing at 7:00 a.m. on June 11, 2019 at the District Office, 139 West 2nd Street, Colorado City, Texas, to receive public comment on draft 5 year Management Plan. Copies of the drafted plan may be obtained by contacting the District Office at 325-728-2027.

APPENDIX H
Posted Agenda

NOTICE PUBLIC HEARING AND MONTHLY MEETING OF THE LONE WOLF GROUNDWATER CONSERVATION DISTRICT BOARD OF DIRECTORS

Notice is hereby given that a public hearing and regular meeting of the Lone Wolf Groundwater Conservation District will be held on the 11th day of June, 2019 at 7:00 a.m. at the Lone Wolf Groundwater Conservation District office at 139 West 2nd Street in Colorado City, Texas, at which time the following subjects will be discussed with possible action:

1. Public Comment
2. Public Hearing - 2019 Management Plan
3. Adjourn public hearing and commence regular meeting
4. Approval of previous minutes
5. Ratification of bills paid
6. Approval of March and April financial statements
7. 2019 Estimated values
8. Well permits
9. District Rules
10. Legislative session
11. Cloud seeding
12. USGS Dockum modeling
13. Executive Session
14. Palmer Drought Index
15. Adjourn

By: Sue Young
Sue Young, LWGCD General Manager

Date: 6-7-19

The above notice of Meeting of the Lone Wolf Groundwater Conservation District was posted on the bulletin board at the Courthouse of Mitchell County, the bulletin board at the Lone Wolf Groundwater Conservation District office and the District website on the 7th day of June, 2019, and said notice will remain so posted continuously for at least seventy-two (72) hours immediately preceding the time of said meeting.

In compliance with Open Meeting laws, the Lone Wolf Groundwater Conservation District Board welcomes any interested party to attend the meetings. The board also welcomes any public comment with a limit of 5 minutes per person. Any person with ADA special needs should notify the board at least three days prior to the meeting so accommodations may be made.

At any time during the meeting and in compliance with the Texas Open Meetings Act, Chapter 551, Government Code, Vernon's Texas Codes, Annotated, the Lone Wolf Groundwater Conservation District Board may meet in executive session on any of the above agenda items for consultation concerning attorney-client matters (§551.071); deliberation regarding real property (§551.072); deliberation regarding prospective gift (§551.073); personnel matters (§551.074); and deliberation regarding security devices (§551.076). Any subject discussed in executive session may be subject to action during an open meeting.

APPENDIX I

Minutes of Hearing

Lone Wolf Groundwater Conservation District
Public Hearing and Regular Meeting
June 11, 2019

Present: Jerold Epperson, Bobby Lemons, David Stubblefield and George Walker
Sue Young and Darlene Moore

Chairman David Stubblefield called to order the public hearing for the 2019 Management Plan at 7:00 a.m.

There were no public comments.

The Board discussed the new management plan and will pass a resolution to ratify the plan at the July board meeting.

The public hearing adjourned at 7:10 a.m. and the regular meeting was called to order.

George Walker moved that the minutes of the May meeting be approved as printed. Jerold Epperson seconded the motion, which passed.

Bobby Lemons made a motion that the bills be ratified as presented. The motion was seconded by George Walker and it passed.

Bobby Lemons moved that the financial statements for March and April from Eide Bailley be approved as presented. George Walker seconded motion, which passed.

The estimated values from the Appraisal District were presented and discussed.

Bobby Lemons moved, and Jerold Epperson seconded the motion, that the irrigation well for the City of Colorado City be approved as presented. The motion passed.

The District Rules were discussed.

There was an update on the groundwater bills from the recent legislative session.

The weather modification program was discussed and reported that no cloud seeding will begin before June 20.

Representatives from the USGS are meeting with LWGCD and WesTex Groundwater District to discuss the possibility of a partnership to provide a localized model for our portions of the Dockum Aquifer.

The Palmer Drought Index was reviewed.

There being no further business, the meeting was adjourned at 7:35 a.m.

Minutes prepared by:

Sue Young

Sue Young

Minutes approved by:

George Walker, Secretary

APPENDIX J

Letters of Coordination with Surface Water Management Entities

LONE WOLF GROUNDWATER CONSERVATION DISTRICT

July 9, 2019

John Grant
CRMWD
PO Box 869
Big Spring, Texas 79721-0869

Dear Mr. Grant:

In accordance with the Texas Water Code and the Texas Water Development Board, we are providing copies of the Lone Wolf Groundwater Conservation District's 2019 Groundwater Management Plan to the CRMWD. A public hearing was held on June 11, 2019 at which time the Board approved the enclosed the plan.

Sincerely,

Sue Young
General Manager

139 WEST 2TH STREET • COLORADO CITY, TEXAS • 79512
PHONE: (325) 728-2027